Geology of Wisconsin : Survey of 1873-1879. Volume III 1880

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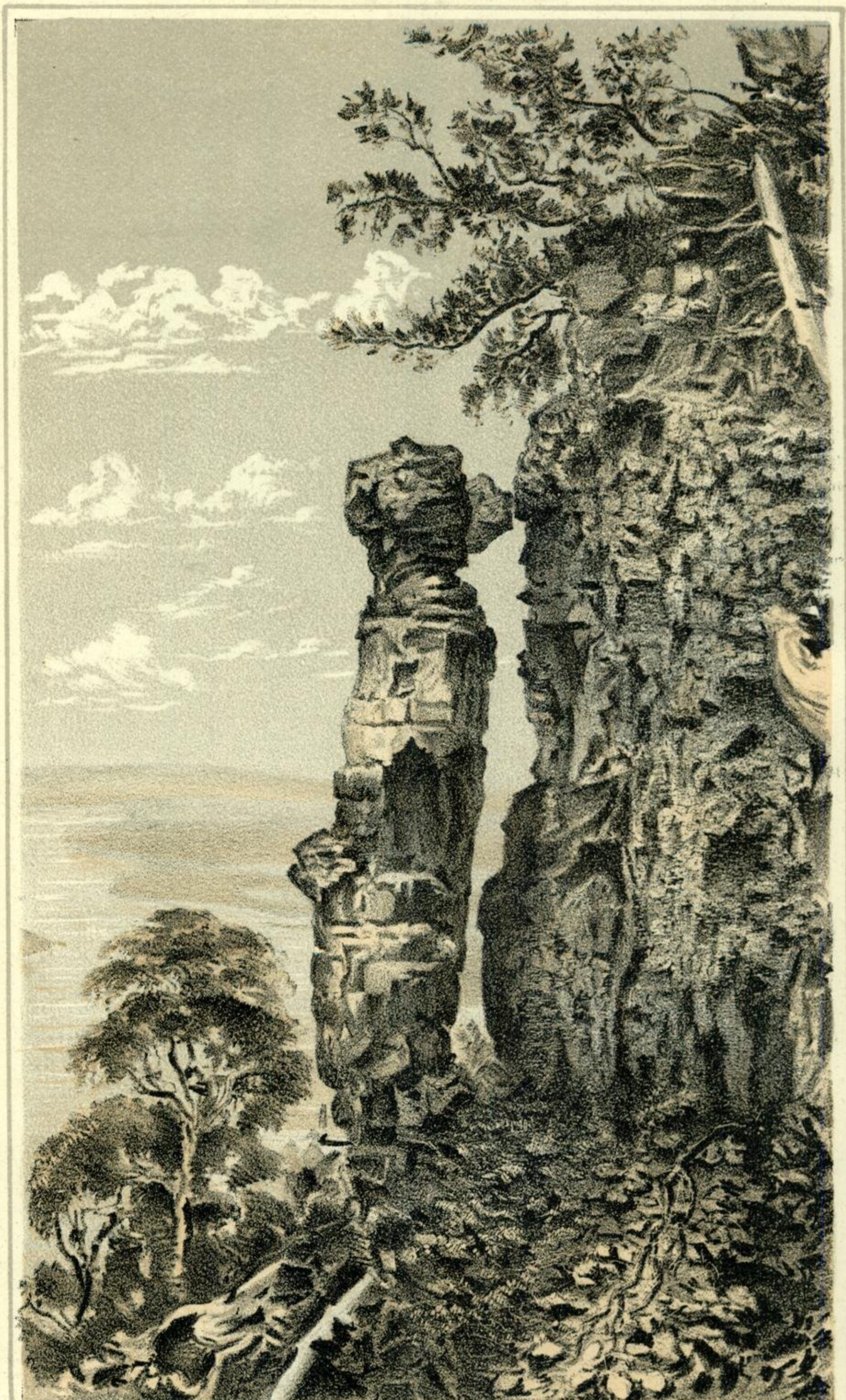

VIEW ON THE MISSISSIPPI RIVER.

Near Fountain City, Showing peculiar erosion.

GEOLOGY

OF

WISCONSIN.

SURVEY OF 1873-1879.

VOLUME III.

PART I. THE LAKE SUPERIOR REGION.
II. KEWEENAWAN ROCKS.
III. EASTERN LAKE SUPERIOR DISTRICT.
IV. HURONIAN BELT WEST OF PENOKEE GAP.
V. WESTERN LAKE SUPERIOR DISTRICT.
VI. UPPER ST. CROIX DISTRICT.
VII. MENOMINEE IRON REGION.
VIII. MENOMINEE IRON REGION (ECONOMIC AND SUPPLEMENTARY).

ACCOMPANIED BY AN

ATLAS OF MAPS.

PUBLISHED UNDER THE DIRECTION OF THE

CHIEF GEOLOGIST,

BY

THE COMMISSIONERS OF PUBLIC PRINTING,

IN ACCORDANCE WITH LEGISLATIVE ENACTMENT.

1880.

David Atwood, Madison,
stereotyper and printer.

Seifert, Gügler & Co., Milwaukee,
lithographers.

To His Excellency, the Hon. WILLIAM E. SMITH,

Governor of Wisconsin.

SIR:—It is my pleasant duty to present herewith the third volume of the final report of the Geological Survey of Wisconsin.

Most respectfully, your obedient servant,

T. C. CHAMBERLIN,

Chief Geologist.

BELOIT, *October 29, 1879.*

PREFACE.

VOLUME I of this series of reports is required by the specifications of the law of publication to embrace a general and systematic presentation of the geological structure of the state and the history of its formation, together with other matter whose preparation can only be advantageously completed after all special and detailed investigations have been finished. Certain portions of it have been for some time ready for the press, and the preparation of others is in an advanced condition; but the final completion and publication cannot well take place till the three other volumes of the proposed series are finished. Volume II was issued in the fall of 1877. A second edition was ordered by the legislature which next convened, and was issued the following summer. This volume related to the geology of the eastern, central and southwestern portions of the state, and was accompanied by an atlas of maps covering the region reported upon.

The original plan of publication contemplated the gathering of the reports upon the western and extreme northern districts together to form the third volume. This plan was followed until about half of the volume was set up and stereotyped, when it was found that the satisfactory completion of the plates of fossils that were to accompany the volume would require considerable more time than was anticipated, and that the appearance of the volume would be correspondingly delayed, unless the work was unduly hastened at the expense of excellence of execution. As it was desirable that the reports upon the iron regions should appear as early as possible, the remaining manuscript which was intended for that volume, and which related to the iron and copper-bearing series of the northwestern part of the state, was combined with the report on the Menominee iron region to form the present volume, leaving the one previously begun to be completed by the addition of other matter, and to constitute Volume IV. This explains a little irregularity in the numbering of the plates, some of which had been completed before the change was determined upon. It is thought that this change, by bringing together the reports on the iron and copper-bearing formations, may prove, on the whole, as acceptable as the original plan.

The atlas accompanying this volume embraces maps of the entire area reported upon, and in addition, some territory that will be described in Volume IV. The sheets are numbered consecutively with those of the atlas accompanying Volume II, the hope being that when the series is completed, the whole will be bound together.

As many inquiries have been addressed to me concerning the best method of mounting the maps for use and preservation, it may be serviceable to make a few suggestions on that subject. It may be remarked, at the outset, that a different size might have been chosen but for the requirement of the organic law of the survey, that all the geological formations of the state should be represented on a *single* map. The smallest scale upon which this can be successfully accomplished is 15 miles to the inch. The sheets of the atlas have the size requisite for such a map, and No. 1 of the series, when completed, will show, on the smallest practicable scale, all the rock formations of the state. On other maps of the same scale, and having the same geographical basis, it is proposed to show the drift formations and other general features. In addition to the advantage of having sheets large enough to present maps of the whole state on an available scale, the sectional areas on a larger scale for the more accurate mapping of the geological details are fewer in number, and, in the aggregate, less expensive, and present the formations in a more connected manner than would have been possible had a smaller size been adopted. So that, on the whole, the size of the atlas, although somewhat inconveniently large, will not be found altogether disadvantageous.

The size of the atlas, however, may be reduced one-half by binding. To do this the right and left halves of the sheet should be folded together face to face and fastened by strips or stubbs along the back. As more or less of damage to the edges of the sheets is incident to the handling of the atlas in distribution, a liberal margin has been allowed for trimming. If the atlas is bound before the series is complete, allowance should be made for sheets that will yet be added. Nos. I and II of the atlas accompanying Volume II were purposely left vacant to be supplied by the general maps above mentioned, which, when completed, will most appropriately stand at the commencement of the atlas. The number of these may, however, be increased to five or six, and it would be prudent to leave the latter number of stubbs vacant at the beginning of the atlas, and perhaps fifteen at the close for sheets to be added in connection with Volume IV.

A renewed expression of indebtedness is due to numerous citizens and corporations for their kindness in rendering aid in various ways in the prosecution of the work. In addition to the more specific acknowledgments that have been made in the annual reports and in other appropriate ways, the corps desire to tender this general expression of their appreciation of the numerous courtesies of which they have been the recipients. It is fitting, also, to make special mention of such assistance as has been directly contributory to this volume. Prof. Raphael Pumpelly not only very generously examined the survey collections of crystalline rocks from the copper-bearing series, but contributed, without compensation, the report on the lithology of these rocks found in this volume. The eminence of his authority on this series lends great value to this report.

In like generous manner, Dr. A. Wichmann of Leipsic examined microscopically for Maj. Brooks a large collection of characteristic Huronian rocks from the region south of Lake Superior and contributed a full report of his results, which constitute Chapter V of Maj. Brooks' report. These examinations will be found of much interest and value to lithologists.

Some special lithological examinations of the same specimens have also been kindly made by Messrs. Samuel Allpert, Frank Rutley, A. E. Törnebohm, F. Zirkel and Herr Wapler, of Europe, and by Geo. J. Brush, J. D. Dana, G. W. Hawes, A. A. Julien and T. Sterry Hunt, of this country, which deserve the appreciation of all interested in Huronian — and indeed any series of metamorphic — rocks.

The leading contributors to the report are Prof. R. D. Irving, who prepared Parts I and III, Prof. Pumpelly, who contributed Part II, as above stated, Mr. C. E. Wright, who furnished Parts IV and VIII, Mr. E. T. Sweet, who wrote Part V, Maj. T. B. Brooks, who prepared Part VII, and the writer, who collated the observations of the late Mr. Strong, forming Part VI.

The larger portion of the maps were drawn under the direction of the lamented Prof. W. J. L. Nicodemus and his associate, Prof. A. D. Conover, but several were also executed by other parties, to whom due acknowledgment is made elsewhere.

The chemical analyses are duly accredited wherever quoted in the report. Mr. I. M. Buell has rendered valuable assistance in proof reading and indexing. Mr. F. J. Knight has read the proof of Maj. Brooks' report.

The printing has been done by David Atwood, of Madison. The lithographical work by Messrs. Seifert & Shœffel, of Milwaukee, and the wood cuts by Messrs. Marr & Richards, of Milwaukee; all Wisconsin firms. Their work speaks for itself.

T. C. C.

BELOIT, *October 29, 1879.*

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NOTE.—The chromo-lithographs of scenery were carefully reproduced from photographs.

FIGURES.

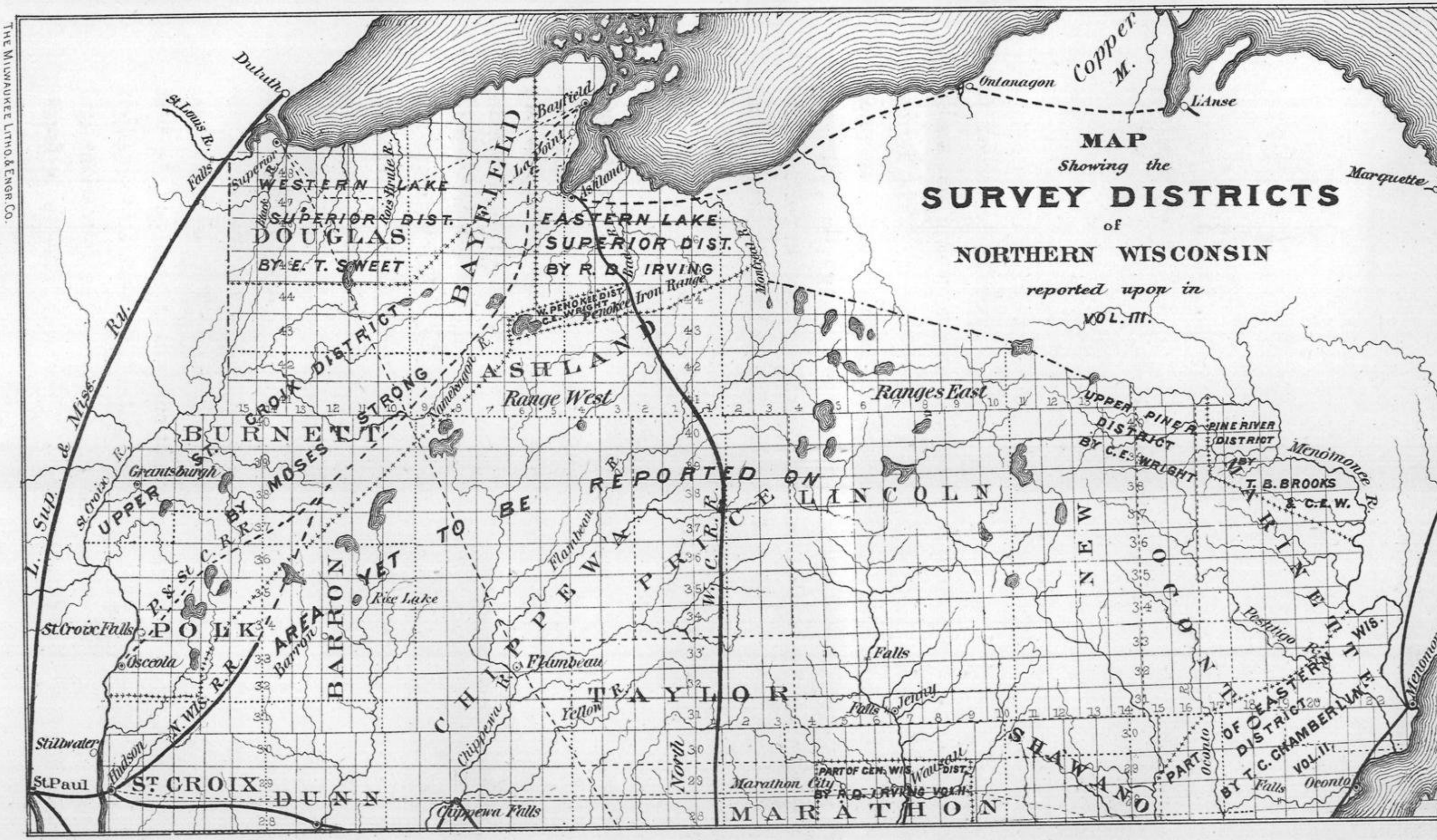
REPORT ON THE EASTERN LAKE SUPERIOR DISTRICT.

REPORT ON THE WESTERN LAKE SUPERIOR DISTRICT.

REPORT ON THE UPPER ST. CROIX DISTRICT.

INTRODUCTION.

In the preceding volume — the only one previously issued in connection with the present survey — the eastern, central and southwestern portions of the state received consideration. The formations there brought under review were mainly the limestones, sandstones and shales of the Paleozoic series; though the quartzites, porphyries and granites of central Wisconsin were important subjects of discussion. It was originally planned that the neighboring Paleozoic area, which lies adjacent to the upper Mississippi, together with the description of fossils and the crystalline formations of the northwestern part of the state, should constitute the subject-matter of Volume III. But practical obstacles intervening, the arrangement of matter found in this volume was adopted instead. While less consecutive geographically, the present collocation possesses greater geological unity and practical convenience. The Huronian, or Iron-bearing series, and the Keweenawan, or Copper-bearing series, constitute the central subjects of study. The adjacent and underlying Laurentian rocks, because of their close relations to these formations, receive passing attention, and the overlying Silurian strata and the still more recent drift deposits are discussed, so far as they are included in the regions described; but these subjects are little more than accessory to the central themes of the volume, the two great metalliferous formations. The deep practical interest that attaches to these formations will, it is hoped, be best subserved by gathering into a single volume the several discussions relating to them; while the scientific study of the formations and of the problems that arise concerning them will likewise be facili-



THE MILWAUKEE LITHO. & ENGR. CO.

PLATE II

tated by the close grouping and simultaneous presentation here afforded.

The areas embraced are the extreme northwestern and northeastern portions of the state. The former constitutes a considerable area bordered by Lake Superior on the north and Minnesota on the west, and included mainly within the counties of Ashland, Bayfield, Douglas, Burnett and Polk. The latter is a more limited area in what, until recently, has been the northern part of Oconto county, but now belongs, in part, to the recently formed counties of Marinette and New.

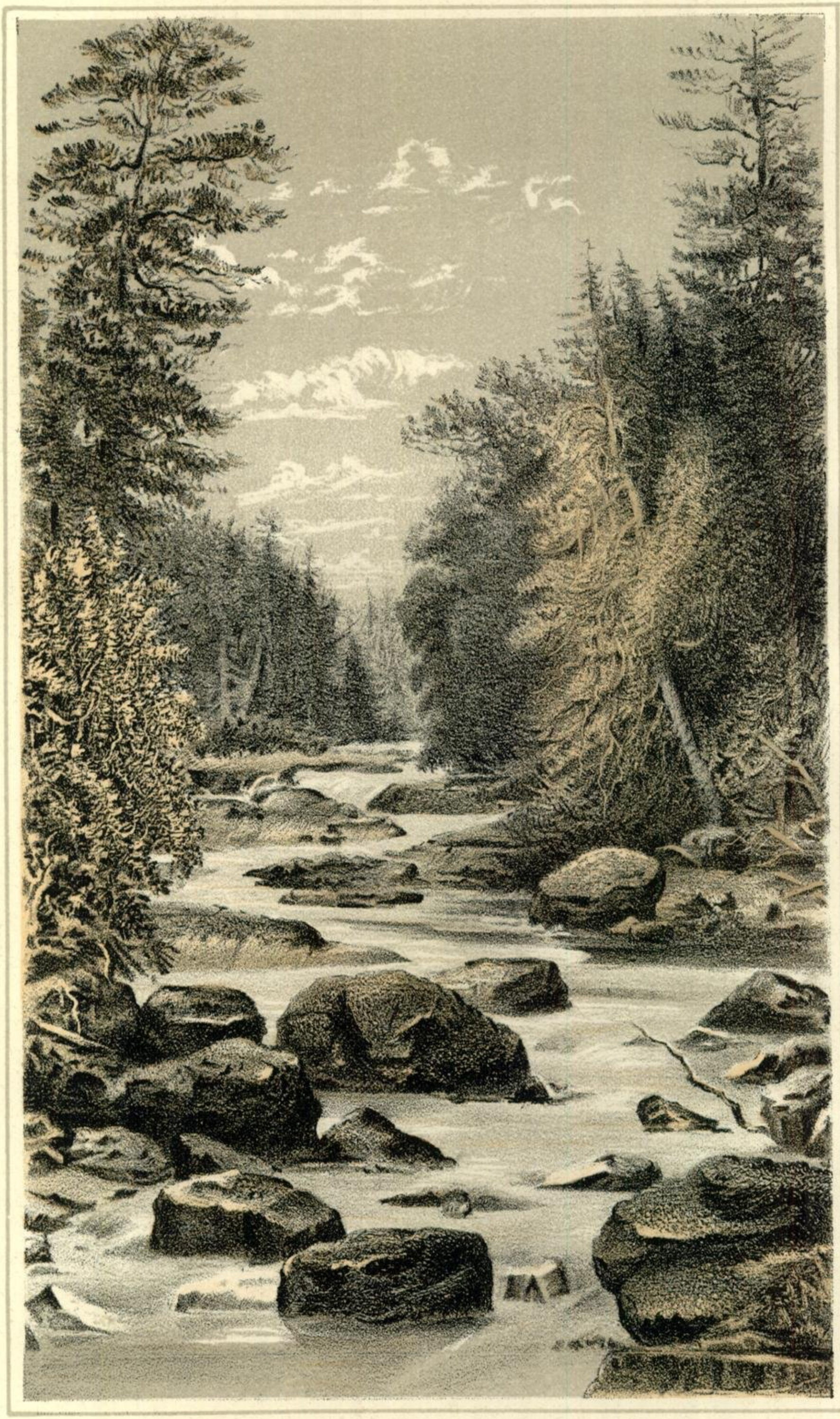
The former region was investigated by Messrs. Irving, Sweet, Wright and the lamented Strong; the latter by Messrs. Brooks and Wright. Such field investigations as have been made by myself in the several districts have been merged with those of my associates. The special field examined by Prof. Irving is embraced in Ashland and eastern Douglas counties; that of Mr. Sweet, in western Bayfield and Douglas counties; that of Mr. Strong, mainly in Polk and Burnett counties, while Mr. Wright made a special examination of the Penokee Range westward from the Gap to its termination. In the northeast, Major Brooks investigated the region adjacent to the upper Menominee and lower Pine and Brulè rivers, as far west as the middle of Town 17 E. Mr. Wright, in addition to association with Major Brooks in the survey of this area, reconnoitered the adjacent territory to the west and south. The precise limits and relations of these districts may be best seen by consulting the accompanying sketch map.

The order of arrangement of the several reports upon these districts is thought to be such as best to present the whole subject-matter. The district of Prof. Irving embraces representatives of all the great formations described in the volume, and these, furthermore, in their simplest form and relations. His report, therefore, best introduces the reader to the salient characteristics of the whole geological series treated in the volume, and so it most appropriately stands at the beginning. The other reports follow in the order which their geological and geographical relationships seem to demand. This order has obviously no reference to the inherent merit or interest of the several reports.

It had been the purpose of the writer to briefly discuss some general questions relating to the subjects embraced in the report, but the size to which the volume has already grown compels its postponement.

T. C. C.

PLATE. VIII.



RAPIDS OF BAD RIVER,

Sec. 30 T. 45 R 2 W. Ashland Co.

PART I.

THE

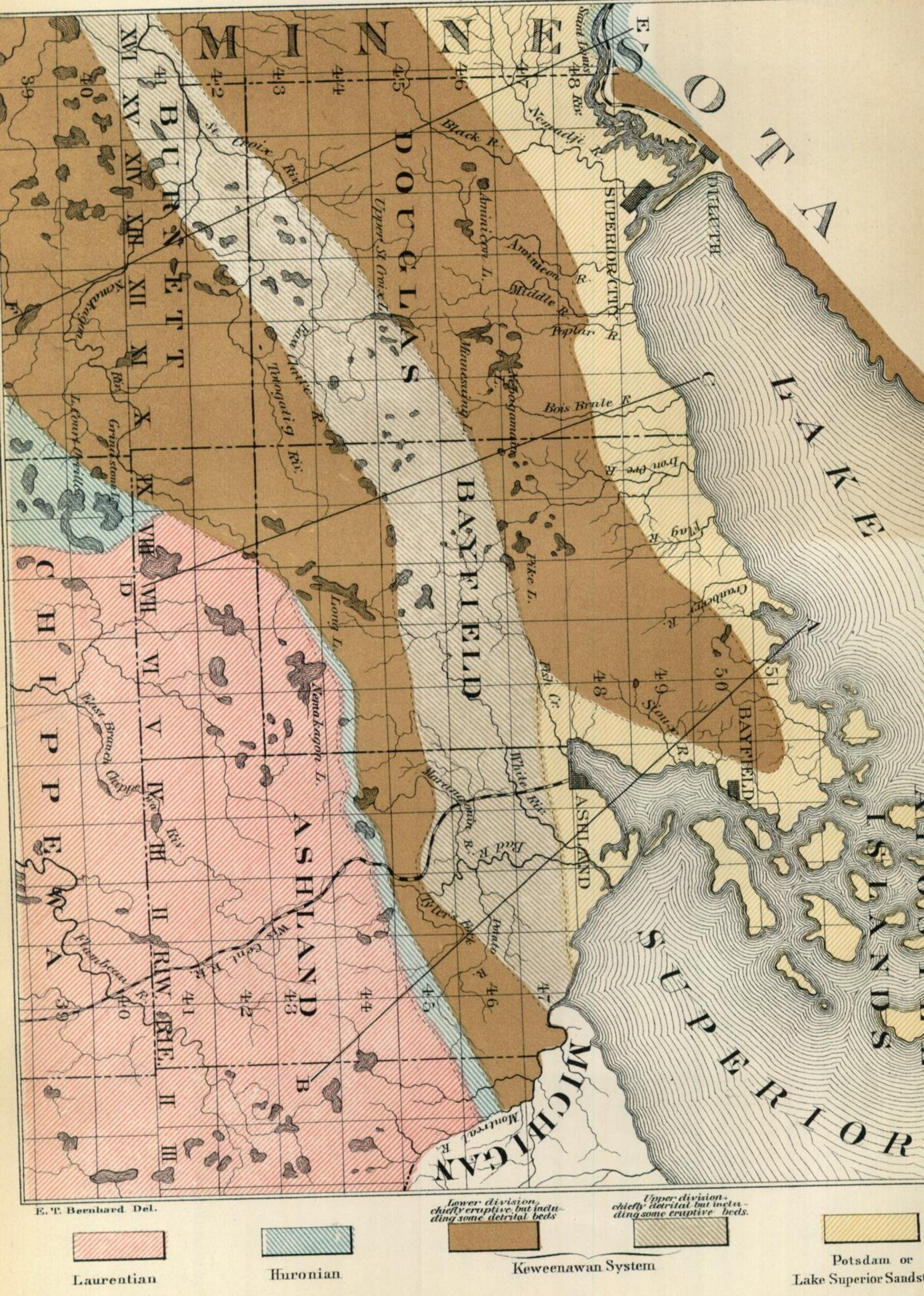
GEOLOGICAL STRUCTURE

OF

NORTHERN WISCONSIN.

BY R. D. IRVING.

OUTLINE GEOLOGICAL MAP
of
NORTHERN WISCONSIN.



Scale, 15 miles to the inch.

GEOLOGICAL STRUCTURE OF NORTHERN WISCONSIN.

It is proposed to give here a brief account of the main features of the rock structure of that part of Wisconsin which borders on Lake Superior, as determined by the labors of those members of the geological corps who have made examinations in that region. The writer having advanced, at the close of the first field season of the survey, a theory of the structure of this region which has in its essentials stood the test of all later investigations by himself and others, it is thought not improper that the task of making the following summary should be assigned him, although his own examinations have embraced the northeastern portion only of the district in question. He had at one time designed to give, in this connection, a *resumé* of the results obtained in the Lake Superior country by other geologists up to the present time, and to offer some generalizations with regard to the structure of the whole Lake Superior trough, and the origin of the formations included in it. Further study, however, of his own results, and of the reports of others, has convinced him, both that such an attempt would be premature, and that, from want of personal acquaintance with different parts of the region, he is not in a position to raise such generalizations sufficiently above the grade of speculation to allow of their introduction into a report of this character.

There is no other region of equal area in North America, east of the great cordilleras, that surpasses this in geological interest, whether we consider the magnitude of the formations involved, the difficulties in the problems offered for solution, or the unique character of one of its great rock systems. Moreover, there is none which has been so inadequately studied. We have here, in a region some seventy thousand square miles in area, to deal with a series of strata measuring probably over one hundred thousand feet in thickness, and including four great systems, each unconformable with regard to its predecessor; besides which there is an extraordinary development of the Quaternary deposits — both of the glacial drift and of the more recent lacustrine sediments. Of the four great systems alluded to, the Laurentian, Huronian, Keweenawan, and Lower Silurian, much the greater part is made up of crystalline rocks of very many different kinds. From the comparative newness of the microscopic method of investigation, it follows that the nature of these rocks, often too fine-grained for macroscopic study, is only partially known. The Keweenawan series, alone, includes many miles in thickness of immense flows, each comparatively thin, of eruptive rocks, which the earlier geologists were content to know as "trap." These extraordinary beds, the earliest true and extended flows of once molten rocks of which we have any knowledge, have recently been studied, both stratigraphically and microscopically, by Professor Pumpelly, to whose admirable work we are indebted for a great advance in our knowledge with regard to them. When such detailed work as his, and that of other members of the Michigan survey, shall have been extended over the whole Lake Superior trough, we may hope for some satisfactory generalizations. There is no region in the United States which stands more in need of minutely detailed work, and none where such work meets so great difficulties as are here encountered. For the most part it is unbroken wilderness, and is everywhere covered with the densest of evergreen forests, traveling in which is to the last degree difficult, and in which no estimates as to distances and relative positions of ledges can be at all relied upon.

Theories enough have been advanced with regard to the origin and age of the Lake Superior formations, and the structure of the trough, not a few of which have crept into the text-books and other standard works. Most of these are but hasty generalizations, and the best of them are influenced by that extraordinary system of geological dynamics, so prevalent a few decades ago, which regarded all massive rocks, including even quartzite — and sometimes even sandstone — as intrusive, and looked upon all dislocations and metamorphism, even where regional, and affecting strata thousands of feet in thickness, as but the natural results of the "outbursts" of "trap." These outbursts, so far as I can understand the idea, were often of already solidified rock, in whose passage to the surface were formed by "friction" the great conglomerate beds of the region, and by whose protrusion sediments thousands of feet in thickness were tilted on end and pushed miles to one side or the other. Such crude and bold conceptions do not stand in the light of the present day; still, though we can point with confidence to the true explanation of some of the phenomena of the Lake Superior country, there remains much, very much, for the explanation of which we must be content to wait for the extension of minute investigation.

In a former volume[1] of this report, I have shown how the Silurian limestone and sandstone formations of the southern, eastern and western portions of Wisconsin curve concentrically around three sides of the Laurentian nucleus of the northern part of the state. On the northern or Lake Superior side, however, we find an altogether different structure; and it is evident at once that the Laurentian nucleus has constituted a barrier between the Lake Superior and Mississippi valley regions since pre-Silurian times.

Laurentian System. The rocks of the crystalline nucleus itself are referred to the Laurentian of Canada, because (1) they sustain precisely the same structural relations to the Huronian, Keweenawan, and Lower Silurian, as observed in the case of the typical Laurentian of Canada, and (2) because they have the same general lithological peculiarities that characterize the Canada series. There can, indeed, be no reasonable doubt that they are directly continuous with the Canada Laurentian. They extend to the shores of Lake Superior in the vicinity of Marquette, Michigan, and appear again on the eastern or Canada shore of the lake. The separation between the Wisconsin Laurentian and that of Canada is therefore only a superficial one, the connection being concealed by the waters of the lake, and by the overlying Silurian depositions in the eastern extension of the upper peninsula of Michigan.

In Wisconsin, the northern limit of the Laurentian approaches most nearly to Lake Superior on the Montreal river, which is here the state boundary — the distance to the lake shore in a direct line being only thirteen miles. From the Montreal river the northern limit trends about southwest-by-west, and on Bad river, twenty-five miles further west, it is twenty-five miles from the lake. From Bad river the course is in general but little south of west, to Numakagon lake, T. 44, R. 6 W. Here a rapid change to a more southerly direction comes in, and we find ourselves following the western side of the Laurentian nucleus, soon to be bounded by the regular Mississippi valley formations. The southern rim of the Lake Superior trough, at an elevation of one thousand to eleven hundred feet above the lake, lies but a few miles south of the northern boundary of the Laurentian area, for about fifty miles westward from the Montreal, after which it passes on to the more northerly and newer formations.

The rocks of the Laurentian nucleus have already been partly described in former reports. Where they approach Lake Superior they are almost wholly gneiss and granite. The prevailing rock along the

[1] Vol. II, p. 457.

northern border is a dark gray to black, often greenish-black, hornblende-gneiss, in which the hornblende has usually been more or less completely altered to chlorite. This alteration, when carried to any considerable extent, gives a greenish tinge and greasy feeling to the rock, and, in cases of extreme alteration, there is a passage to a green chloritic-schist. The associated granites are usually light pinkish-tinted to gray, and highly quartzose, a frequent gneissoid tendency showing their sedimentary nature. These rocks have a nearly due E.–W. strike, and, near the northern border, a high southerly dip. They are, however, beyond question greatly folded, and have as certainly an enormous thickness.

Huronian System. Lying immediately against the Laurentian, and very sharply defined from it, we find, extending from the Montreal river westward for fifty miles to Lake Numakagon, a belt of schistose rocks which we refer unhesitatingly to the Canada Huronian, and which are beyond question the direct westward extension of the iron-bearing series of the upper peninsula of Michigan. This belt has a width, in general, of from one and a half to two and a half miles, and includes an aggregate thickness of strata of nearly 13,000 feet, with a number of well-marked subdivisions, several of which are persistent throughout the entire length of the belt. These subdivisions may be briefly summarized as follows, beginning below: (1) crystalline tremolitic limestone, at times overlaid by a band of white arenaceous quartzite, and at times absent, the next formation above then coming into contact with the Laurentian, 130 feet; (2) straw-colored to greenish quartz-schist, and argillitic mica-schist, often novaculite, 410 feet; (3) tremolitic magnetite-schists, magnetitic and specular quartzites, lean magnetic and specular ores — forming the "Penokee Iron Range," 780 feet; (4) alternations of black mica-slates with diorite and schistose quartzites, and unfilled gaps, 3495 feet; (5) medium-grained to aphanitic, dark gray mica-schists, with coarse intrusive granite, 7,985 feet — in all 12,800 feet. These rocks all dip to the northward, the angle being usually high, but lessening towards the west, and trend with the course of the belt, which has numerous minor corrugations, while preserving one general direction. The strike-directions are always oblique to the trends of the underlying Laurentian gneiss, proving the unconformability of the two systems, the actual contact of which may indeed be seen in several places.

Westward from Lake Numakagon the Huronian belt is lost sight of, the Laurentian gneiss and Keweenawan gabbro and diabase coming apparently into direct contact with each other.

The reference of the schistose series of the Penokee region to the

Huronian is justified by the following considerations: (1) there appears to be a direct continuation with the iron-bearing system of the Marquette region of Michigan; (2) as shown on a subsequent page, the grand subdivisions of the Bad river and Marquette systems are strikingly similar; (3) the Bad river and Marquette systems both show the same relation to the Laurentian and Keweenawan systems as found in the Huronian of Canada; i. e., are newer than the former and older than the latter; (4) the Marquette system is found in unconformable contact with the Lower Silurian red sandstone of Lake Superior. The Marquette Huronian, in its southerly extension in the Menomenee region, is also found in unconformable contact with the fossiliferous primordial sandstone of the Mississippi valley, a fact which, even if the evidence were not amply sufficient without, would demonstrate the futility of the attempts made by some to refer the whole series of Lake Superior crystalline rocks to the Silurian.

Keweenawan System. This remarkable series of rocks, peculiar to the Lake Superior basin, covers much the greater part of the region under consideration, having in Wisconsin alone an area of not far from ten thousand square miles. It is a distinctly stratified system, but is in large measure made up of eruptive rocks, in the form of great flows. These appear to constitute in Wisconsin the lower ten thousand to thirty thousand feet of the system, apparently without interstratified detrital beds. Above these we find the detrital beds increasing in frequency, until they seem to exclude the igneous rocks altogether; the upper portions for some fifteen thousand feet being apparently composed wholly of sandstone and shale, with a heavy mass of conglomerate at the base.

There are two prominent belts of these rocks in northern Wisconsin, lying parallel to each other, and having between them a true synclinal depression. One of these crosses into Wisconsin at the Montreal river, and trends thence west-south-west entirely across the state, broadening greatly in its more western portions. Along the whole course of this belt the rocks dip to the north, the angle lessening steadily from verticality on the Montreal river, nearly to horizontality on the St. Croix. The eruptive members lie to the southward, the fragmental to the north. The second belt forms the back-bone of the Bayfield peninsula, and extends westward to the Minnesota line, where it has its greatest breadth. The rocks of this belt never seem to have so high a dip as observed on those of the southern one, but the same lessening in angle to the westward is observed. The rocks here are in reverse order, the eruptive to the north, the detrital to the south. Topographically, the Chaquamegon bay depression, with its encircling horizontal sandstones, lies between the two ridges of Keweenawan rocks; it does not, however, occupy the middle of the synclinal, being carved out altogether in the southward-dipping beds. The north and south belts would seem, therefore, to come in fact together, without any overlying formation in the trough.

The eruptive rocks of this series are chiefly of the augite-plagioclase kind, containing hornblende only in unusual varieties, and then always as a paramorphic product of the augite. There is thus presented a marked contrast with both massive and schistose rocks of the Huronian system, in which amphibole in some form is a very common primary ingredient. The three varieties of the augite-plagioclase rocks of the Keweenawan series, named in order of relative abundance, are diabase, melaphyr and gabbro.[1] These differ from each other only in minor particulars, the melaphyr retaining some glass-base, or an alteration product from it, and the gabbro having the augite in a foliated condition. In fact, these distinctions are not sharp, still there are important microscopic differences between the three kinds, peculiar to the Keweenawan series, which generally enable us to distinguish them at once. This is especially true of the gabbro, as compared with the diabase and melaphyr.

The characteristics of both the diabase and the melaphyr are described in detail by Prof. Pumpelly in another part of this volume. His descriptions apply especially to these rocks as developed in the typical region of Keweenaw Point. As he says, however, after examining a set of specimens from Wisconsin, they are applicable as well to the Wisconsin rocks. It is only necessary to quote, in the present connection, a few of the most important points.

The ordinary diabase, which is many times the most abundant of the three kinds, varies from almost black to dark green or brown, and even bright red, or is made up of a minute mixture of these colors, which are due to varying proportions of chlorite and ferric oxide, both decomposition products of the augite. The texture is fine-grained to aphanitic, the latter being much the most common, and the fracture even to chonchoidal. One of the most interesting facts about these rocks is their occurrence in distinct beds, each marking a great molten overflow, which are distinguishable from each other by the common occurrence of three subdivisions in each flow, besides at times by minute shades of difference in aspect. The upper portion of each bed is a true amygdaloid, in which the originally smooth-surfaced gas cavities are now filled with amygdules of calcite, chlorite, epidote, quartz, prehnite,

[1] Following the nomenclature of H. Rosenbusch.

laumontite, copper and orthoclase, or their decomposition products. These portions evidently represent the upper vesicular parts of the lava flows. The lower, and usually much the larger portion of each flow, is massive, without amygdules, and, in Wisconsin at least, very frequently possessed of a marked columnar structure. Between the amygdaloidal and compact portions there is commonly a zone grading in both directions, in which many of the same minerals as found in the true amygdaloids occur in an apparently amygdaloidal condition. In this rock, however, to which Prof. Pumpelly has given the name of pseudo-amygdaloid, these minerals are seen, under the microscope, to occupy the positions of primary constituents, whose alteration-products they are. Both the true amygdaloids and the pseudo-amygdaloids tend to an extreme degree of alteration, when they become irregular mixtures of quartz, epidote, calcite and prehnite, or, more commonly in Wisconsin, of laumontite and calcite, patches of the original amygdaloid frequently remaining interspersed in the most irregular manner. The green and white bands frequently met with in Douglas county belong to the former kind, while the still more common pinkish bands are those that have undergone the laumontitic decay. Under the microscope, the primary constituents of these rocks are seen to be plagioclase, augite and magnetite or titanic iron. The plagioclase crystals, which are usually near oligoclase, are the older, and the intervening spaces are occupied by the augite.

A second and less common variety of diabase, described by Prof. Pumpelly as the "Ashbed type," is also well represented in Wisconsin. In this, which, in the Wisconsin varieties, is dark gray to black, and very compact, having a strongly marked conchoidal fracture, the augite occupies a subordinate position, occurring in minute grains, whose contours are not determined by the feldspar crystals.

The melaphyrs are less abundant in Wisconsin, and we may pass them over more rapidly. They are described by Prof. Pumpelly as identical with the rock known as "The Greenstone," on Keweenaw Point, where it forms a long and bold ridge, with a steep southern face. It is a dark greenish to greenish-black, minutely crystalline, compact rock, characterized by peculiar surfaces of reflection, which, on close inspection, appear to be of the same composite character as the surrounding matrix. These are seen, under the microscope, to be due to the inclusion within large crystals of augite, of hundreds of the feldspar crystals. The same peculiar structure causes a weathering of the rock into knobs representing the pyroxene individuals. The primary constituents are plagioclase, pyroxene, olivine, magnetite and the glass-base. The plagioclase is near anorthite, and the olivine and glass-base are usually altered. This alteration, since the olivine is mostly crowded into the spaces between the large pyroxenes, has produced a mottling of dark green and dark brown, the former corresponding to the pyroxene crystals, and the latter to the intervening olivine-bearing spaces. The brown color is due to the peroxidation of the iron of the olivine. The melaphyr does not, according to Pumpelly, commonly have the amygdaloidal and pseudo-amygdaloidal portions that characterize the diabase. Like the diabase, it is prone to extreme stages of alteration. These alterations have been traced out in detail by Pumpelly in his paper on the "Metasomatic Development of the Copper Bearing Rocks of Lake Superior."

In the Keweenaw Point region gabbros are rare, and not very sharply defined from the other rocks. They have, consequently, received but little attention in Professor Pumpelly's descriptions. In the Bad river country of Wisconsin, however, there is a great development of gabbro at the base of the Keweenawan system, and other gabbros occur in the north belt in Douglas county. My own investigations show that there are two well marked varieties of these gabbros, the most common of which is light to dark gray, perfectly crystalline, and usually of a very coarse-grained texture. The plagioclase in this rock is commonly labradorite, and occurs in perfectly defined and generally very fresh crystals, the linearly bounded spaces between which, in the thin section, are filled by the augitic ingredient. Generally a number of the augitic areas are seen to be crystallographically identical. In structure the augite shows every gradation from that of true diallage to that of common augite. Olivine is present in many varieties, often in large quantity, and is often macroscopically visible. It at times undergoes a peculiar alteration, but, as a rule, is, for olivine, extraordinarily free from decay. Magnetite is the other constant primary ingredient. Hornblende-bearing phases of this variety of the gabbro occur, the thin sections of which show at times a deep brown basaltic hornblende, and at others, and this is more common, the greenish kind. The latter is certainly always, and the former as certainly in most cases, only a paramorphic product of the augite.

The second variety of the gabbro is a very coarse-grained, red-and-black-mottled, or red-and-gray-mottled rock, in which the plagioclase is always altered in a saussurite direction, having in some crystals a grayish, dull appearance, and in others a red stain due to iron infiltration. The diallage, when fresh, is black, lustrous, and highly foliated, showing, however, a frequent change to a soft chloritic substance. The free iron oxide ingredient, which is now magnetite and now titanic iron, is in very large, abundant, highly lustrous, and often pinkish-tinted grains. The first kind of gabbro is found only in the Bad river belt, of which it forms the lower and larger portion. The last-named kind forms the upper part of the Bad river belt, and is also represented among the south-dipping beds of the Douglas county region.

The acid rocks are represented in the Keweenawan system by granite and felsitic porphyries. The granite is of restricted occurrence, and is found penetrating alike the upper mica-schists of the Huronian, and the gabbro at the base of the Keweenawan. It is known only in the townships immediately west of Bad river, where it is coarse and of a pinkish color, with predominating pink orthoclase and gray quartz, rarer white plagioclase, and fine-scaled black biotite.

The porphyries are chiefly of the quartz-porphyry kind, and from lilac to brick red in color, with porphyritic white orthoclase, and black quartz. True non-porphyritic felsites also occur. These rocks, which form persistent and often broad bands, interstratified with the basic members in both the southern and northern belts, nearly always present a massive appearance, being for the most part without sign of clastic origin. It is quite possible that they are true non-clastic rocks; and this supposition would not be questioned for a moment but for the fact that at one or two places they have been seen with a conglomeratic tendency, and the further fact that all the porphyry beds as yet examined in detail in the Michigan region are clastic. From Foster and Whitney's Lake Superior report it appears that there are large developments of similar rocks at several little known points in the Michigan region, notably in the Porcupine mountains. The true nature of the porphyries and their relations to the surrounding rocks, is a point deserving the earnest attention of all geologists working in the Lake Superior country.

The clastic or fragmental rocks of the Keweenawan system include shale, sandstone and conglomerate, with a thickness, in all, of not less than 10,000 to 15,000 feet.

The shales are both true clay shales of a dark gray to black color, and red sandy shale grading into sandstone. The former are restricted to the lower portions of the upper division of the system, and are possibly at times carbonaceous, while the latter occur through all parts of this division.

The sandstones are chiefly of a red color, of varying coarseness of grain, and always highly aluminous, owing to a large proportion of feldspar fragments, which are not unfrequently more or less changed to a kaolinic substance. These sandstones constitute the greater part of the upper division of the system, with a thickness of 10,000 to 13,000 feet. Similar sandstones — and this is true also of the red shales into which they grade — are found alternating with diabase flows, for a thickness at times of over a thousand feet, near the junction of the eruptive and sedimentary divisions of the system.

The sandstones are also found grading into fine conglomerates, but besides these there occur sharply defined boulder-conglomerates, with the pebbles reaching one to two feet in diameter. One such layer as this has been traced westward from the Montreal for over 70 miles, with a thickness of from 100 to 1,200 feet. The pebbles are quite largely of quartzose porphyry, but abundant ones occur of the ordinary basic eruptive rocks of the system, and in places large sized quartzite boulders are plenty. Besides the boulder-conglomerate places have been noticed, as stated on a previous page, where the great porphyry bands of the eruptive portion of the system show a conglomeratic tendency, reminding us of the true porphyry conglomerates of the Michigan portion of the system.

The importance of the Keweenawan series in the structure of northern Wisconsin will warrant a rapid summary in this place of the main facts obtained by the several members of the survey who have worked on it, with regard to the relations and distribution of its several members.

Beginning with the southern or northward-dipping belt, we find, on the Montreal river, where it crosses into Wisconsin from Michigan, the following succession above the Huronian schists: (1) green chloritic diabase and diabase-amygdaloid, black conchoidal-fracturing diabase of the Ashbed type, and the ordinary diabase and diabase-amygdaloid (the latter constituting the upper and greater part, and all without satisfactory appearance of bedding), included in which are at least three porphyry bands, one having a width of many hundreds of feet — in all, about 33,000 feet; (2) alternations of diabase, and diabase-amygdaloid, with red sandstone and shale, 1,200 feet; (3) boulder-conglomerate, 1,200 feet; (4) alternating black shale and hard gray quartzless sandstone, 350 feet; (5) red sandstone and shale, 12,000 feet, to which should probably be added some 4,000 to 5,000 feet covered by the waters of the lake; the last four members presenting a distinct bedding and very steep northern dip. These measurements give us a total of some ten or eleven miles, measured horizontally. Should we regard the series as a continuous one, after making all allowances for variations in dip, we have here at least a thickness of 50,000 feet.

Ten miles southwest, following the trend of the formations, we find along Potato river the green diabase of the Montreal section replaced by coarse gabbro, while the whole eruptive portion of the series is

Proc. Amer. Acad. Sci., XII, 268 (1878).

considerably reduced in thickness. The succession here measured from south to north, is as follows: (1) gabbro, 13,000 feet; (2) diabase and diabase-amygdaloid, some of the Ashbed type, and including three porphyry bands, one a mile in width, 21,000 feet; (3) alternating diabase and sandstone, but the sandstone beds barely represented, 2,000 feet; (4) boulder-conglomerate, 800 feet; (5) alternating black shale and sandstone, 250 feet; (6) red sandstone and shale, in sight, 2,000 feet. Above this the measures are concealed by the red lacustrine clays of the lowlands. The dip is still nearly vertical, with a lessening to 75°–80°, in the more northern sandstones.

Ten miles farther southwest again, Bad river crosses the series. Here we have several changes, the eruptive portion of the series being greatly reduced in thickness, while the alternations of diabase and sandstone have wholly disappeared. The following is the succession above the Huronian: (1) gabbro, with granite veins, 12,000 feet; (2) diabase and diabase-amygdaloid (none of the Ashbed type), with two (three?) porphyry bands, only 5,000 feet; (3) boulder-conglomerate, 300 feet; (4) alternating black shale and sandstone, 120 feet; (5) sandstone and red shale, in sight, 300 feet; beyond which the measures are buried beneath the clay of the lowlands. The inclination is still a vertical one, with a lessening to 75°–80° in the more northern sandstone, as before.

At Bad river the trend of the formations changes to a westerly one. Eight miles west, on the Brunschweiler, we have: (1) gabbro, with occasional granite veins, 32,000 feet; (2) diabase and diabase-amygdaloid, with two narrow porphyry bands, and one narrow band of sandstone, 3,000 feet; (3) conglomerate, 600 feet. Above the conglomerate the measures are unexposed.

At the Brunschweiler the dip has already begun to flatten. Westward from here the flattening goes on very rapidly, as a result of which the series spreads to a much greater surface width, and the boldness of the topography disappears. Other results are the passage of the belt we are following on to the Mississippi river slope, and, since there are no more rapid streams, the lack of any such magnificent sections as those of the Montreal, Potato and Bad rivers. The exposures become rarer, and more difficult to assign to their proper places in the formation. By the time the west line of R. 6 W. is reached, the gabbros disappear, and diabase and melaphyr seem to make up the whole of the eruptive portion of the system. In R. 7 W., in the vicinity of Long lake and the Numakagon river, these have a surface width of nine miles, and are apparently directly in contact on the south with the Laurentian, the Huronian schists having disappeared. In townships

43 and 44, R. 9 W., the northward dip is only about 25°, as shown by numbers of exposures, descriptions of which are found in the notes left by the late Mr. Strong.

As far as the northwest corner of T. 44, R. 8 W., the course of the northern border of the diabase beds, which is marked by the westward continuation of the same conglomerate belt as found farther east, is nearly east and west. Beyond this point it trends southwest again, passing in the vicinity of the Eau Claire lakes, where what is not improbably the same conglomerate may be seen, this being the westernmost point at which it has been observed. A line from here across the diabase belt, in a direction of right angles to the general tread, measures twelve miles. Further west, as shown by Mr. Strong's notes, the dip lessens still more, probably in a large portion of the area approaching horizontality, the width of the district covered at the same time greatly increasing.

As the St. Croix river is approached, the whole country from township 41 southward to township 33 has been shown by Mr. Strong to be underlaid by the typical diabase and melaphyr of the Keweenawan series. In the immediate vicinity of the St. Croix, and to some extent away from the river, there is often a covering of the horizontal Potsdam sandstone, which, at the contact, is commonly filled with pebbles and boulders worn from the older diabase and melaphyr, and is, moreover, often crowded with the characteristic Primordial fossils.

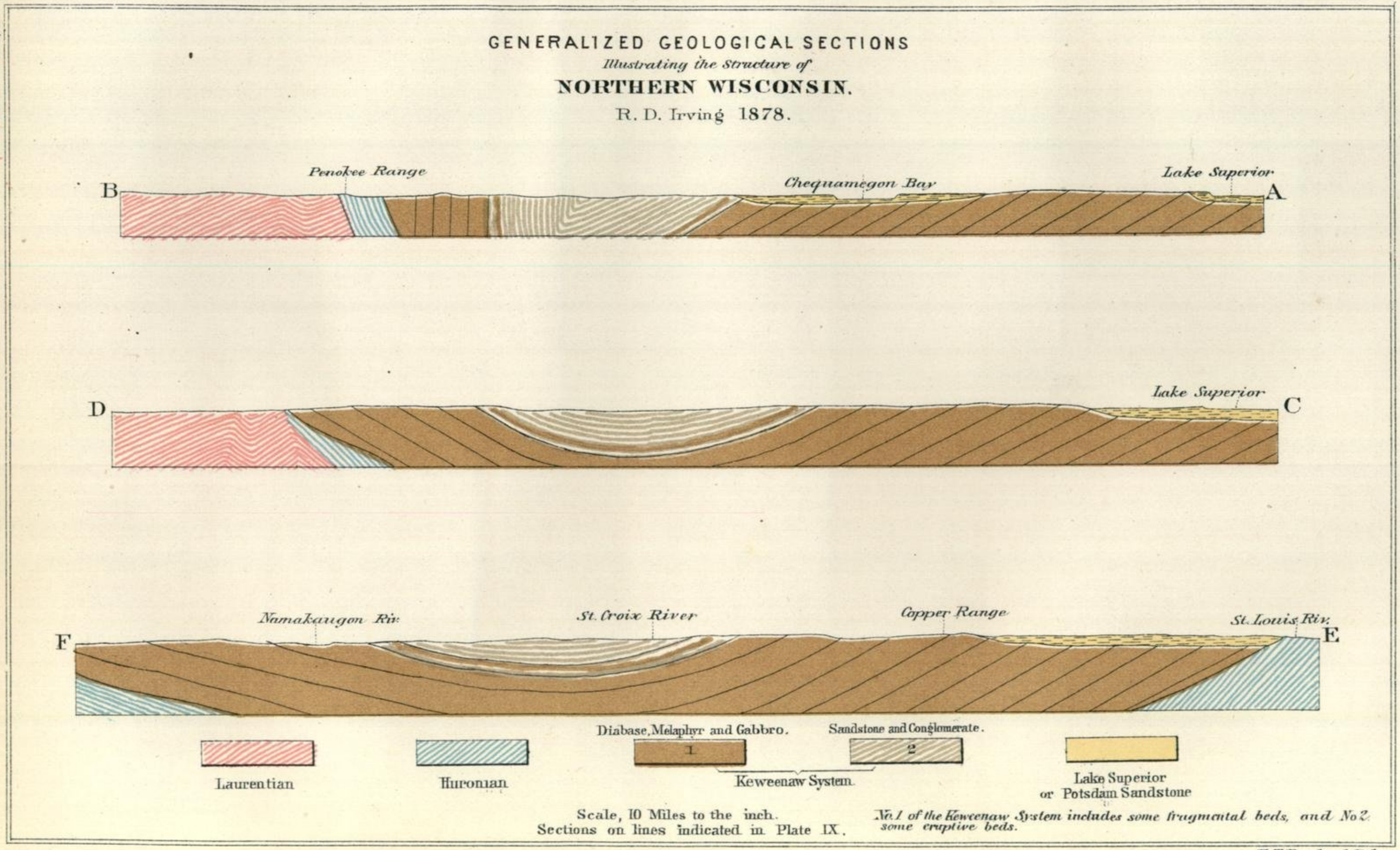
The northward-dipping sandstone beds which are exposed on so large a scale on the Bad and Montreal rivers, are not to be seen west of Ashland county, though on the north side of the synclinal the same beds occupy their true positions as far as the west line of the state. It is supposed that to the southward they are buried beneath the heavy drift accumulations of the region, and, moreover, that they may have been largely eroded.

Passing now to the northern side of the synclinal, where the strata dip southward, we find the same order as before — eruptive rocks below, and to the north, the sandstones above, and therefore on the south.

The easternmost exposure of these south-dipping rocks is met with on Bad river, Sec. 25, T. 47, R. 3 W., where are seen red sandstones and shales, 2,000 feet in thickness, dipping southeastward at an angle of 38°. A thickness of several hundred feet of the same rocks inclined also to the southeastward, now at an angle of 25°, is exposed on White river, Sec. 5, T. 46, R. 4 W. To the westward from here there are many square miles of country without exposures.

The central ridge of the Bayfield peninsula appears to be made up beyond doubt of some of the crystalline rocks of the Keweenaw system.

PLATE IX, A



F. T. Bernhard Del.

These are, however, not exposed until we get as far west as Iron river, T. 48, R. 9 W. From here, in a direction west of south, fifty miles across Douglas county to the Minnesota line, is a prominent ridge with a bold northern face, made up of beds of melaphyr and diabase. These beds, which are exposed both on and away from the rivers, over a belt two to four miles wide, dip constantly to the south at an angle of 20° to 40°. On the north they are seen frequently in unconformable relations with the horizontal Lake Superior sandstone, which is filled with boulders and pebbles derived from their destruction.

Southward from the Douglas county Copper Range, the country is level and swampy for twelve to fifteen miles. Beyond this barren interval, however, are found, in townships 43 and 44, numerous ledges of diabase and diabase-amygdaloid, with a low southern dip; immediately overlying which is a great thickness of red sandstone and shale, inclining southward at an angle of about 14°. These sandstones are seen along the St Croix river, in townships 42, 43 and 44, and in the branch streams, for a distance of over twelve miles. According to Mr. Sweet, the total thickness exposed is over 9,000 feet, but from Mr. Strong's notes it would appear that there are included eruptive beds.

Lake Superior Sandstone. The newest of the four great formations of the Lake Superior region presents itself as a horizontal sandstone, which varies from deep reddish-brown, through various tinges of red, to fawn color, the red shades being the common ones. This sandstone is generally quite aluminous, carrying usually some feldspathic particles, whose alteration has often given rise to a kaolin-like substance, which, in lighter-colored varieties, is readily perceptible as a white substance between the grains. These peculiarities have already been noticed as characteristic of the sandstones of the upper portion of the Keweenaw series, but the newer or horizontal sandstones have always a much larger, and frequently even a predominating quantity of quartz granules. The following analyses, by Mr. E. T. Sweet, show well the differences between the typical sandstones of the two systems. No. I is of a coarse grained, highly feldspathic rock from Leihy's Falls on Bad river, Sec. 25, T. 47, R. 3 W. No. II is of the dark-brown stone quarried on Bass Island, opposite Bayfield. The large percentage of magnesia in No. I is evidently due to the presence of a pyroxenic alteration product:

	I.	II.
Silica	69.78	87.02
Alumina	15.43	7.17
Iron peroxide	7.93	3.91
Lime	.49	.11
Magnesia	1.17	.06
Potash	2.64	1.43
Soda	2.42	.22
Totals	99.86	99.92

Plate XIX A, of this volume, gives several representations of the appearance under the microscope of thin sections of both Keweenawan and Lake Superior sandstones.

The horizontal sandstone is confined to the vicinity of the shores of the lake, above whose level it has never been observed at a greater height than 370 feet. This figure must, therefore, the position of the layers being practically a horizontal one, be taken as the maximum known thickness of the formation. It undoubtedly extends to a greater depth, and quite possibly at one time filled a large portion of the Lake Superior trough.

The easternmost point at which the horizontal sandstones are known in Wisconsin, is on the lake shore at Clinton Point, Sec. 32, T. 48, R. 1 W. Four miles east of here, on the Montreal river, the nearly vertical Keweenawan sandstone is in sight, with a thickness of thousands of feet. West of Clinton Point, the horizontal sandstone seems to underlie the low country about the mouth of Bad river, but does not appear to view until the head of Chaquamegon Bay is reached. From here it is constantly exposed in low cliffs around the entire coast of the Bayfield peninsula, and for short distances up the rivers flowing into the lake. It is also visible in similar cliffs on the shores of nearly all the islands of the Apostle group. Beyond the mouth of Iron river, T. 50, R. 9 W., the sandstone is no longer seen in the lake bluffs, which are now wholly of red clay, but is constantly exposed up the northward-flowing streams as far as the foot of the Douglas County Copper Range, which is composed, as previously shown, of southward-dipping eruptive beds of the Keweenawan series. According to Mr. E. T. Sweet, from whose reports all the facts with regard to the country about the western end of the lake are taken, the belt of horizontal sandstone north of the Copper Range has a width of from five to ten miles. Mr. Sweet also states that the elevation of the sandstone at its junctions with the other rocks, varies considerably. On the St. Louis, in the vicinity of Fond du Lac, where the horizontal sandstone directly overlies the Huronian schists, it reaches an altitude of between 200 and 250 feet above the lake level. On Black river, in Douglas county, where the sandstone is seen nearly in contact with the Keweenawan eruptive rocks, in a deep gorge, its upper surface is at an altitude of 365 feet. For the other principal streams flowing into Lake Superior, named in order from west to east, the corresponding figures given by Mr. Sweet are as follows: Copper creek, 296 feet; Aminicon river, 220 feet; Middle river, 155 feet; Brulé river, 212 feet; Iron river, 150 feet; Flag river, 115 feet; Siscowet river, 95 feet.

The several junctions of the Lake Superior sandstone and Keweenawan rocks, exposed in Douglas county, present some points of general interest. I quote in this connection from Mr. Sweet's report: "Most of the northward-flowing streams in Douglas county leave the crystalline rock area and enter upon the sandstone district through deep gorges and in wild falls. In the walls of these gorges both formations are usually beautifully exposed, but the sandstone, for a distance of from twenty to three or four hundred feet from where we would expect to find the contact, has evidently been affected by some great lateral pressure; for we find the layers broken into short lengths and tilted at various angles, generally to the northwest, or away from the crystalline rocks. In following down the streams, the sandstone layers in the walls of the gorges gradually show less and less the effects of disturbing influences, and finally assume horizontality and regular bedding. On Middle river the original lines of deposition have been entirely obliterated, and the very argillaceous sandstone transformed into a transverse-cleaving slate." From other portions of Mr. Sweet's report, it appears that at the contact there is in many cases a confused brecciated mass of sandstone and crystalline-rock fragments, some of which are of great size, while in places they become rounded, and the rock passes into the ordinary conglomerate. These peculiar appearances, only in one case reaching to any considerable distance from the crystalline rocks, are to be attributed in the first place to the naturally confused mode of deposition on the cliffy shore of the waters in which the sandstones were originally deposited, but, as I have shown in another place,[1] a slight movement northward of the deep-seated crystalline rocks against the more superficial sandstone would account for much. Another thing tending to confuse, would undoubtedly be the chemical action, which, as is well known, is so apt to be set up with unusual energy along the contact of dissimilar formations.

The contact of the Lake Superior sandstones with the Huronian slates of the St. Louis river, in Minnesota, is without such peculiar phenomena as just described, being a case of true unconformable superposition, and not of mere abutment against the higher ledges of an older system. According to Mr. Sweet, in descending the St. Louis river from the railroad crossing at Thompson, the horizontal sandstones first overlie the slates near the center of Sec. 11, T. 48, R. 16 W., two miles above the Wisconsin line. The sandstone is here a conglomerate of pebbles of quartz and of greenish chloritic slates from the underlying Huronian, the quartz pebbles coming from veins in the latter formation. Above, these conglomerates grade into and are directly succeeded by the ordinary red sandstone and shale.

[1] "On the Age of the Copper-Bearing Rocks of Lake Superior." Am. J. Sci. June, 1874.

The *resumé* thus given, together with the accompanying map (Plate IX) and sections (Plate IX A), will serve to convey a comprehensive idea of the relations to each other of the several North Wisconsin formations, and of the position and extent of the great synclinal depression which extends entirely across the state, from the Michigan to the Minnesota boundary. A number of interesting conclusions, as to structure, covering a wider area than is included within the Wisconsin region, are suggested by the results obtained by our survey. As to some of these, I can have but little doubt of their truth; still, the needed investigations have not been made, and their final demonstration must be left to the geologists of the adjoining states.

One of the most interesting of the points left in some doubt is the nature of the continuation of the North Wisconsin synclinal into Minnesota, and the relation of the rocks on the north shore of the western end of Lake Superior to those in Wisconsin. The descriptions given in Owen's report of the rocks exposed on Kettle river, which crosses the extension of the synclinal in Minnesota, are of no avail in this connection, for, in the first place, his distances are estimates only, made in canoe traveling, and, moreover, he has failed to distinguish between the Potsdam sandstones of the Mississippi valley and the sandstones of the Keweenaw Series. This distinction will, indeed, be a matter of some difficulty to any one, even now that the structure of the Wisconsin region is known, for the Keweenawan sandstones are here but little inclined, and the Potsdam sandstone, which probably often directly overlies the others, is frequently filled with boulders of the eruptive rocks of the Keweenaw Series, the resulting conglomerates looking much like some of the true Keweenawan conglomerates. It is very evident that the Mississippi valley sandstone stretches well to the northward in the St. Croix region.

It is supposed that the North Wisconsin synclinal terminates at no great distance west of the Minnesota line, in a shape which might be likened to that of the end of a shallow spoon, one side of which has been beaten out nearly flat, as indicated by the wide spread, southward, of the nearly horizontal eruptive rocks.

The Huronian schists, so largely exposed along the St. Louis in Minnesota, from Thompson nearly to the Wisconsin line, dip constantly to the southward, at an angle of from 30° to 40°, the strike being nearly east and west. These schists appear to be representatives on the north side of the synclinal of the Penokee Huronian System, whose western extension we suppose to be buried beneath the overflows of the Keweenawan diabase and melaphyr. If this view is correct, the two must connect, also in spoon-fashion, somewhere in that part of Minnesota southwest of the St. Louis. The hills immediately back of Duluth are made up of a coarse-grained hornblende gabbro,[1] behind which pass the Huronian schists of the St. Louis, and above which, a few miles along the lake shore, begin to appear the characteristic diabases and sandstones of the Keweenaw series, dipping at low angles (5° to 15°) to the southward.[2] It seems altogether probable that we have in these rocks of low dip merely a portion of the same south-dipping series met with in Douglas county, Wisconsin. From the publications of Owen and Whittlesey with regard to the northwest shore of Lake Superior, I gather that the same low southern dip prevails throughout. It reappears, as Foster and Whitney have shown, in the Isle Royale rocks, so that the North Wisconsin synclinal would appear, on the whole, to be the same as that long recognized as lying between Isle Royale and Keweenaw point. The westermost portion of the lake or the "Fond du Lac," is then, on this view, excavated entirely in the south-dipping layers of the north side of the synclinal, and possibly, to judge from the position of the island, in those layers that appear in Isle Royale. The varying breadth of the depression is easily explained by the variations in inclination on either side, as also by the thinning and thickening of different members of the series. The relation of the Porcupine Mountain rocks to the synclinal is, however, with our present knowledge, a point of difficulty.[3]

The subject of the age of the Lake Superior formations is one deserving a few additional words. That the gneissic and schistose rocks of the region are correctly referred to the Laurentian and Huronian systems of Canada, would seem to be sufficiently proven from facts already given. The relations of the Keweenawan system and of the horizontal Lake Superior sandstone to each other, to the Huronian schists, and to the fossiliferous Potsdam sandstone of the Mississippi valley, are, however, points needing further consideration.

That the Keweenawan system is newer than the Huronian, is evident enough from the relative positions of the two, both in the Penokee region and in the region of the northwest shore of Lake Superior. That the two systems are in actual non-conformity in these regions is not so evident. Pumpelly and Brooks, after a rapid examination of the re-

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[1] Streng and Kloos. Neues Jahrbuch für Mineralogie, 1877.

[2] Col. Charles Whittlesey. "Physical Geology of Lake Superior." Proc. Am. Assoc., 1875. Also Owen's Geological Survey of Wisconsin, Iowa and Minnesota.

[3] The nature of the depression south of Keweenaw Point, and of the westward extension of the Copper Range of Keweenaw Point, now occupied by the horizontal Lake

gion between Bad river and Lake Gogebic, announced, in 1873,[1] their belief in the essential conformity of the two systems. The opinion was based on the close approximation in the amount of northward dip through all of this region; the Keweenawan beds, when differing in inclination from the adjacent Huronian, presenting a higher inclination, instead of a lower one, as would be expected in a case of non-conformity.[2] After my own first season's work in the Penokee country, I acquiesced in this conclusion, and so stated in a paper published in 1874.[3] In an article published in 1876,[4] however, Mr. Brooks reverses his former opinion, now regarding the Huronian and Keweenawan systems as unconformable. I give his arguments in his own words:

"As supporting the view that these pre-Silurian systems are of distinct periods, I would call attention to their well known points of difference. The Huronian series of stratified greenstones, chloritic and related schists, clay slates, quartzites, marbles, micaceous and hornblende-schists, gneisses and granites, containing no copper or other metallic ores, except great conformable beds of magnetite, hematite, and limonite, differ as widely as may be from the compact and amygdaloidal melaphyrs, friable sandstones, conglomerates with porphyry pebbles, which constitute the bulk of the copper series, the whole more or less charged with native copper and silver; all of which points strongly toward a different origin of the two systems.

"In their metamorphoses and movements subsequent to their deposition, there is a not less wide divergence noticeable. The friable sandstones of the copper series, showing no greater metamorphism than the overlying Silurian, for which they are often mistaken, have no counterpart in the highly crystalline schists and quartzites of the Huronian, where we have only just enough of the arenaceous character left in some of them, to leave no doubt as to their fragmentary origin. But the difference in the amount, sharpness, and regularity of the folding and bending of the rocks of the two systems into existing wave forms, is, if possible, wider than their lithological variations. Contrast the

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Superior sandstone as far west as Lake Gogebic, is another point of difficulty as well as of great interest in this connection. A few facts given by Foster and Whitney, and by Brooks and Pumpelly, suggest the thought that there may be here another true synclinal depression, the southern rim of which is represented by the "South Copper Range" of the region of Lake Gogebic; but this is a mere conjecture.

[1] Am. Journal of Science and Arts, Vol. II., 1872.

[2] See Sections, Atlas Plates XXI and XXII.

[3] "On the Age of the Copper Bearing Rocks of Lake Superior." Am. Journal of Sci., June, 1874.

[4] "On the Youngest Huronian Rocks south of Lake Superior." Am. Jour. of Sci., March, 1876.

magnificent regular sweeps of the copper series, the main ranges of which preserve the same strike and direction of dip from Keweenaw Point westward for 150 miles, presenting for half the distance only the south unturned edge of the broad synclinal which embraces one-fourth of the great lake in its basin; with the older system everywhere sharply folded into narrow troughs and irregular basins, trending in every direction, the upturned edges of whose enclosing rocks box the compass, winding and zig-zagging in outcrop like a sluggish river.

"If we extend our observations to the older and again non-conformable Laurentian, we find the rocks still more plicated and metamorphosed, often even to the extent of entirely obliterating all evidences of stratification. If we suppose the forces which have produced the metamorphosis and the wave forms to have acted regularly and constantly from the beginning of Archæan time to the beginning of the Paleozoic, we may easily suppose the above results produced, viz: the Laurentian, most disturbed and changed, the Huronian next, and the copper series least, the Silurian practically not at all.

"A fact not without interest is the entire absence, so far as I know, of any patch, even, of rocks of the copper period south of the great Keweenaw belt. If the two systems were conformable and of the same age, it is difficult to suppose it possible that erosion should have entirely denuded all the Huronian area which must have been covered by the copper series, of the rocks of that period. One would expect that somewhere a mass of these supposed younger Huronian beds would have been embraced in some one of the numerous sharp, deep synclinals, and have been found by those indefatigable mineral prospectors who have so thoroughly searched this region. On the hypothesis of non-conformability, it is much easier to conceive how it was possible for Silurian breakers coming from the south, slowly advanced by a subsidence from the same direction, to have done their work in completely uncovering the present Huronian area, and leaving the great copper range escarpment one of the most striking topographical features as well as the most difficult geological problems in the northwest. It is easy to suppose, for example, the horizontal Silurian rocks being entirely eroded from any Archæan terrains, but not of the Huronian rocks being entirely eroded from a Laurentian area for the reason already given. Lastly, Logan states, Geology of Canada, 1863, p. 77, that 'certain conglomerates of the Lower Copper-bearing rocks north of Lake Superior repose non-conformably on the upturned chloritic schists of the Huronian.'"

It will be seen that Mr. Brooks' arguments are based chiefly upon the relations and main structural features of the two systems as developed in Michigan, and that, therefore, "the approximate conformability in strike and dip of the Huronian and copper series between the Montreal river and Lake Gogebic, would in this view be only accidental, and not prove identity of age." These arguments appear to me to be, for the most part, quite sound; and, moreover, I conceive that further evidence of non-conformity is afforded in the Wisconsin region by the following facts: (1) In the Penokee country, the uppermost beds of the Huronian are gradually cut out, as we trace them westward, by the gabbro that forms the base of the Keweenawan series, a fact which appears to me best explained by the supposition that the gabbro[1] covers and conceals these missing beds. (2) There is not an absolute uniformity in dip between the Huronian and Keweenawan rocks in this region, the latter standing commonly at a higher angle. (3) West of Lake Numakagon, the diabases and other eruptive rocks of the Keweenaw series appear to completely cover the Huronian, in a great overflow. Nevertheless, the approach to conformity in Wisconsin is close, and were we to draw our conclusions from this region only, the non-conformity could hardly be regarded as proven. There are no such undulations in the Huronian of the Penokee district as in Michigan, the subordinate members making long and regular bands conforming to the general trend of the formation, and also, in a general way, to the trend of the several belts of the Keweenaw series. Moreover, the lessening in dip towards the west, already noted as affecting the latter rocks, is observed also in the underlying Huronian, so far as these can be traced westward. Again, from the relation of the Huronian and Keweenawan rocks on the St. Louis and the district bordering the northwest shore of Lake Superior, it appears evident that the North Wisconsin synclinal affects Huronian as well as Keweenawan rocks.

The older geologists all speak of the Keweenawan series and the horizontal Lake Superior sandstones as forming part of the same system. Sir William Logan,[2] in his Geology of Canada, gives good reasons for believing in a non-conformity between the two; and Brooks and Pumpelly, in the publication above referred to, distinctly announce such a non-conformity. Their opinion is based (1) on the unconformable abutment of the horizontal sandstones all along the south side of Keweenaw Point against the northwest-dipping diabase and included sandstones of the Keweenawan series; (2) on the occurrence of a small patch of horizontal sandstone, placed directly upon the tilted diabase

[1] This gabbro belt occupies the position of the belt called granitic by Major Brooks, in the paper above quoted, and by Colonel Whittlesey, in Owen's Geological Report, "granitic and syenitic."

[2] Geology of Canada, p. 85.

beds; (3) on the relations of the two series in the vicinity of Lake Gogebic; and (4) on the general dissimilarity in structure of the two systems, the one presenting itself always as a constantly horizontal sandstone of no great thickness, confined to the immediate vicinity of the lake, or to low depressions extending inland from the lake, while the other is a series including enormous thicknesses not only of eruptive rocks, but of fragmental sediments as well, which are always inclined, and rise to great heights above the lake level. The unconformable abutment of Keweenaw Point was formerly explained by supposing the existence of a great longitudinal fault. That the tilted diabase beds had, however, the same position as now, when the horizontal sandstone was deposited, is evident from the pebbles and boulders of diabase found in the sandstone at the contact.

The relations of the two systems, as observed in Wisconsin, are, I think, wholly confirmatory of this view. The constant horizontality of the sandstone series; its restriction to low levels; the actual unconformity visible in Douglas county; the proximity of the horizontal sandstones to the enormously thick perpendicular fragmental beds of the Montreal river; and the relations of the two series on the St. Louis, appear to amount to demonstration. In the Thunder Bay region, the Canada geologists have proved a similar non-conformity, and Sir William Logan's arguments would seem to show that the same is true for the southeastern shore of the lake. That it may at times be difficult to tell whether we have to do with the Keweenawan or the newer sandstones, is undoubtedly true in some of those cases where the Keweenawan beds have a low inclination, but such cases of difficulty are rare.

Sir William Logan, supposing the horizontal sandstones, because overlaid in the vicinity of the Sault St. Marie by beds with Trenton fossils, to belong to the Chazy horizon, was inclined to refer the Keweenawan series to the Calciferous and Potsdam. The researches of Dr. Rominger, State Geologist of Michigan, would, however, seem to show that the horizontal sandstones really belong to the Potsdam horizon of New York, which would indicate a pre-Primordial age for the Keweenawan system.

Fortunately, however, we have at hand a more absolute proof than this, of the age of the Keweenawan System, for at the Dalles of the St. Croix river, thirty miles above its junction with the Mississippi, and on the west line of Wisconsin, we find horizontal sandstones and shales, crowded with characteristic Primordial fossils, lying upon the irregular and eroded surface of a Keweenawan melaphyr.[1] The contact is finely

[1] E. T. Sweet, Transactions Wis. Acad. Sci., Vol. III; also, Owen's Geol. Survey Wis., Iowa, and Minn.

exposed, and the sandstone near the junction is full of rounded and angular fragments of the underlying melaphyr. This place was described by Owen, but, so infected was he with the prevalent ideas of intrusive rocks, that he looked upon the melaphyr as the newer of the two, disregarding the overwhelming evidence of direct superposition, of the undisturbed condition of the sandstone, and of the melaphyr pebbles and boulders it contains. Mr. Strong has found similar contacts in numbers of other places in the St. Croix region. It is evident enough, then, that we have here proof absolute that the Keweenawan series belongs below the base of the Paleozoic column of the Mississippi and above the Huronian schists of Lake Superior.

The relation of the Lake Superior horizontal sandstone to the Potsdam sandstone series of the Mississippi valley, needs a few remarks. As already stated, Logan has proved the sandstones of the Sault to lie below beds with Trenton fossils, and Rominger seems to have nearly as clearly established a similar relation to the Calciferous strata. These facts would go far towards placing the two series in question at nearly the same horizon. An absolute proof of their exact relations is wanting, because nowhere as yet have the two been traced into each other. Judging from the low altitude above the lake to which the Lake Superior sandstone has been seen reaching, it appears improbable that any connection ever existed between the two formations in the Wisconsin-Minnesota region. The only place, in this vicinity, where such a connection would seem to have been possible, would be along the bottom of the synclinal depression; but even here the elevation seems too great, and, moreover, so heavily is the country covered by drift materials that no trace of the connection would be likely to develop itself, did it exist.

It is much more possible that a connection may exist in that portion of the upper peninsula of Michigan where the formations of the west side of Lake Michigan swing around from a northeastward to an eastward trend. That the fossiliferous Potsdam sandstone is continuous to the Michigan line, Prof. Chamberlin has shown.[1] As to a connection across the seventy to eighty miles intervening between here and Lake Superior, I find no evidence in the reports of the Michigan geologists. The idea that a connection exists here between the St. Peter's, or Upper sandstone, of Wisconsin, and the Lake Superior sandstone, need only to be mentioned for the sake of denying the existence of any such connection.

It appears, on the whole, that the evidence is all in favor of an approximate equivalency of the Lake Superior and Mississippi valley Potsdam sandstones. It seems probable to me, with my present knowledge

[1] "Geology of Eastern Wisconsin," in Vol. II, Geology of Wisconsin.

of the facts, that they were deposited in always disconnected basins, and that their sharply contrasted lithological peculiarities are to be explained by corresponding differences in the ancient rocks from whose ruins they are built.

Judging from the facts obtained in the western part of the Lake Superior region, the sequence of events during the periods represented by these formations would, then, seem to have been as follows: the deposition of the sediments which afterwards became the Huronian schists, in a trough bounded by lofty elevations of Laurentian gneiss; the deepening of the trough, with the partial alteration and dislocation of these sediments; the first great molten outflows, presumably of fissure origin, of the Keweenawan system; the further crystalization — due to the heat at the depth reached — of the Huronian sediments, with the contemporaneous formation of the granite now found penetrating the upper Huronian schists and the gabbro at the base of the Keweenawan; the formation by alternate igneous outflow and sedimentation of the enormously thick Keweenaw system, the trough continuing to deepen meanwhile, but not enough to carry the Keweenawan sediments into the region of alteration; the gentle folding into a wide synclinal, or synclinals, of the whole series of beds whose history has been thus traced; the enormous denudation which removed the Laurentian highlands, and produced the beveled edges of the Huronian and Keweenawan series; and, finally, the deposition of the Lake Superior horizontal sandstones in the depressions left by the movements and erosion of the preceding periods.

PART II.

LITHOLOGY

OF THE

KEWEENAWAN SYSTEM.

BY RAPHAEL PUMPELLY.

LITHOLOGY OF THE KEWEENAWAN SYSTEM.

Agreeably to the request of Prof. Chamberlin, I have examined the rocks sent me from the collections made by Prof. Irving, Mr. Strong and Mr. Sweet, and from the University collection. In doing this, I have had one hundred, or more, thin sections cut for study under the microscope. I have limited my observations chiefly to the classification of the rocks; thinking that the most important direction that I could give to my study would be that one in which I might be able to contribute some aid towards the comparison of the rocks of the Keweenawan or Copper-bearing series of Michigan [1] with those of Wisconsin.

In classifying the Wisconsin rocks, I have followed the system of Rosenbusch,[2] which, in so far as the rocks in question are concerned, is expressed in the following scheme:

I. Granular Plagioclase-Augite Rocks.

a. Plagioclase-Augite=Diabase.

b. Plagioclase-Augite-Chrysolite=Chrysolitic Diabase.

II. Porphyritic Plagioclase-Augite Rocks; containing more or less of a base which, under the microscope, is not resolvable into individualized minerals.

a. Plagioclase-Augite=Porphyritic Diabase.

b. Plagioclase-Augite-Chrysolite=Melaphyr.

III. Granular Plagioclase-Diallage Rocks.

a. Gabbro.

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[1] The lithological descriptions of the Michigan copper rocks are given in the Report of the Geol. Survey of Mich., Vol. 1st, Part 2, 1873. I refer here more particularly to the rocks of the Eagle River section, because that section is a very long and continuous one, and because a suite of specimens collected by Mr. Marvine, and numbered to correspond with the numbers used to designate the beds, and used also in his very clear descriptions in pp. 95 to 140, of the above report, has been presented to the Wisconsin Survey. In reading Mr. Marvine's chapter, it will be necessary to remember that pyroxene should stand in place of hornblende in every instance, and that the rocks indicated as "diorite" all belong to the diabase family, some being diabase proper, some, as 108, melaphyr, and others, as 95 and 107, gabbro. Throughout the whole report, the term melaphyr is used in a generic sense, and should be replaced by diabase, also as a generic name.

[2] "Mikroskopische Physiographie der Massigen Gesteine," von H. Rosenbusch. Stuttgart, 1877.

In determining the feldspars, I have used my own modification of Des Cloiseaux's method. Des Cloiseaux cut thin sections of the various triclinic feldspars parallel to the basal cleavage, and measured, between crossed nicols, the angle between the edge *O:iĭ* and the principal section — maximum extinction of light — or between the maxima of extinction in the alternate hemitropic bands of the twinned crystals.

Des Cloiseaux found this double angle from a long series of observations to be:

For Oligoclase	0°	—2°
Andesine	3°	—4°
Albite	7°40′	— 9°40′
Labradorite	10°34′	—13°56′
Anorthite	40°	—80°
Microcline		30°54′

The application of this beautiful and exact method requires crystals large enough to be managed in cutting, and these are very rare in these rocks.

To make this principle applicable to ordinary thin sections, I have determined approximatively for each of the triclinic feldspars, the range of the angle included between the principal sections of alternate hemitropic bands in the zone *O:iĭ*. These values are based on the position of the optic-axial plane and of the bisectrix, as established by Des Cloiseaux.[1]

Feldspars.	Minimum.	Sections cut parallel to *O*.	Maximum in the zone *O:iĭ*.
Orthoclase	0°	0°	0°
Albite	0°	7°30′—10°	32°—34°
Oligoclase	0°	0° — 4°	36°
Labradorite	0°	10° —14°	62°
Anorthite	0°	40° —80°	20°—80°

[1] To determine whether a triclinic feldspar, in a thin rock section, is cut in the zone *O:iĭ*, the following conditions should be fulfilled: The position of one of the cross-hairs in the eye-piece should coincide with a nicol plane; the nicols being crossed, turn the thin section till the line of separation between two hemitropic bands of the feldspar coincides with a cross-hair; then revolve the stage till the maximum extinction of light occurs in one set of bands, and note the number of degrees of revolution; then revolve in the opposite direction till maximum extinction occurs in the alternate set of bands, and note the amount of revolution; if the two readings are equal, then the random section is cut in the zone *O:iĭ*. In practice, it is found that where there are many feldspar individuals in a section, there are almost always some that happen to be cut in the required zone.

Inasmuch as the terms oligoclase and labradorite now represent only convenient subdivisions in the series of isomorphous mixtures of albite and anorthite substance, the corresponding figures in the table are intermediate for each subdivision; and since the maxima (as appears from the table) increase with the basicity, observations on a sufficient number of separate individuals should give a more or less exact determination of the position of the feldspar in the series. Practically, I have, in my determinations, designated as oligoclase those feldspars of which several individuals in a section gave angles between 32° and 36°; as labradorite those between 36° and 62°; and as anorthite those over 62°.

The rocks represented in the four collections sent me are:

Diabase.
Melaphyr.
Gabbro.
Uralitic gabbro.
Uralitic diabase.
Augite-diorite.
Felsitic Porphyries.

Diabase proper forms the greater number of the specimens. The different varieties of this rock are dark in shade, varying from almost black in unaltered specimens to dark green or dark brown, or varying, minutely subdivided mixtures of these colors, according to the relative proportions of chlorite and ferric oxide among the decomposition products. They vary in texture from medium fine grain to cryptocrystalline, and the fracture from uneven and hackly to conchoidal. Throughout the copper district of Keweenaw Point, the diabase occurs in beds from a few yards to several hundred feet thick, which undoubtedly represent great fissure overflows. These beds have, as a general thing, three well marked subdivisions.

I. An *amygdaloidal upper portion*, containing originally small, smoothly rounded cavities, rarely connected, and sometimes drawn out in long irregularly cylindrical openings, which are always perpendicular to the plane of bedding. These cavities are now almost always filled with secondary minerals, generally the following, in combinations: calcite, chlorite, epidote, quartz, prehnite, laumontite, copper, orthoclase, or their products of alteration.

II. A *lower, massive portion* of the bed; and

III. A *pseudo-amygdaloidal portion* which is intermediate in position between the two others. This part of the bed is marked by the presence of secondary minerals — chlorite, quartz, prehnite, calcite — in forms which, to the naked eye, resemble those of the amygdaloids, but which, under the microscope, are seen to occupy the places of primary constituents that have been removed. I have described the stages of this change elsewhere.[1] Sometimes one or other of these members is not present. In external appearance, the specimens of diabase in your collections are not to be distinguished from the Michigan varieties.

The upper portion has, in some places, undergone an extreme alteration; large parts of the bed have lost their amygdaloidal character, and now consist of masses of quartz, epidote, calcite, prehnite, chlorite and decomposed amygdaloid, associated in the most irregular manner. Such are the beds worked for copper on Keweenaw Point, and, to judge from the specimens sent, the same subdivision of the beds exists in Wisconsin.

Under the microscope, the diabase is seen to have for primary constituents plagioclase, augite, and an opaque black mineral, which may be either magnetite or a titaniferous iron ore. The plagioclase appears from optical measurements to belong near oligoclase, in the feldspar series. It occurs in tabular polysynthetic crystals, whose long, narrow sections are scattered confusedly through the section, while the spaces between the crystals are occupied by augite; the augite in each space generally giving the integral polarization which indicates a single individual. In ordinary light, the augite is distinguishable from the plagioclase by its very faint, delicate violet-gray color, and by its anastomosing cracks. The sharpness with which it fills the interstices between the feldspar crystals shows that it crystallized after them.

The magnetite occurs in small grains, rarely with an appearance of crystal outlines.

In the occurrences represented by the above description, the augite occupies a very prominent position; but there is another variety in which it occurs only as a very subordinate constituent and in minute grains, whose contours are not determined by the feldspar crystals. This internal difference is accompanied by marked external characteristics; the rock is light or dark gray or black, very compact, and with a conchoidal fracture. This variety, which is generally almost unaltered, forms the traps of the "Ash-bed" series, on Keweenaw Point, and is represented by the lower part of Nos. 65 and 66, Eagle River section, while the lighter forms resemble the rocks east of the Hungarian mine, in Houghton county. To this variety belong: 9, University collection; 386, 393, 426 and 435, Strong collection; 7 and 8, Sweet collection.

Melaphyr. Among the Wisconsin specimens from which I have cut thin sections, I have found but one variety of melaphyr; and that one is identical in all its characteristics, external and microscopic, with

[1] Metasomatic Development of the Copper-Bearing Rocks of Lake Superior. Proc. of the Amer. Acad. Arts and Sciences, Vol. XIII, p. 268 (1878).

the rock which, on Keweenaw Point, under the name of "*The Greenstone*," extends as a high and picturesque ridge, with a vertical southern escarpment, from Point Keweenaw to near the Calumet mine. I cannot describe this rock better than by quoting, with slight changes, my former description of it from the paper already cited.

"In its fresh state it is dark-green, or greenish-black, finely crystalline, very compact, hard and brittle, and breaks with an uneven to semi-conchoidal fracture. The powder of the rock yields to the magnet a beard of magnetite. The specific gravity is 2.90–2.95. It is an important characteristic of this rock, that its freshly fractured surface is mainly occupied by spots one-sixteenth to three-fourths of an inch in diameter, each of which reflects the light with a satin-like sheen. The reflection is not carried to the eye from all the spots at once; it is generally necessary to change the position of the specimen many times to observe the different reflections. Aside from this sheen, there is nothing, either in difference of color or texture, visible to the naked eye, to betray the presence of these spots, which might be called lustre-mottlings. To the naked eye, this phenomenon suggests, at once, interrupted cleavage of large individuals of one of the constituents, as the cause; but under a strong hand-glass, these reflecting surfaces show the same granular texture and character as the rest of the rock; and it is only when examined under the microscope, with an objective of low power and in polarized light, that the appearance to the unaided eye is corroborated. We here find the cause in the fact that each spot is the cross-fracture or cleavage of a crystal of pyroxene, which, in crystallizing, has enclosed hundreds of feldspar crystals. The weathered surface is rusty gray, scarcely one-fiftieth of an inch thick; but it is covered with knobs, which are due to the more rapid destruction of the materials between the pyroxene individuals. Examining thin sections under the microscope, we find the constituents to be plagioclase, pyroxene, olivine, and the alteration product of the latter, as well as magnetite, and an unindividualized substance, both fresh and altered, occupying interstices. In thin sections, the plagioclase is seen to exist in very sharply defined, and fresh, thin, tabular crystals, .001 to .002 inches thick, and .01 inch and less long. It contains scattering interpositions of an opaque black substance, and minute brown particles, which may be, or have been, glass. The crystals of plagioclase have predetermined the contours of all the other constituents, except the olivine, which crystallized first. The predominating feldspar is near anorthite, as determined by the angle between the principal sections. Occasional exceptionally large individuals, evidently cut nearly in the plane *iĭ*, have their principal sections at an angle of 23°, with the edge *O: iĭ*, which would indicate albite or labradorite. The augite is very fresh and transparent, almost colorless in the thin section, but with a tendency to purple-gray. An imperfect cleavage is indicated by somewhat irregular parallel fractures. It fills the interstices between the closely-packed individuals of feldspar in such a manner that a single pyroxene crystal encloses many hundreds of these, while its crystalline integrity is shown by the uniform color in polarized light, and by the arrangement of the cleavage cracks throughout the area of the augite individual. It is a remarkable fact that, while these large individuals of pyroxene contain thousands of feldspar crystals, they enclose only very few of olivine or of magnetite. These minerals, together with the unindividualized substance, are crowded into the spaces between the pyroxenes. In this intermediate space, which surrounds the pyroxene individuals with a continuous network, we find, also, a few small pyroxenes, just as isolated grains of olivine occur in the pyroxene areas. A careful examination of this occurrence will, I think, convince the observer that, at the time the pyroxene crystallized, both the olivine and the feldspar crystals, and apparently the magnetite, were already individualized; for where we find any of these in contact with the augite, we find that the latter has adapted itself to the already defined contours of the others. While the augite enclosed the feldspar crystals with ease, it crowded the other constituents almost wholly into the surrounding spaces; a process which was facilitated by the presence of the then fluid unindividualized substance. The magnetite is in irregular-shaped bodies, which mould themselves sharply around the contours of the feldspar and olivine. The olivine is abundant in grains and roughly outlined crystals, but as a rule, however fresh the melaphyr may otherwise be, the olivine is partly or wholly altered."

The best type of this rock in the Michigan copper district is bed No. 108, Eagle River section; but, in a less conspicuous form, with the lustre-mottlings less than an eighth of an inch in diameter, and generally much altered, it forms a considerable portion of the trap-beds of Keweenaw Point; and, to judge from the collections of the Wisconsin Geological Survey, it is also widely distributed in the Keweenawan area of that state. No. 400, of Mr. Strong's collection, is a typical specimen. The first constituent to undergo a change is the olivine; and where this change has been accompanied, as is usual, by a change of the ferrous oxide to the ferric state, the rock presents a true color-mottling, dark greenish spots corresponding to the augite areas, surrounded by red or dark brown alteration products of the olivine which abounded in the spaces between the augite crystals. In many instances, the whole rock has been permeated with the red iron-stain, giving it a rich liverbrown color, as in No. 427 of Mr. Strong's collection, which also contains pseudo-amygdules of chloritic substance.

Coarse Grained Rocks. There are, among the collections of the Wisconsin Geological Survey, a number of specimens that, both externally and under the microscope, resemble some of the rocks which overlie the so-called "Greenstone," or great melaphyr horizon, 108 of the Eagle River section, on Keweenaw Point. These rocks, with a tolerably coarse grain, contain a very basic feldspar — labradorite or anorthite — while the pyroxene shows every gradation in structure from augite to diallage. Thus, 93 (University collection) resembles the dark type of 107, Eagle River section; 158 (University collection) resembles the light type of 107, Eagle River section. These rocks seem to stand as a variety of diabase between diabase proper and gabbro.

Another variety, No. 26 (Sweet coll.), and No. 202 (Irving coll.), is identical in character with No. 94, Eagle River section. It is a medium coarse-grained rock, externally resembling a syenite. To the naked eye, it appears to consist of red feldspar in elongated crystals, some of which show no striation under the hand-glass, and of irregularly-shaped spots of a dark-green chloritic substance, with more or less magnetite and particles of pyrite. Specific gravity, 2.76.

Under the microscope, we find it to be much altered; its constituents stand revealed as oligoclase, and probably orthoclase, with augite or diallage, which is mostly altered to a dark-green chloritic substance; coarse apatite in numerous comparatively large crystals, and some magnetite. Besides these, there is considerable quartz, which occurs under conditions which make it appear to be a replacer of feldspar. The alteration resembles closely that of the rock of bed 94, Eagle River section, which I have described in the above mentioned paper.

Gabbro. True gabbros are represented, in the collections sent me, by several specimens. Here belong, especially, 164 (University coll.), 23 (Sweet coll.), 86 (Irving coll.), 158 and 6 (University coll.), 205 and 206 (Irving coll.). In some specimens the pyroxenic constituent is associated with one or more kinds of amphibole; and while in some instances this last appears to be primary hornblende, in others, it is clearly a paramorphic product of the pyroxene. Thus specimen 137 (University) contains a highly dichroitic hornblende which has the appearance of being a primary constituent; in addition to this, it contains, besides diallage, a true augite, which is associated with uralite, into which it appears to be changing. Here, too, belongs, perhaps, the exceedingly interesting uralitic rock, No. 119 (University coll.). This is an even and medium-grained dark green rock, which would formerly have passed for a typical granular hornblende rock.

Under the microscope, it exhibits tabular crystals of labradorite. The spaces between these are wholly occupied by a pyroxene, which is marked by a well-defined cleavage, but, perhaps, with less lamination than diallage, and this mineral is largely changed to uralite. The paramorphic relation of the two minerals could hardly be better exemplified than in this rock. These rocks seem to belong with that described by Streng,[1] under the name *hornblende-gabbro*, as occurring on the St. Louis river at Duluth. The only rock of this class that I remember to have seen in the Keweenawan area of Michigan is near the center of the south half of Sec. 5, T. 45, R. 46, on Black river, where, to judge from the condition under which it occurs, I think there can be little doubt of its post-Huronian age.

On the Menomonee river (between Michigan and Wisconsin) there occurs, as the barrier rock causing the Sturgeon Falls and Bequenesec Falls and intermediate cataracts, a gabbro which also contains some hornblende, and in which the feldspar has changed to saussurite. The position of this rock, which I have observed at various points along a distance of twenty miles, is high up in the Huronian, being No. XV of Major Brooks' series. But it remains to be shown whether it is interbedded or whether it occurs as a dyke.

There are two specimens, Nos. 96 and 187, University collection, that are very interesting as being intermediate between diabase and diorite. I have designated them as augite-diorite, since both the augite and hornblende appear to be primary constituents. I know of no rock in the Keweenawan of Michigan that in any way resembles these. It would be interesting to determine whether these rocks are intermediate stratigraphically as well as lithologically between the diorites of the Huronian and the diabases of the Keweenawan.

The question of the relative ages of the various eruptive rocks of the Wisconsin-Michigan district is one of great interest. We have here vast areas of eruption occupied by rocks of every degree of acidity, and dating from Archæan time. It is here, if anywhere, that the law of succession of volcanic rocks, established for the Tertiary eruptions of the Rocky mountains by Richthofen and King, can be tested upon these, the oldest known eruptions on the globe. Much remains to be done before this can be attempted.

While the absolute identity of the diabases and melaphyr and of their varieties and amygdaloids, and of the interbedded porphyry conglomerates of the Wisconsin area with those of Keweenaw Point, is evident, I am struck by the comparative scarcity in the former of one

[1] Neues Jahrb. für Mineralogie, etc., 1877, p. 113.

of the most important forms of alteration that abounds in Michigan; I have found in the four collections but one instance of change of feldspar to prehnite.

The presence of pyrite in small grains in many specimens is also remarkable, because it may be said to be practically unknown in the rocks of Keweenaw Point. The very interesting rocks from Taylor's Falls and the St. Croix river, are somewhat different from the Keweenawan rocks of Keweenaw Point. By some mistake, no sections of these were cut. But the rocks of that region have been elaborately described by Streng and Kloos.[1]

MICROSCOPIC DESCRIPTIONS.

[NOTE.—U. M. stands for "Under the Microscope."]

UNIVERSITY COLLECTION.

No. 1. Obscure, but possibly a much altered diabase of the Keweenaw series, indurated with quartz.

No. 2. DIABASE; very compact, black, microcrystalline rock; conchoidal fracture. U. M.: *labradorite* in small strips; *augite* in small grains; *green substance* scattered in clouds of granular masses; resembles the compact rocks of the "Ashbed series" on Keweenaw Point.

No. 3. Red crystalline rock, showing to the naked eye a mass of red granular orthoclase, mottled with dark green. U. M.: *orthoclase*, often almost wholly changed to a colorless, nearly or quite amorphous substance; *plagioclase (oligoclase* or *albite)* in smaller individuals. The rock is impregnated with *quartz*, apparently secondary, *chlorite* and *calcite*, and stained red with ferric oxide.

No. 4. DIABASE; greenish, highly altered diabase. Sp. Gr. 2.86. U. M.: *oligoclase* much altered; *augite* in scattering remnants; *titaniferous iron*, mostly altered to an opaque, white substance. Secondary minerals are *chlorite*, *epidote*, *quartz*.

No. 5. Obscure; both to the naked eye and U. M.: resembles a felsite.

No. 6. GABBRO; coarse-grained rock. Sp. Gr. 2.89. U. M.: *plagioclase*, and apparently some *orthoclase; augite*, approaching diallage in structure. This rock resembles externally No. 205 (Irving), and a Keweenawan gabbro from Sec. 5, T. 47, R. 46, Michigan.

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[1] Leonhard und Geinitz Neues Jahrb., pp. 31, 131, 225, 1877. See subsequent page of this volume, for a translation in full of Streng and Kloos' description.

No. 9. DIABASE; black, compact, fine-grained rock; sub-conchoidal fracture. Sp. Gr. 2.98. U. M.: *oligoclase; augite*, in aggregated grains; *magnetite* or *titaniferous iron.*

No. 13. URALITIC DIABASE; fine-grained, dark gray rock; conchoidal fracture; contains pyrite. Sp. Gr. 3.02. U. M.: *oligoclase;* original *hornblende*, in twinned crystals; *augite; uralite; little magnetite.*

No. 22. DIABASE. Sp. Gr. 2.85. U. M.: *oligoclase; augite;* little *magnetite;* some *chlorite.*

No. 24. RED FELSITIC PORPHYRY.

No. 26. PSEUDO-AMYGDALOIDAL DIABASE; typical Keweenawan. U. M.: *anorthite; augite.* Contains pseudo-amygdules of *chlorite* and *calcite.*

No. 40. DIABASE. Sp. Gr. 2.81. U. M.: *labradorite; augite;* pseudo-amygdaloidal *chlorite.*

No. 63. PSEUDO-AMYGDALOIDAL DIABASE. Sp. Gr. 2.90. U. M.: *olig oclase*, largely altered to *chlorite; augite*, abundant and fresh; *magnetite*, in small irregular forms, apparently filling cracks; pseudo-amygdules of *chlorite.*

No. 81. ALTERED MELAPHYR; very fine-grained; lustre-mottling of minute greenish spots, $\frac{1}{20}$ inch in diameter, surrounded by brown alteration products. U. M.: *plagioclase*, fresh, but the section too thick for measurement; *augite*, fresh; highly altered *olivine.*

No. 87. MELAPHYR; fine-grained; lustre-mottlings $\frac{1}{10}$ to $\frac{1}{8}$ inch in diameter. Sp. Gr. 2.87. U. M.: *anorthite; augite*, exactly as in 108, Eagle River section, and very fresh; *chrysolite*, mostly or wholly altered to the characteristic pseudomorphous substance; but little *magnetite.*

No. 93. DIABASE. Sp. Gr. 2.95. U. M.: *anorthite; augite* tending to diallage; apparently a very little altered magma. Resembles somewhat No. 107 (dark variety), Eagle River section.

No. 96. AUGITIC DIORITE; fine-grained, dark-gray rock; externally appears to consist of feldspar and hornblende. Sp. Gr. 3.08. U. M.: *oligoclase; hornblende* mostly primary; *augite*, much broken; some *magnetite.*

No. 119. URALITIC GABBRO; medium-grained, dark green rock; externally resembles a hornblende-rock. U. M.: *labradorite; augite*, mostly changed to *uralite;* some *magnetite.* While some of the magnetite may be original, much of it is apparently connected with the paramorphic change from augite to uralite. Some of the hornblende may possibly be original.

No. 134. URALITIC GABBRO. U. M.: *anorthite; augite; uralite; chlorite.* The anorthite contains the same parallel, short, rod-like inclusions that abound in the Laurentian labradorite from Labrador.

No. 137. HORNBLENDE-GABBRO; fine-grained, dark greenish-brown; the glass reveals hornblende and a triclinic feldspar; weathers green and brown, and disintegrates to an angular sand. Sp. Gr. 3.21. U. M.: *labradorite;* original *hornblende* (highly dichroitic); *augite; uralite; diallage; magnetite.*

No. 154. FELSITIC PORPHYRY.

No. 155. DIORITE OR DIABASE; dark green, highly altered rock; porphyritic, with thin tabular crystals of red plagioclase. Sp. Gr. 2.93. U. M.: almost wholly altered to *quartz*, *chlorite* and *calcite;* resembles the decomposed diabases of Marquette and L'Anse, Mich.

No. 156. AUGITIC DIORITE? Sp. Gr. 3.07. U. M.: *granular feldspar; augite* in grains and long individuals; *hornblende* in grains similar to those of *augite; magnetite.*

No. 157. URALITIC GABBRO. Sp. Gr. 2.90. Medium-grained, dark rock. U. M.: *plagioclase (labradorite)*, in long crystals, and seemingly another feldspar, younger and with undefined outlines; *uralite* (mostly changed to *chlorite* and associated with *quartz)*, occupying the wedge-shaped interstices; *magnetite.*

No. 158. URALITIC GABBRO. Sp. Gr. 2.81. Coarse-grained, light gray rock, consisting under the loupe of pearly white *triclinic feldspar;* a *dark green fibrous mineral* and some *magnetite.* U. M.: *plagioclase (labradorite);* little *diallage*, and this mostly changed to *uralite; magnetite?*

No. 159. GABBRO. Sp. Gr. 2.85. U. M.: *plagioclase (anorthite); diallage; magnetite; actinolite*, apparently an alteration product of the diallage, and occurring as in the gabbro of Volpersdorf, in Silesia; a *serpentine-like substance*, apparently an alteration-product of diallage or actinolite.

No. 162. FELSITIC PORPHYRY.

No. 164. GABBRO. Fine-grained, dark gray, lustrous rock. Pearly-white, thin, tabular crystals of triclinic feldspar, $\frac{1}{8}$ to $\frac{1}{4}$ inch long, and isolated flakes of brown mica lie in the fine-grained feldspar-augite matrix; weathers yellowish gray. U. M.: *plagioclase (anorthite); diallage; magnetite;* a little *biotite.*

No. 168. RED FELSITIC PORPHYRY.

No. 187. AUGITIC DIORITE. Black, medium-grained. Externally, appears to consist of hornblende, mica, and a little feldspar. Resembles a lustrous hornblende-rock. U. M.: *plagioclase (labradorite);* abundant *hornblende;* some *augite*; *magnetite; mica.* Resembles 96 (University).

IRVING COLLECTION.

No. 65. NON-QUARTZIFEROUS PORPHYRY. Brown, with long thin plates of red *feldspar.* Sp. Gr. 2.75. U. M.: *triclinic feldspar (oligoclase),* much altered to aggregates of *chlorite;* some isotrope areas.

No. 37. QUARTZ-PORPHYRY. Weathered brown; contains grains of quartz and crystals of red feldspar, highly altered to a light green substance. U. M.: *felsitic base,* with abundant grains of *quartz,* into which club-shaped masses of the base often project. The altered feldspar grains still show feeble polarization, but are full of holes, and are partly replaced by a colorless mineral, which revolves brilliant between crossed nicols, with a minute aggregate polarization, *kaolin?*

No. 42. Similar to No. 37.

No. 66. FELSITIC PORPHYRY.

No. 86. GABBRO. Resembles No. 205, Irving; very coarse-grained, light gray rock; thin broad crystals of triclinic feldspar; weathers gray, and shows the augite on the weathered surface. U. M.: *labradorite;* the individuals often crushed and displaced, and the spaces occupied by fibrous aggregates of a green, slightly dichroitic mineral, *uralite; augite* occurs in exactly the same manner as the uralite, which is probably derived from it; *magnetite* or *titaniferous iron.*

No. 112. GABBRO. Coarse-grained, greenish rock. U. M.: *plagioclase;* some *orthoclase; magnetite* or *titaniferous iron; chlorite,* probably product of alteration of feldspar; *hornblende.* Resembles the hornblende-gabbro of Sec. 5, T. 47, R. 46, Michigan.

No. 130. ALTERED DIABASE. Dark brown, easily cut. U. M.: no feldspar left; matrix changed to ferruginous *laumontite,* in which the real amygaloidal cavities are filled with *laumontite* and some *calcite.*

No. 138. U. M.: essentially a mass of minute tabular feldspar crystals, of which some show twinning, stained brown with particles of iron oxide. Sp. Gr. 2.38.

No. 139. DIABASE. U. M.: *labradorite; augite; chrysolite* altered; *alteration-product of augite.*

No. 162. QUARTZ-PORPHYRY.

No. 202. DIABASE. Coarse-grained, red rock, spotted with green. Externally it appears to consist of red, triclinic feldspar, dark green chlorite, some magnetite and a little pyrite. Sp. Gr. 2.76. U. M.: *oligoclase,* stained red; possibly some *orthoclase;* some *diallage,* but this is mostly altered to a dark green substance. The feldspar is colored red with iron, often impregnated with chlorite, and in places apparently replaced by *quartz* and *chlorite.* It contains *apatite* in long crystals. It is similar to No. 26, Sweet, and resembles No. 94, Eagle River section, Mich.

No. 205. GABBRO. Resembles externally No. 86, Irving. Sp. Gr. 2.83. U. M.: *labradorite* [in sections cut at random in the zone $O:i\bar{i}$ the angle between the points of extinction of light ranged from 32° to 50°; a section cut independently and carefully parallel to O, gave 12° to 14°]; *orthoclase; augite; diallage*, often in twinned plates. The diallage is perhaps a paramorphous product of the augite, of which it often forms the outer part to a considerable depth. Except in absence of hornblende, resembles the gabbro of Sec. 5, T. 47, R. 46 W., Mich.

No. 245. DIABASE-PSEUDO-AMYGDALOID. Sp. Gr. 2.93. U. M.: *oligoclase; augite* in aggregated grains; *chlorite*, in rare and small pseudo-amygdules.

STRONG COLLECTION.

No. 309. QUARTZIFEROUS PORPHYRY.

No. 316. DIABASE; fresh, very compact, and basalt-like rock. U. M.: *oligoclase; augite* in grains; particles of *magnetite*.

No. 335. DIABASE-PSEUDO-AMYGDALOID. U. M.: *labradorite* or *anorthite; augite* occupying sharply the interstices between the feldspars, more or less red-stained, and in places altered to a red product.

No. 365. MELAPHYR. U. M.: *labradorite* or *anorthite; augite* in large individuals enveloping the feldspar crystals; little or no *magnetite;* red alteration-product of *chrysolite*. Resembles 108, Eagle River section, Mich.

Nos. 379, 380, 381, 382, 383, 388. A series of rocks which, in a greenish-gray, fine-grained matrix, have a greater or less amount of red feldspar in porphyritic crystals, $\frac{1}{30}$ and $\frac{1}{8}$ inch in diameter, which have, at least in part, the striation of a triclinic variety. Sp. Gr. 2.90, generally. U. M., the large crystals show a polysynthetic structure, consisting of broad and narrow bands, while the ground-mass is made up of tabular crystals of *plagioclase (oligoclase), actinolite*, and grains of *epidote;* and pseudo-amygdaloidal chloritic substance. The rock has not much similarity to any Keweenawan occurrence that is known to me. Externally, it resembles somewhat, if I may trust my memory, a series of Keweenawan rocks east of the Hungarian mine on Keweenaw Point, which have not been examined under the microscope.

No. 386. DIABASE; black, aphanitic; conchoidal fracture. U. M.: *oligoclase;* grains of *augite; magnetite;* pseudo-amygdules of *chlorite*, with a little *quartz*.

No. 393. DIABASE; black aphanitic rock; weathers dirty gray. U.

M.: *plagioclase*, predominant; grains of *augite; magnetite.* Resembles some of the "Ash-bed" traps, Keweenaw Point.

No. 400. MELAPHYR. U. M.: *augite*, in large individuals inclosing countless small crystals of *labradorite* or *anorthite*, and many grains of *chrysolite* mostly altered to a soft green substance; *magnetite*, chiefly in the spaces between the *augites; pseudo-amygdules* of chloritic substance. Resembles exactly No. 108, Eagle River section, Michigan.

No. 404. DIABASE. U. M.: *oligoclase; augite*, filling the spaces between the feldspars, much of it altered to a green substance. Sp. Gr. 2.87.

No. 426. DIABASE; fine-grained, black rock; conchoidal fracture; weathers dirty-gray. U. M.: *oligoclase; augite*, in grains; *hornblende* in few small grains; *magnetite.*

No. 427. MELAPHYR; with abundant grains of altered *chrysolite*, producing a very red color. Sp. Gr. 2.90. U. M.: *plagioclase* and *augite* quite fresh; small pseudo-amygdules of *chlorite.*

No. 429. Same as 427, Sp. Gr. 2.93.

No. 435. DIABASE. U. M.: *plagioclase; augite* in small individuals; *magnetite;* resembles Ashbed traps, Keweenaw Point.

SWEET COLLECTION.

No. 7. DIABASE; very fine-grained, almost black rock, with conchoidal fracture. Sp. Gr. 2.93. U. M.: *plagioclase* altered and obscure; *augite* in small grains; *magnetite;* impregnated with *calcite.*

No. 8. DIABASE-PSEUDO-AMYGDALOID. Sp. Gr. 2.84. U. M.: *plagioclase*, porphyritic and in small crystals; *augite* wholly altered.

No. 11. DIABASE; dark-green, fine-grained rock, much broken up, and having all cracks coated with *chlorite.* Under a hand-glass, crystals of triclinic feldspar and magnetite are seen in a dark-green matrix. Sp. Gr. 2.83. U. M.: *anorthite; augite.* The augite has been wholly altered, and each individual of this is now represented only by a network in which the meshes are occupied by a carbonate, while the reticulation is formed by a single individual of chlorite, which gives an integral polarization throughout the whole network of a former augite crystal; this chlorite usually shows strictly parallel cleavage cracks, though not very near together, and the mineral becomes dark when these coincide with a nicol-plane. In some instances (and there are then no cleavage cracks), the mineral remains dark through a revolution. It is therefore probably a uniaxial chlorite. The same change, though to a less degree, has affected the feldspar, with this difference, that here the chlorite product has the fibrous aggregate structure common to the pseudo-amygdaloidal chlorite; and there is less chloritic product, and often only the carbonate.

No. 12. DIABASE; fine-grained rock; conchoidal fracture; delicately speckled brown, and light and dark green. Sp. Gr. 2.97. U. M.: *oligoclase; augite;* largely altered to a red transparent substance, *magnetite; pseudo-amygdules* of light green *epidote?;* and a soft dark green *chloritic* substance, and some *calcite.* Minute grains which have a color and lustre of metallic copper, but which are perhaps due to a laminated structure of the alteration-product of the augite.

No. 18. DIABASE. U. M.: *oligoclase; augite,* large individuals, inclosing many *feldspar* crystals; perhaps a little *chrysolite; magnetite; pseudo-amygdules* of *chloritic substance.*

CATALOGUE OF COLLECTIONS EXAMINED.

Specimens examined under the microscope are marked with a *.

UNIVERSITY COLLECTION.

Made by Colonel Chas. Whittlesey, 1860.

No.	Place. Qr. Sec.	Sec.	T.	R.		Name, etc.
1*	W. ½..	26	46	1 W.	Potato river........	Obscure; possibly indurated altered diabase.
2*	....	24?	46	1 W.	Potato river........	*Diabase;* resembles 65, Eagle River section, Keweenaw Point.
3*	....	24	46	1 W.	Potato river........	Possibly Keweenawan, though unfamiliar to me.
4*	N. ½...	34	46	1 W.	Ironton trail........	*Diabase.*
5*	[1]	.....	....	......	Ironton trail........	?
6*	[2]	.....	....	......	Ironton trail........	*Gabbro.*
9	....	34	46	1 W.	Ironton trail........	*Diabase.*
13*	N. W...	2	45	1 W.	....	*Uralitic diabase.*
22*	....	34?	46	1 E.	....	*Pseudo-amygdaloidal diabase.*
24*	....	8?	46	1 E.	....	*Red felsitic porphyry.*
26*	....	21	47	1 E.	Montreal river, crossing of the Flambeau trail..............	*Green amygdaloidal diabase,* typical Keweenawan.
40*	....	20	47	1 E.	Montreal river	*Diabase,* typical Keweenawan.
48	....	18?	46	2 E.	Flambeau trail.....	*Diabase-pseudo-amygdaloid,* Keweenawan type.
49	....	19?	46	2 E.	Flambeau trail.....	*Green diabase,* Keweenawan type.
51	....	30?	46	2 E.	Flambeau trail.....	*Diabase,* Keweenawan type.
62	....	16	46	2 E.	....	*Pseudo-amygdaloidal diabase.*
63*	....	16	46	2 E.	....	*Pseudo-amygdaloidal diabase,* Keweenawan type.
64	....	16	46	2 E.	Gogogashugun river.	*Pseudo-amygdoloidal diabase,* Keweenawan type.
77	....	17	46	1 W.	Potato river........	*Diabase,* Keweenawan type.
78	....	17	46	1 W.	Potato river........	*Diabase.*
79	....	17	46	1 W.	Potato river........	*Diabase,* typical Keweenawan.
80	....	15	46	1 W.	Potato river........	*Quartz-porphyry.*
81*	....	17	46	1 W.	Potato river........	*Altered melaphyr,* 108 type.
82	....	17	46	1 W.	Potato river........	*Diabase,* typical Keweenawan.
83	....	17	46	1 W.	Potato river........	*Diabase,* Keweenawan type.
84	....	17	46	1 W.	Potato river........	*Pseudo-amygdaloidal diabase,* Keweenawan type.
87*	....	17	46	1 W.	Potato river........	*Melaphyr,* 108 type.
89	....	17	46	1 W.	Potato river........	*Diabase,* Keweenawan type.
90	....	17	46	1 W.	Potato river........	*Diabase,* Keweenawan type.
93*	S. E. cor.	6	45	1 E.	....	*Diabase* or *gabbro;* resembles 107, Eagle river, Mich.
96*	S½	15	45	1 W.	....	*Augite-diorite.*
113*	N.E. S.E.	12	45	2 W.	....	*Diabase,* Keweenawan type.
116	N.W. cor.	29	46	6 W.	....	*Diabase,* Keweenawan type.
119*	S. W...	14	44	6 W.	....	*Uralitic gabbro.*
134*	....	2	44	4 W.	....	*Uralitic gabbro.*
137*	N.W. cor.	35	45	4 W.	....	*Hornblende-gabbro.*
150	S. W...	15	45	4 W.	....	*Diabase,* typical Keweenawan.
154*	N. E....	15	45	4 W.	....	*Felsitic prophyry.*
155*	E. side..	15	45	4 W.	....	*Porphyritic diabase;* altering in the direction of quartz, chlorite and calcite.

[1] Near No. 4. [2] Same place as No. 5.

UNIVERSITY COLLECTION (WHITTLESEY) — continued.

No.	Place.					Name, etc.
	Qr. Sec.	*Sec.*	*T.*	*R.*		
156*	E. side..	15	45	4 W.	....	*Augite-diorite ?*
157*	....	15	45	4 W.	....	*Uralitic gabbro.*
158*	S. E....	15	45	4 W.	....	*Uralitic-gabbro.*
159*	N. W...	22	45	4 W.	....	*Gabbro.*
162*	....	22	45	4 W.	....	*Felsitic porphyry.*
164*	....	22	45	4 W.	Brunschweiler river.	*Gabbro.*
166	....	22	45	4 W.	....	*Diabase*, Keweenawan type ?
167	....	15	45	4 W.	....	*Diabase*, resembles traps of the Ashbed type.
168*	....	22	45	4 W.	....	*Felsitic porphyry.*
187	....	5	44	3 W.	English lake	*Augite-diorite.*

IRVING COLLECTION.

No.	Qr. Sec.	Sec.	T.	R.	Place	Name, etc.
37*	....	17	45	2 W.	Mouth of Tyler's Fork	*Felsitic porphyry.*
39	....	17	45	2 W.	Tyler's Fork........	*Diabase-amygdaloid*, typical Keweenawan.
42*	....	17	45	2 W.	Near the mouth of Tyler's Fork......	*Quartz-porphyry.*
43*	....	17	45	2 W.	Tyler's Fork........	*Diabase-pseudo-amygdaloid*, typical Keweenawan.
65*	N. W...	22	45	4 W.	....	*Non-quartziferous porphyry.*
68	N. W...	22	45	4 W.	....	*Felsitic porphyry.*
86*	S. E....	14	44	5 W.	....	*Gabbro.*
110	S. E....	7	44	5 W.	....	*Diabase*, Keweenawan type ?
112*	N. E...	12	44	6 W.	....	*Gabbro.*
116	N. W...	6	44	5 W.	....	*Brown-amygdaloid;* amygdules of quartz and epidote; typical Keweenawan.
127	....	6	46	4 W.	....	*Sandstone*, typical Keweenawan.
130	S. E....	15	45	3 W.	....	*Altered laumontitic diabase*, typical Keweenawan.
132	N. E...	22	45	3 W.	....	From highly altered part of an *amygdaloidal diabase.*
134	....	22	45	3 W.	....	*Felsitic porphyry.*
135	S. W...	22	45	3 W.	....	*Laumontitic rock* from a vein or highly altered amygdaloid.
136	S. W...	22	45	3 W.	....	*Brown-amygdaloid;* calcite amygdules.
138*	S. E....	17	45	2 W.	....	?
139*	S. E....	17	45	2 W.	....	*Diabase;* typical Keweenawan
140	S. W...	16	45	2 W.	....	*Diabase-pseudo-amygdaloid*, Keweenawan type.
143	S. W...	16	45	2 W.	....	*Diabase-pseudo-amygdaloid*, Keweenawan type.
144	S. W...	16	45	2 W.	....	Aphanitic altered *Diabase* or *melaphyr.*
148	S. W...	15	45	2 W.	....	*Green diabase.*
154	S. E....	17	45	2 W.	....	*Sandstone*, Keweenawan type.
156	S. E....	17	45	2 W.	....	*Slaty sandstone*, Keweenawan type.
162*	S. E....	15	46	1 W.	....	*Quartz-porphyry.*
164	....	34	46	1 W.	....	*Felsitic porphyry.*
165	....	34	46	1 W.	....	*Granitic porphyry.*
202*	....	.....	.....	.....	....	*Diabase.*

IRVING COLLECTION—continued.

No.	PLACE.					NAME, etc.
	Qr. Sec.	*Sec.*	*T.*	*R.*		
205*	N. E...	32	45	12 W.	Aminicon river.....	*Gabbro.*
206	S. E....	29	48	12 W.	....	*Gabbro.*
207	N. E...	29	48	12 W.	....	*Altered diabase*, Keweenawan type.
220	....	15	47	14 W.	....	*Diabase-pseudo-amygdaloid*, typical Keweenawan.
234	....	28	47	14 W.	....	*Melaphyr*, 108 type.
245*	N. W...	27	48	10 W.	....	*Diabase*, typical Keweenawan.
255	N. W...	28	48	10 W.	....	*Epidotic rock* from highly altered portion of an amygdaloid.

STRONG COLLECTION.

300	....	.....	....	......	St. Croix Falls, Wis.	Probably *melaphyr.*
303	....	.....	....	......	St. Croix Falls, Wis.	*Epidotic diabase-amygdaloid.*
308	N. W...	12	37	16 W.	....	*Diabase.*
309*	N. W...	12	37	16 W.	....	*Quartziferous porphyry.*
310	S. E. ...	16	43	7 W.	Numakagon river...	*Diabase-amygdaloid.*
311	S. E. ...	16	43	7 W.	Numakagon river...	*Diabase.*
312	S. E. ...	16	43	7 W.	Numakagon river...	*Diabase-amygdaloid;* amygdules of orthoclase and epidote.
313	....	16	43	7 W.	Not in place........	*Diabase-amygdaloid.*
314	N. W...	6	43	6 W.	Numakagon river...	*Diabase* or *melaphyr.*
316*	N. W...	6	43	6 W.	Numakagon river...	*Diabase.*
317	N. W...	6	43	6 W.	Numakagon river...	*Diabase.*
318	N. W...	6	43	6 W.	Numakagon river...	*Diabase-amygdaloid.*
320	....	18	42	10 W.	....	*Diabase-amygdaloid.*
321	Cent. of.	18	42	10 W.	....	*Melaphyr*, similar to 108, Eagle river, Michigan.
322	....	24	42	11 W.	....	*Diabase.*
323	....	26	42	11 W.	....	*Diabase.*
326	....	24	42	11 W.	....	*Melaphyr*, similar to 108, Eagle river.
327	N. E....	13	42	10 W.	Totogatic dam......	*Diabase.*
328	S. W...	12	42	10 W.	Totogatic river.....	*Diabase* or *melaphyr.*
329	S. E. ...	1	42	10 W.	Falls of Totogatic...	*Diabase-amygdaloid.*
330	S. E. ...	1	42	10 W.	Falls of Totogatic...	*Melaphyr*, similar to 108, Eagle river.
332	....	2	42	10 W.	....	*Diabase-amygdaloid.*
333	....	3	42	10 W.	....	Probably the representative of a porphyry *conglomerate*, and composed of the same material in a fine state.
334	S. W. ..	6	42	10 W.	Totogatic river.....	Epidotic portion of a highly altered *diabase-amygdaloid.*
335*	S. W. ..	5	42	10 W.	Totogatic river.....	*Diabase-pseudo-amygdaloid.*
336	....	5	42	10 W.	....	*Diabase*, with chlorite.
337	....	5	42	10 W.	....	*Diabase-tufa;* similar to Hancock beds, Portage lake.
338	Center. .	4	42	10 W.	Totogatic river.....	*Epidotic amygdaloid* (diabase).
339	....	4	42	10 W.	Totogatic river.....	*Epidotic rock*, from a highly altered diabase-amygdaloid.
340	....	6	42	10 W.	....	*Epidotic rock* from a highly altered diabase-amygdaloid.
342	N. E....	6	42	10 W.	....	*Epidotic diabase-amygdaloid.*

STRONG COLLECTION — continued.

No.	Place. Qr. Sec.	Sec.	T.	R.		Name, etc.
343	Center. .	6	42	10 W.	....	*Epidotic diabase-amygdaloid.*
345	N. W...	6	42	10 W.	Lower Falls of Totogatic river	*Quartz.*
346	N. W...	6	42	10 W.	....	*Chlorite.*
347	....	28	43	10 W.	....	*Epidotic diabase-amygdaloid.*
348	....	4	42	10 W.	....	Typical Keweenawan *conglomerate* and *sandstone.*
349	....	4	42	10 W.	....	
350	....	4	42	10 W.	....	
352	N. E....	5	42	10 W.	....	
353	N. E....	5	42	10 W.	....	
354	N. E....	5	42	10 W.	....	*Diabase.*
355	N. E....	5	42	10 W.	....	*Diabase.*
356	N. E....	5	42	10 W.	....	Probably *diabase* proper.
357	N. E....	5	42	10 W.	....	Probably *diabase.*
359	S. W. ..	18	43	9 W.	....	*Epidotic diabase-amygdaloid.*
360	S. W. ..	6	43	9 W.	....	*Diabase-amygdaloid.*
361	S. W. ..	32	44	9 W.	....	*Diabase.*
363	....	28	44	9 W.	....	*Conglomerate.*
365*	....	12	44	9 W.	....	*Melaphyr.*
366	....	7	44	8 W.	....	*Diabase.*
367	....	7	44	8 W.	....	*Melaphyr* or *diabase* proper.
369	....	33	45	8 W.	....	*Diabase-pseudo-amygdaloid.*
373	S. W. ..	11	36	18 W.	....	*Diabase-amygdaloid.*
374	S. W. ..	11	36	18 W.	....	*Epidotic diabase-amygdaloid.*
375	S. W. ..	11	36	18 W.	....	*Diabase-amygdaloid.*
376	S. W. ..	11	36	18 W.	....	*Epidotic diabase-amygdaloid.*
377	Center. .	18	36	18 W.	....	*Diabase-amygdaloid.*
378	Center. .	18	36	18 W.	....	*Diabase-amygdaloid.*
379*	N. E....	26	37	17 W.	....	*Pseudo-amygdaloid* (pseudo-amygdules of epidote, chlorite and quartz). This rock does not recall strongly any Keweenawan variety; but, to judge from memory, it resembles more nearly some of the beds east of the Hungarian mine on Keweenaw Point.
380*	S. W...	26	37	17 W.	....	Same rock as 379.
381*	S. E. ...	27	37	17 W.	....	Same rock as 379.
382*	S. E. ...	27	37	17 W.	....	Same rock as 379.
383*	N. E....	26	37	17 W.	....	Same rock as 379.
384	¼ post .	28	37	16 W.	....	*Epidotic diabase-amygdaloid.*
385	N. W...	24	37	17 W.	....	*Epidotic diabase-amygdaloid.*
386*	N. W...	24	37	17 W.	....	*Diabase pseudo-amygdaloid.*
387	¼ post .	28	37	16 W.	....	Similar to 379.
388*	¼ post .	23	37	16 W.	....	Similar to 379.
389	¼ post .	28	37	16 W.	....	Similar to 379.
391	N. W...	24	37	17 W.	....	*Diabase pseudo-amygdaloid.*
393*	S. W. ..	28	42	11 W.	....	*Diabase pseudo-amygdaloid.*
394	S. W. ..	28	42	11 W.	....	*Diabase pseudo-amygdaloid.*
396	N. W...	26	44	13 W.	....	Typical Keweenawan *conglomerate.*
397	N. W...	26	44	13 W.	....	
398	N. W...	26	44	13 W.	....	
399	N. W...	26	44	13 W.	....	
400*	N. W...	2	44	13 W.	....	*Melaphyr* (identical with 108, Eagle river).
401	N. W...	2	44	13 W.	....	*Diabase pseudo-amygdaloid.*
402	N. W...	2	44	13 W.	....	*Diabase pseudo-amygdaloid.*

STRONG COLLECTION—continued.

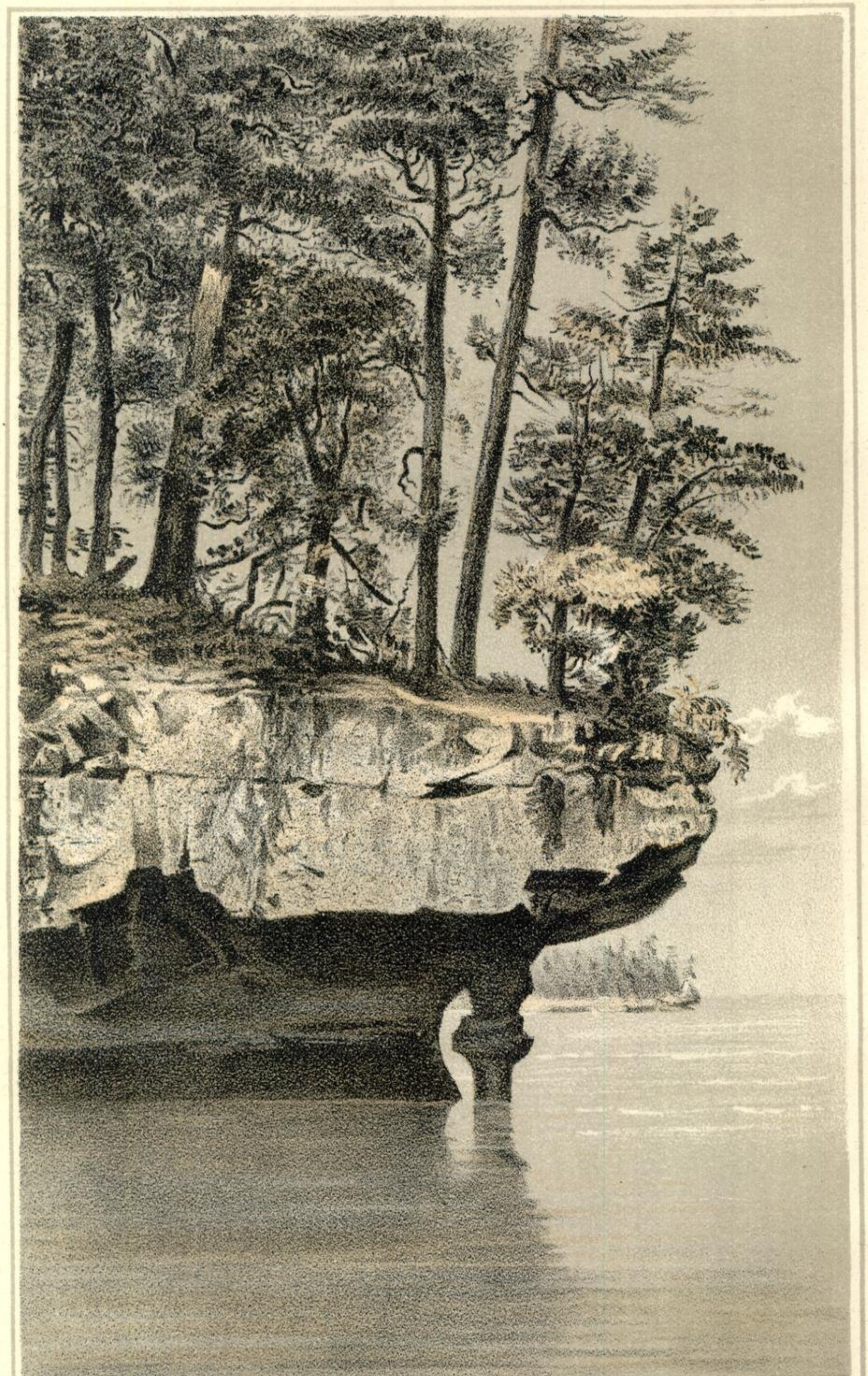
No.	Place.					Name, etc.
	Qr. Sec.	*Sec.*	*T.*	*R.*		
404*	N. W...	2	44	13 W.	....	*Diabase.*
405	N. W...	2	44	13 W.	....	*Diabase pseudo-amygdaloid.*
406	N. E. ..	14	44	13 W.	....	*Melaphyr* (same as 108, Eagle river).
410	N. E....	22	44	13 W.	....	*Melaphyr* (same as 108, Eagle river).
412	....	6	43	13 W.	....	*Melaphyr.*
418	S. W. ..	31	44	13 W.	....	*Diabase amygdaloid* of highly altered forms; resembles portions of Pewabic and Huron copper-bearing beds.
419	S. W. ..	31	44	13 W.	....	
422	N. W...	28	43	14 W.	....	*Melaphyr* (similar to 108 Eagle river).
423	N. W...	15	43	14 W.	....	*Diabase.*
425	N. E. ..	9	43	14 W.	....	*Diabase-amygdaloid.*
426*	S. E. ...	6	43	14 W.	....	*Diabase?*
427*	S. W. ..	15	43	14 W.	....	Altered *melaphyr.*
429*	S. W. ..	22	43	14 W.	....	Probably *diabase.*
431	....	.....	....	......	Falls of Chase brook, Douglas Co.......	*Melaphyr* (similar to 108, Eagle river).
432	N. W...	2	39	19 W.	....	*Melaphyr* (similar to 108, Eagle river).
435*	N. W...	29	39	19 W.	....	Probably *diabase.*

SWEET COLLECTION.

1	....	23	48	10 W.	....	*Diabase.*
2	....	22	48	10 W.	Percival mine, main shaft	*Diabase-amygdaloid.*
3	....	24	48	12 W.	....	*Laumontitic diabase-amygdaloid.*
5	Center..	13	47	14 W.	....	*Diabase pseudo-amygdaloid.*
6	....	15	47	14 W.	Copper creek	*Diabase pseudo-amygdaloid.*
7*	....	15	47	14 W.	Belt above No. 6....	*Diabase* (resembles Ashbed traps).
8*	S. E. cor.	15	47	14 W.	Above No. 7, Copper creek mine.......	*Diabase pseudo-amygdaloid.*
9	S. E. cor.	15	47	14 W.	Shaft No. 3	Epidotic portion of a highly altered amygdaloid.
10	S. W. ..	14	47	14 W.	Niccolite mine......	*Diabase amygdaloid* (orthoclase, chlorite, epidote, quartz, calcite in amygdules).
11*	S. E. ...	21	47	14 W.	Black river falls	*Diabase.*
12	N. E. ..	8	47	14 W.	Fond du Lac mine ..	*Diabase pseudo-amygdaloid.*
13	N. W...	27	48	10 W.	Percival mine, wall rock, east shaft...	*Diabase.*
14	N. E. ..	4	47	12 W.	Middle river........	*Diabase.*
15	S. E. ...	1	47	13 W.	....	*Diabase.*
16	....	28	47	14 W.	Upper Black river falls	*Diabase.*
17	S. E. ...	21	47	14 W.	Gorge, Black river falls	*Diabase.*
18*	....	1	47	14 W.	....	*Diabase* or *melaphyr.*
19	....	28	47	14 W.	Upper Black river falls	*Diabase-amygdaloid;* alteration-products of prehnite.

SWEET COLLECTION—continued.

No.	Place.					Name, etc.
	Qr. Sec.	*Sec.*	*T.*	*R.*		
22	N. W....	27	48	10 W.	Percival mine	*Diabase epidotic amygdaloid.*
23	N. E. ..	32	48	12 W.	....	*Gabbro.*
26	S. E....	32	48	12 W.	Aminicon river	*Diabase*, tending to gabbro.
27	S. E....	21	47	14 W.	Black river falls	*Diabase.*
28	....	2	47	12 W.	Wisconsin mine	*Diabase.*
39	....	2	47	13 W.	Wisconsin mine	Epidotic portion of highly altered amygdaloid.
30	....	2	47	13 W.	Wisconsin mine.....	*Diabase-amygdaloid.*



LAKE SUPERIOR SANDSTONE,

Hemlock Island, Lake Superior, (Ashland Co.)

PART III.

GEOLOGY

OF THE

EASTERN

LAKE SUPERIOR DISTRICT.

BY R. D. IRVING.

INTRODUCTION.

The field work on which this report is based occupied parts of the seasons of 1873, 1876, 1877 and 1878; about six months in all. The total area of the district is only about 1,643 square miles, exclusive of the included portions of Lake Superior, so that this region has had proportionally a much longer time devoted to it than that whose geology I have described in a previous volume. The more extended time was demanded in this case not only by the enormous thickness of the formations included within the district, each having many subordinate members, for the most part composed of complicated crystalline rocks; but also by the economic interest attaching to two of the great rock systems. Moreover, the whole region is a wilderness, and, since the streams nearly all make too rapid a descent for canoeing, all investigations have to be made on foot, and all provisions, instruments, camping utensils and rock specimens carried on the back. The amount of time consumed in this kind of work, and the fact that any one trip was necessarily limited by the amount of provisions it was practicable to carry, made it, of course, impossible to visit every section of land within the district. The trips were therefore planned so as to reach the most important points, and at the same time to traverse the country as thoroughly as possible. A brief account of the work of the several years is given below.

The instructions received from Dr. I. A. Lapham, then chief geologist, for the field season of 1873, the first of the survey, were as follows:

MILWAUKEE, *May 3, 1873.*

DEAR SIR: The governor having commissioned you as one of the assistants in the geological survey of Wisconsin, you will proceed to organize a party, and supply yourself with the necessary outfit and instruments, to explore the iron and copper ranges in Ashland county as soon after the first of June as possible.

It will be your duty, besides examining the iron and copper ores, and their relations to the adjoining rock formations, with a view to discoveries in other districts, to note all facts throwing any light upon any of the special matters required to be considered in the law authorizing the survey.

While it is not intended to prescribe in detail what you are to do, much in this respect being left to your own judgment and discretion, I may call your attention to a few points of special importance.

The relative age of the red sandstone, with its accompanying red shale, has not been fully ascertained, and hence all facts showing whether it is of the age of the Potsdam sandstone or not should be carefully noted.

Whether the Azoic rocks are of different ages should be ascertained, the more crystalline being supposed to be older than those of a slaty structure, etc.

It is a matter of great importance to the mining interests to study the system of folding of the strata, involving the question whether the iron beds continue to great depths into the earth, or whether they soon terminate.

Note such facts as show the natural fertility of the soil; especially as indicated by actual cultivation, and by animal and vegetable products.

You will not be required to collect in remote localities any more specimens than are needed for examination and analysis.

Examine the surface deposits, the lake beaches, the drift striæ, etc.

Make barometrical measurements of the relative elevation and depression of the ground.

It being obviously impossible to visit every section or square mile in the country, you will so plan your routes as to be able to examine the points of greatest importance to the material interests of the state, extending your lines south of the Iron Range only to the region where the rocks are concealed by drift.

Collect information relating to the former explorations and mining operations carried on in the districts examined.

Upon the completion of your survey of Ashland county you will extend your work, overland if found practicable, into Douglas county, where the Copper Range will require special attention.

Two months time will probably suffice for the examination of these two counties, leaving time to visit Black River Falls and such other points as may be deemed advisable before the close of the working season.

Upon your return to Madison, you will prepare a full detailed report, with the necessary maps and diagrams, having the same completed by the first of December next. Such portions of the report as are deemed suitable to the purpose, will be included, under your own name, as a part of the Annual Report of the Progress and Results of the Survey.

When not engaged in the field work, you will, jointly with Prof. W. W. Daniells, take charge of the chemical analyses required by the law authorizing the survey, except such as relate to the mineral waters, selecting for that purpose such ores, clays, minerals, etc., as it may be deemed necessary to have analyzed. * * * * * *

Yours very truly, I. A. LAPHAM, *Chief Geologist.*

In accordance with these instructions, the work began immediately after the first of June, and continued uninterruptedly until the middle of September. The following were the several trips of the season: (1.) Along the line of the Wisconsin Central Railroad (then unbuilt), to Penokee Gap in Sec. 14, T. 44, R. 3 W., where some time was spent in detailed examinations, with excursions along the Penokee Range westward to its extremity in T. 44, R. 4 W., and eastward to Mt. Whittlesey, in T. 44, R. 2 W.; from Penokee Gap to the old Ashland mine at the junction of Bad river and Tyler's Fork, Sec. 17, T. 45, R. 2 W.; thence by raft down Bad river to the falls at Leihy's mill, Sec. 25, T. 47, R. 3 W.; thence by boat down the river to the Indian village of

Odanah; and thence through the Kaukaugon to Ashland. (2.) By boat around the several islands of the Apostle group, and along the whole coast of Bayfield county from the head of Chaquamegon Bay to the Douglas county line, the object being the examination of the red sandstone so constantly exposed on these coasts, as also of the overlying red Quaternary clays. (3.) From Ashland, along the line of the railroad to the Maringouin river in Sec. 36, T. 46, R. 4 W.; thence up that stream to Roehm's clearing, in Sec. 32; thence across sections 6, 5, 8, 9 and 17, T. 45, R. 4 W., to the Brunschweiler river in Sec. 22; thence down that stream to Sec. 11; thence, the party dividing, up the Brunschweiler to Sec. 36, and southeast from here to English lake, also through the western and southern parts of T. 45, R. 3 W., to English lake; thence across to the lower end of Bladder lake; thence down the Brunschweiler to the point reached before; thence to the head of Bladder lake; thence across T. 44, R. 4 W., to the Huronian ridges in T. 44, R. 5 W.; thence, following these ridges, to the west line of this township; thence north to the southwest corner of T. 45, R. 5 W.; thence diagonally across this township to Roehm's clearing in Sec. 32, T. 46, R. 4 W.; thence north to the rapids of White river, Sec. 6, T. 46, R. 4 W.; and thence north to Ashland. (4.) From Bayfield by boat to the mouth of the Montreal river; thence *via* the old Ironton trail to the Potato river, in Sec. 15, T. 46, R. 1 W., with excursions from here up and down the river; thence, *via* the same trail, to the passage of Tyler's Fork through the Iron Range in Sec. 33, T. 45, R. 1 W.; thence along the Iron Range to the east line of R. 1 E.; thence back along the Iron Range to the gorge of Tyler's Fork; thence along the Iron Range to Penokee Gap, T. 44, R. 3 W.; and thence along the railroad line to Ashland. In the middle of the season I was myself incapacitated by a severe rheumatic fever, and the work was continued by my assistants, Messrs. Sweet and Jenney, during the remainder of the time. The greater part of the season was spent on the Penokee Range, in sampling and examining the outcrops of ore. It will be seen that the instructions given above assign only one month for what had thus taken three and a half months and was yet incomplete. The work in Douglas county, indicated in the letter of instructions, had not yet been entered upon. This was now assigned to Mr. Sweet, on account of my continued ill-health, and the results will be found in his report.

In 1876, a month was spent in this region, the first half of the time being given to a detailed magnetic and topographical survey of the vicinity of Penokee Gap, with a view to a more exact determination of the subordinate structure of the Huronian series, whilst during the latter part of the time a trip was made along the Montreal river from its mouth to its passage through the Iron Range.

In 1877, the month of August was devoted to a detailed examination of the Iron Range from Bad river to Potato river, with incidental observations on the more northern formations. In October of the same year, Professor Chamberlin extended this examination eastward to the state line. His results are included in this report. The exact extent of his work is indicated on Atlas Plate XXVI, and in those portions of the text based on his notes.

In 1878, Professor A. D. Conover made an excursion, under my instructions (chiefly with a view to adding to the collections of specimens), up the Montreal to the mouth of the Gogogashugun; thence across to the Potato at the crossing of the Ironton trail; thence down to the falls of that stream, where a detailed map of the exposures was made; thence southward to the southeast corner of T. 45, R. 2 W.; thence west three miles; thence northward to Tyler's Fork; and thence down that stream to its junction with Bad river.

In 1875, Dr. O. W. Wight, then chief of the survey, employed Mr. C. E. Wright, of Marquette, Michigan, now Commissioner of Mining Statistics to the State of Michigan, to make an examination in the vicinity of Penokee Gap. Subsequently the same gentleman was employed by Professor Chamberlin to extend his examinations along the western portion of the Penokee range. Mr. Wright's report and mine then cover in part the same ground. He, however, extended his examinations to the west, beyond the limits of my district, and, moreover, my later detailed examinations were not extended west of Penokee Gap. What he reports on in detail, therefore, I only cover in a general way, for the sake of showing the connection of the several subordinate members of the Huronian with their more eastern extensions. It is, of course, not unpleasant to me that Mr. Wright's views coincide in every respect with those I had previously expressed as to the value of the Penokee ores; a dissatisfaction with the unfavorableness of my first year's report (never published), on the part of the citizens of Ashland county, having been, in fact, the cause of Mr. Wright's employment for this work.

A large portion of the formations of this district being composed of crystalline rocks, often peculiar and very fine-grained, it became necessary to have recourse to the modern methods of microscopic analysis. A set of the crystalline rocks of the Keweenawan series from the several districts of northern Wisconsin was sent to Professor Raphael Pumpelly, who had had extended experience in the Michigan region, and who was, in fact, the only scientist having any minute acquaintance with these interesting rocks. He returned the specimens named, with brief microscopic descriptions of a number, as also the thin sections upon which these descriptions were based. The exact nature and extent of his work will be understood from his report in this volume. To Mr. A. A. Julien, of New York, was sent a collection of eleven specimens, chiefly from the Huronian. He returned detailed microscopic descriptions of these, also with the thin sections. His descriptions are given in an appendix to this report. In addition to this, I have myself examined about two hundred thin sections, having during the past eighteen months familiarized myself with this new method of investigation. This extended work was needed in order to throw ledges of fine-grained rocks into their proper stratigraphical positions, as also to cover a number of varieties not represented by the collections sent Mr. Julien and Professor Pumpelly. My own work has been chiefly on the Laurentian and Huronian, and the gabbros at the base of the Keweenawan System. From the statements in the text, and from the accompanying reports of Messrs. Pumpelly and Julien, it will always be evident on whose authority microscopic descriptions are given. The microscopic plates herewith were all drawn under my immediate direction, and include some of the slices described by Messrs. Pumpelly and Julien, as well as those exclusively examined by myself.

North Wisconsin was visited over two hundred years since by the French Jesuit fathers, who have left their traces all around Lake Superior in the shape of French geographical names. A settlement was made on one of the Apostle Islands by Father Claude Allouez as early as 1665. Many references to the Lake Superior country, including also portions of Wisconsin, are to be found in the "Relations" of these Jesuit fathers, which were published in France between the years 1632 and 1672, and which contain, along with many geographical details, accounts of the earliest mineral discoveries. A map published in Paris in 1672, of which a *fac simile* is to be found in Foster and Whitney's U. S. Geological Report, represents with general accuracy the entire coast of the lake.

A report to the secretary of war by John Stockton, "On the Condition and Government of the Mineral Lands of Lake Superior" (pp. 22), published at Washington in 1845, has some brief references to the geology of Ashland county. The same is true of a brief report "On the Copper Mines of the Montreal River," made in 1845 by James T. Hodge to some private parties, and published afterwards in a pamphlet of nineteen pages. Foster and Whitney give a section along the Montreal river, but their district stopped at the Wisconsin line.

The only geological examinations of this region, however, previous to those on which this report is based, and deserving the name, were those of Colonel Charles Whittlesey, of Cleveland, Ohio. This gentleman was connected with Dr. D. D. Owen's U. S. Geological Survey of Wisconsin, Iowa and Minnesota, and in this connection examined the Bad river country in 1848. The results are given in Dr. Owen's final report, published at Washington in 1852. In 1860 (August to October), Colonel Whittlesey engaged in another geological exploration in Ashland, Bayfield and Douglas counties, on part of the geological survey of Wisconsin, then organized under James Hall. His report, presented to Professor Hall in the ensuing year, was never published, on account of the stoppage of the survey. A suite of specimens collected by Colonel Whittlesey during these explorations is at present preserved in the cabinet of the State University, at Madison, and it bears testimony to the laborious manner in which that gentleman prosecuted his work. Although his report was never published, he has issued a number of pamphlet publications giving the main results obtained by him. A list of these, together with full extracts from some of them, will be found in an appendix to this report. In the same appendix I have had reproduced a geological map of the region, prepared by Colonel Whittlesey in 1860. A photographed copy of this map was sent to me in 1873, and at my request the original map was furnished to the lithographers in 1878. From this appendix, which I have made thus full, since Col. Whittlesey's publications are so scattered, it will be possible to ascertain the amount and nature of the work that preceded mine, and of which mine must, in a measure, be regarded as a continuation. It is only necessary to add that, while in many points I differ very widely from him in my conclusions, it is evident enough that Colonel Whittlesey caught the main geological features of the region. It should be remembered that at that time the country was largely without the government sectional surveys, and that there was no knowledge whatever of the lithology of the Lake Superior formations.

As in my report on the Geology of Central Wisconsin, I give here also parenthetical numbers referring to the type lithological specimens of the geological survey collections.

All chemical analyses given, except where it is otherwise stated, are by Professor W. W. Daniells, chemist to the survey.

During the season of 1873 I was aided in the field work by Mr. E. T. Sweet, now of Silverton, Colorado, and by the late Mr. F. B. Jenney. of New York. In 1876, Mr. Frank Brotherton, of Escanaba, and in 1877, Mr. Paul B. Wood, of Peshtigo, both expert woodsmen and

surveyors, aided me in the field. In draughting, I have been assisted by P. L. Norman, S. W. Tullock, Magnus Swenson, and F. T. Bernhard; the last named rendering his services gratuitously. Mr. Thomas Barden, of Ashland, has aided me greatly by collecting specimens and making chain measurements in the vicinity of Penokee Gap. C. R. Vanhise has made, gratuitously, a number of specific gravity and analytical determinations for me in the University laboratory.

R. D. I.

UNIVERSITY OF WISCONSIN, *February 25, 1879.*

CHAPTER I.

TOPOGRAPHY.

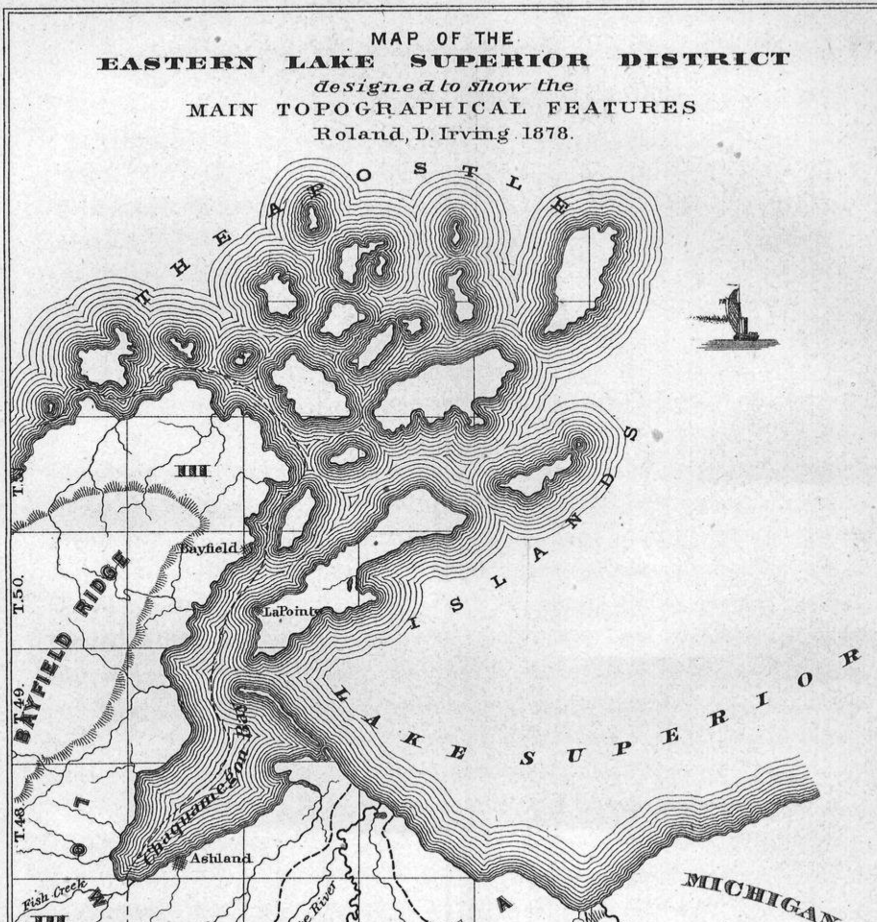
GENERAL TOPOGRAPHICAL SUBDIVISIONS AND SURFACE RELIEFS.

That portion of Wisconsin which borders Lake Superior is traversed by two parallel belts of high and ridgy country, about thirty miles apart, between which lies a trough of lower land, which occupies a true synclinal depression. The northern one of these, in part almost a mountainous belt, extends from the Minnesota line east-northeast through northern Douglas county into the Bayfield peninsula, whose existence, as also that of the group of islands beyond, it has undoubtedly determined; while the southern belt is the westward continuation of the high land which forms the back-bone of Keweenaw Point, and skirts the lake shore from the eastern extremity of that point, southwestwardly to the Wisconsin line.

During most of its course, before reaching Wisconsin, the latter belt is flanked on the south by a lower and level country, the extension westward of the depression of Keweenaw Bay, to the south of which is yet another highland belt, which itself merges into the elevated but not ridgy country of granitic and gneissoid rocks that forms the watershed between the northward-flowing tributaries of Lake Superior and those that run southward into Lake Michigan and the Mississippi. Before reaching the Wisconsin line, however, the ridges to the north and south of the Keweenaw Bay depression have met and joined, forming one broadened mass of high land, which, at the Montreal river, has a width of about twelve miles from the lake shore southwestward to the elevated granitic region of the interior. Moreover, immediately after crossing the Montreal into Wisconsin, the lake shore takes a sudden bend, nearly at right angles to its former direction, as a result of which the highland, continuing on its southwesterly course, recedes from the lake shore, leaving in front a rapidly widening lowland, the eastern end of the synclinal valley which extends all across northern Wisconsin.

Of the Bayfield ridge, the northern side of the synclinal, the district now described includes only the extreme eastern portion where it

PLATE, XI



S.W. Tulloch, del.

I	II	III	IV	V
Bad River System,	*Montreal River System,*	*Lake Shore System,*	*Chippewa River System,*	*St. Croix River System,*

— — — — — — Boundaries between River Systems.

descends to the lake, forming the coast of Bayfield county. Continuing beyond, however, in the same line, we find the Apostle group of islands, which, while without any considerable elevation above the lake, are really an extension of the Bayfield ridge, with which they have an intimate geognostical as well as topographical relation.

Briefly, then, our district, having a total land area of about 1,643 square miles, divides naturally as follows: (1) an *elevated interior*, lying north of township forty-two and south of the Penokee Iron Range, with an area of about 586 square miles; (2) a ridge or *mountainous belt*, lying immediately north of the preceding, varying in width from about twelve miles on the east to about six on the west, and having a total area of about 346 square miles; (3) a *lowland area*, extending from the foot of the highland to the lake shore, and around the head of Chaquamegon Bay to the Bayfield ridge, with an area of about 400 square miles; (4) *The Bayfield highland*, extending well to the lake shore all around the peninsula, with an area of about 234 square miles; and (5) the *Apostle Islands*, twenty-four in number, with a total land area of about 77 square miles. The relative sizes and positions of these several subdivisions will be best understood from the sketch map, Plate XI. A few words are given below to each subdivision.

Elevated Interior. The region south of the Penokee Iron Range, which forms the southern rim of the ridge or mountainous belt, has a level to gently undulating surface, with an average altitude of 900–950 feet above Lake Superior, the extremes being about 750 and 1,100. From the crest of the Penokee Range, with an average altitude of about 1,000 feet, southward, there is generally a descent of from 100 to 300 feet within a quarter to half a mile. Thence further southward, the ascent is very gradual to the watershed, which is a very irregular line, with an average altitude of about 950 to 1,050 feet. From the watershed southward, the slope is exceedingly gradual, and the country for many miles preserves the same general altitude, having a surface without any considerable ridges, but much diversified in minor detail by drift knolls and kettles, the latter producing the myriads of small lakes which characterize this region. Where the Wisconsin Central Railway crosses the watershed, near the east line of Sec. 27, T. 43, R. 11 W., the altitude is 948; but thence southward, it continues above 900 until the Flambeau river is reached, in Sec. 24, T. 40, R. 1 W. The railroad crosses the watershed at a comparatively low place, the height being greater both to the east and west. Dr. Norwood, in Owen's report on Wisconsin, Iowa and Minnesota, gives an altitude of 1,183 feet for a point on the divide on the Flambeau trail, in township forty-three, Lincoln county.

The surface of this interior region is largely occupied by tamarack and cedar swamps, which, for the portion included in our district, cover more than half the surface. In these swamps, some of which have an area greater than that of a township, head the tributaries of Lake Superior and the Mississippi river, the waters of the same swamp not unfrequently flowing in both directions. So interlocked are the streams of the different drainage systems, that the government surveyors have frequently been at fault in deciding to which system the smaller streams should be assigned. Throughout most of this area, which is everywhere underlaid by granitic and gneissoid rocks, rock ledges are rare, on account of the large swamps and heavy accumulations of drift. In the northern portions, however, rounded domes of pinkish granite are occasionally found, and along the stream valleys near the Iron Range, cliffs and ledges of dark-colored, amphibolic and chloritic gneiss not unfrequently appear.

The Ridge or Mountain Belt. In passing northward from the high interior, a belt of country is crossed which is occupied by a number of parallel ridges that constitute, as it were, a series of steps down to the lowland skirting the lake. These ridges are often bold, and even precipitous, showing cliffs and ledges of rock in every direction, while the streams are very rapid, and have their courses constantly broken by chutes and falls, the whole area thus contrasting greatly with the lowland on the north, and the swampy region on the south. The bands of deep color which cross the middle of Atlas Plate XXII correspond nearly exactly with the position of the ridge belt, while the lighter colors to the north and south show the more level areas. The several ridges that make up the belt, as also the valleys between them, follow directly the strike of the rocks; and the same peculiarity is, of course, shown by the streams, while even the larger rivers that break through from the swampy region on the south show a constant tendency to make excursions to the right or left along the strike, from which they return from time to time to resume their northward courses. These digressions run all the way from a few rods to ten miles, and are much more numerous than shown on the best maps, the government surveyors having located the streams only at the crossing of section lines.

Three principal ranges, known as the Penokee Iron Range, the Granite Range and the Copper Range, have been recognized as making up the ridge belt. The two latter are not well defined from each other; but still, having direct relation to the geological structure, the grouping becomes a convenient one, and is here retained, with the substitution of the term "Gabbro Range" for "Granite Range," since the granite is comparatively unimportant in the structure of the ridge.

Along the northern edge of the interior table land, the Penokee[1] Range presents itself as a sharply defined ridge, often rising abruptly, or even precipitously, 100 to 300 feet from the lower ground to the southward, though at times, especially near the eastern end of the range, swelling up much more gradually. On the north, the range is never so steep, but is still always well defined, falling off in some places over 300 feet within a mile; the difference between north and south sides being due chiefly to the fact that the rocks composing the ridge dip northward, but also in part to the fact that the northern slope has arrested a considerable quantity of glacial drift. The crest, and indeed the mass of the ridge, is nearly all along made up of quartzose rocks carrying more or less specular iron, and it is wholly to the hardness and power of resisting chemical action possessed by these rocks that the ridge owes its existence. Moreover, a close connection can be drawn between the variations in direction, shape and width of the ridge, and the variations in strike, dip and mineral character of the belt of rocks which make it up; for the course of the range follows always the strike of the rocks, the steepness of the northern slope being frequently decreased or increased by the decrease or increase in the amount of northern dip. A lessening in amount of quartzose material, or the introduction of softer layers, often causes a lessening in the width of the ridge.

The Penokee Range is, in general, much higher than the ridge to the northward of it, and, from the few high points where the thick forest does not prevent, Lake Superior can readily be seen; while from the lake, at a distance of from ten to fifteen miles from the shore, the crest of the range shows as a blue line against the sky, coming to an abrupt end towards the west, where, in T. 44, R. 4 W., it drops down suddenly some 200 to 300 feet. A nearer view is much harder to get; indeed, it is only very rarely that the dense forests of the region permit one to see a distance of more than a few rods. Quite a view can be obtained, however, from a point on the Wisconsin Central road, about two miles south of Penokee Gap. Here a heavy "windfall," over a mile in width, crosses the track, and permits one to see the crest of the Penokee Range to the northward, trending a number of miles east and west and alternately swelling into high peaks and sinking into gaps. A very much better and more instructive view, of the north face of the range, is obtainable from the top of a mass of rock which rises abruptly 170 feet from the low ground at foot, on the west line of the northwest quarter of Sec. 11, T. 44, R. 3 W. From here, one sees the range for

[1] It will be seen from appendix A, that the term Penokee originated in a printer's mistake for *Pewabic*, a Chippewa word, meaning iron; but long usage has so fixed the name that it does not seem wise to try to change it.

some eight to ten miles east from Bad river rising abruptly 200 to 500 feet into a narrow serrated crest, whose highest points in sight are nearly 1,200 feet above Lake Superior. Another wide view, the most extended I have met in the whole region, is obtainable from the crest of the Penokee Range itself, where the great windfall crosses it, near the north line of Sec. 18, T. 44, R. 2 W. From here, the western extension of the ridge from Bad river is seen to be very high and well-defined, one point, on about the north line of Sec. 17, T. 44, R. 3 W., jutting northward from the rest of the ridge in an especially prominent manner. From the same point, Lake Superior, the Apostle Islands, and the Bayfield ridge, with much of the intervening country, are plainly visible, as well as a wide stretch of the swampy region to the south.

In altitude, the Penokee Range varies from 900 to about 1,200 feet, and in breadth, from a mere crest a few rods wide to a broad, rounded swell, a mile across; the latter feature being characteristic of its eastern portions as it approaches the Montreal river. Upon the accompanying special maps of the Huronian series is given an outline of the crest of the Penokee Range for a considerable distance, with a number of natural scale cross-sections, which will serve to convey more definite ideas with regard to its character at different places. A few details are added here — beginning on the east — which should be consulted with the atlas plates in hand.

The Montreal river crosses the range in the S. E. quarter Sec. 24, T. 46, R. 2 E., in quite a wide and shallow valley. On the west line of Sec. 24 the ridge is quite flat, having gentle slopes either way; the summit, near the southwest corner of the section, having a width of 400 paces, and rising to an altitude of 1,040 feet above Lake Superior. For half a mile northward, the descent is only 60 feet. All along the south line of Sec. 23 the ground is nearly level, not varying 40 feet. On the west line of Sec. 26, the top of the ridge is near the quarter-post, with an altitude of 1,060 feet; half a mile both north and south, the ground is only 90 feet lower. In the south half of Sec. 27, the Gogogashugun, the main tributary of the Montreal, crosses to the northward in a narrow rock gorge, with steep hills on the west side and a much more gradual rise on the east. Where it crosses the south line of Sec. 27, the Gogogashugun has an altitude of about 980 feet. West of this river, we find the ridge having the following course and altitudes: crossing the south line of Sec. 27, 400 paces east of the southwest corner — altitude 1,080 feet, and 100 feet above the Gogogashugun; passing near the center of Sec. 32 — altitude 1,100 feet; leaving Sec. 32 near the southwest corner — altitude 1,060 feet; crossing the west line of Sec. 6, T. 45, R. 2 E., 400 paces north of the southwest corner — altitude 1,100 feet, from where the descent northward is about 100 feet in half a mile, the ridge now beginning to be more sharply defined; crossing Sec. 1, T. 45, R. 1 E., to the south quarter-post, where the altitude is 1,100 feet; leaving Sec. 11, 300 paces north of the southwest corner — altitude 1,100 feet, and descent 100 feet to the west quarter-post; crossing the south line of Sec. 10, 300 paces east of the quarter-post — 1,140 feet, and descent to the southwest corner 190 feet; leaving Sec. 15 at about the west quarter-post, where the altitude is 1,140 feet, and where the descents to the northwest and southwest corners are respectively 200 and 100 feet; and leaving Sec. 16 near the southwest corner — altitude 1,120 feet, and descents within half a mile north and south, respectively, 200 and 70 feet.

On the west line of Sec. 20, the Potato river crosses the Iron Range in a narrow valley over 150 feet deep, with high cliffs of rock on the east side. Where the west line of Sec. 20 crosses the Potato, 600 paces north of the southwest corner, the river surface is 950 feet above Lake Superior. Thus far, the range, though for some time it has been growing more prominent, has shown only rare and small rock exposures. From the Potato westward, it continues to become more prominent, and the rock exposures more and more numerous, especially near the summit. At the southwest corner of Sec. 19, the top of the ridge has an altitude of 1,090 feet, and in Sec. 25, T. 45, R. 1 W., one of 1,120 feet, at 700 paces south of the north quarter-post, at which the altitude is 1,023 feet, the crest being quite narrow. Farther east, the crest-line crosses the section lines as follows: west line Sec. 25, 200 paces south of the quarter-post — altitude 1,155 feet; west line Sec. 26, at the southwest corner — 1,195 feet.

In the N. W. quarter of Sec. 34, numerous deep ravines, setting down towards the Tyler's Fork branch of Bad river, indent the north face of the ridge. On the west line of Sec. 34, Tyler's Fork passes the Iron Range in a deep valley similar to that at the passage of the Potato, but having at the bottom a narrow rock gorge, with a series of water-falls. Above the falls, 200 paces north of the west quarter-post of Sec. 34, the river surface is 860 feet above the lake. Sec. 33 is crossed from about 200 to 300 paces north of the east quarter-post, to 245 paces north of the southwest corner; 600 paces north and 150 south of the east quarter-post, the crest of the ridge is at 940 feet altitude, and on the west line of the section, 972 feet, with a fall to the northward of a hundred feet within a quarter of a mile. Half way across Sec. 33, on the north slope and near the top, is one of the large exposures of magnetic schist which, from here westward, continue almost constantly to mark the crest of the range. It is 200 feet long and 20 feet high. Westward from here, we find the crest line crossing the south line of Sec. 32, 100 paces east of the quarter-post — altitude 1,120 feet; the west line of Sec. 5, T. 44, R. 1 W., 400 paces south of the northwest corner — altitude 1,175 feet, descending to 1,030 at the northwest corner; the west line of Sec. 6, 100 paces south of the quarter-post, at the top of a bold precipice of siliceous slate, facing southward — altitude 1,140 feet; the middle line of Sec. 1, T. 44, R. 2 W., 150 paces south of the centre — altitude 1,070 feet; and the west line of the same section, at the southwest corner — altitude 950 feet, descending northward 100 feet in a quarter of a mile. In Sec. 11, Carrie's creek passes the ridge from the southward, in a deep and narrow valley, the hill-side to the west of the creek showing high cliffs of slate. Where the creek crosses the north line of Sec. 11, 275 paces east of the north quarter-post, the surface is 860 feet above Lake Superior. Westward from here, we find the ridge quite narrow, and with the valley of Carrie's creek 200 to 400 feet deep all along in front. The following are the positions and altitudes of the crest: 189 paces south of the north quarter-post of Sec. 11, 990 feet; just north of the west quarter-post of the same section, 995 feet; 300 paces north of the south quarter-post of Sec. 10, in which section the ridge takes an abrupt turn from a northeast-southwest course to one nearly due west, 1,190 feet, or over 400 feet above Carrie's creek, a mile northward; and 200 paces north of the southwest corner of the same section, 1,085 feet. Beyond the last point, the course is nearly along the south line of sections 9, 8 and 7, changing gradually from the north to the south side of the line; 200 paces north and 100 east of the south quarter-post of Sec. 9, the altitude is 1,080 feet; and 60 paces south of the southwest corner of the same section, 940 feet. The last point is on the top of a bold south-facing cliff of slate, 200 feet high, from which a wide view of the interior is obtained. This cliff, known as Mount Whittlesey, swings abruptly around and faces eastward towards the valley in which two small tributaries of Carrie's creek cross the range. Where the easternmost of these crosses the south line of Sec. 8, it is 710 feet above Lake Superior. Passing this valley, we soon rise again rapidly, reaching, at a point 105 paces south of the quarter-post of Sec. 8, an altitude of 850 feet. Westward from here to the crossing of Bad river in Sec. 14, T. 44, R. 3 W., the range continues without break, having numerous ledges of rock, especially on the summit and southern slope, and about the following course and altitudes: across the northern part of Sec. 17, to a point on the west line, about 150 paces south of the northwest corner of the section — altitude 940 feet; through the northern part of Sec. 18, with a slight curve southward, crossing the west line 500 paces south of the northwest corner — altitude 910 feet; through the northern part of Sec. 13, T. 44, R. 3 W., crossing the west line 500 paces south of the northwest corner — altitude 915 feet; and about half way across Sec. 14 to the passage of Bad river, known as Penokee Gap.

The topography of the district in the immediate vicinity of Penokee Gap is shown in detail on Atlas Plate XXIII. Where the river crosses the north line of Sec. 14, it is 670 feet above Lake Superior. The valley is 50 to 300 steps in width, with highest and boldest hills on the west side, where there are large cliffs, above which the ground rises rapidly to over 200 feet above the river at foot. Moreover, we find the ridge to the west of Bad river, making an abrupt set-off northward of about 800 feet, in direct correspondence with a faulting in the rocks, having a similar direction and amount.

Westward from Penokee Gap, the Iron Range continues high, narrow and bold. Sec. 14 is left 100 paces south of the northwest corner, where the altitude is 919 feet, and the descent northward over 250 feet in half a mile. Thence, Sec. 15 is crossed just south of the north line, the crest having, near the Penokee mine, at a point about 65 paces south and 600 west of the northeast corner of the section, an altitude of just 1,000 feet, as determined with the level by Mr. W. W. Rich, chief engineer of the Wisconsin Central Railway. Beyond this to the westward, no accurate barometrical observations have been taken. Through Sec. 16, the ridge continues on its easterly course to the northwest quarter, when it begins to veer more towards the southwest. This new course is maintained through Sec. 17, which is left a quarter of a mile north of the southwest corner, where there is a partial gap; through Sec. 18 to the southwest corner; and a short distance into Secs. 13 and 24, T. 44, R. 4 W., where the ridge comes to an abrupt end, the ground dropping off 150 feet within a few hundred steps. In all this portion of its course, there are frequent mural exposures on the south side of the range, which are due, together with a simultaneous flattening of the northern slope, to a very considerable lessening in the angle of the dip, which everywhere east of Bad river is 60° to 70°, while now it decreases to 50°, 40°, and even 25°. Beyond, a low ridge continues with a northwesterly course, thus coinciding with the trend of the formation, through Sec. 13, to the west quarter-post, where it ceases altogether. All across T. 44, R. 4 W., the ground is low and wet, although Mr. C. E. Wright's magnetic observations seem to demonstrate the continuance with a somewhat devious course of the rock belts which make up the Penokee Range. Some change in nature or dip, or both, must, however, be imagined to account for this entire absence. Here, then, the granitic region to the south and the Gabbro Range to the north of the line of the Penokee Range, merge into one another.

Passing now to T. 44, R. 5 W., we find the Huronian rocks reappearing at the surface, and forming again a prominent ridge, which is, however, broken into more or less thoroughly detached portions. In the northern part of Sec. 23 and southern of Sec. 14, we first find a ridge again, made up of essentially the same formations as the Penokee Range proper, and some 200 to 250 feet high. It runs along the north side of the Maringouin river, to Sec. 15, where the ground becomes low again, until Sec. 16 is reached. There the same rocks rise into a ridge some 300 feet high, in the southern part of the section, and to the southeast of the Maringouin, passing out at the southwest corner, and again falling off. In the southwest quarter of Sec. 17 is again a ridge some 400 feet in height, but made up of more northern belts of rock than those constituting the Penokee Range proper.

The region of ridgy country lying north of the Penokee Range is not to be subdivided into a series of sharply defined ridges, stretching, like the Iron Range itself, entirely across the district, but rather consists of one broad mass, which, in the vicinity of the lines of the several large streams that pass it to the northward, separates into a succession of short and, for the most part, rather broad belts of high land, that owe their existence to the tendency of the subordinate streams to hollow out valleys in the lines of strike. Midway between the main streams, these secondary ridges blend more or less completely into one broad elevation. As already said, however, usage has recognized two main ridge belts, which have a somewhat close relation to the underlying rock structure.

Of these two, the Gabbro Range includes the series of ridges lying immediately north of the depression which nearly all along marks the front of the Iron Range. The width of the gabbro belt of high land is from three to four miles, and its general altitude, away from the main water courses, 700 to 900 feet. Beginning on the Montreal river, in Secs. 13, 11 and 12, T. 46, R. 2 E., we find this ridge with a general altitude of about 900 feet, and showing numerous low mural rock ledges. Thence we follow it across the Gogogashugun to the southwest corner of T. 46, R. 1 E., in the southern and southeastern parts of which township some heavy cliffs of rock are found bounding the ridge on its southern side, towards the valley of that branch of the Potato river which here occupies the depression to the north of the Iron Range. Thence the course is in the same direction across T. 45, R. 1 W., in which town the belt is crossed by both the Potato and Tyler's Fork rivers. On the west line of T. 45, R. 1 W., there is a blending of the several constituent ridges into one, even the usual depression in front of the Iron Range becoming less marked. In T. 45, R. 2 W., the valleys of the two westward flowing branches of Carrie's creek, and that of the long southwesterly stretch made by Tyler's Fork, produce four very prominent and well defined ridges, counting from the Iron Range on the south to the low land on the north.

In the southwestern part of T. 45, R. 2 W., and the adjoining northwest corner of T. 44, R. 2 W., Bad river passes the Gabbro Range. The river surface, at the south line of Sec. 30, is about 600 feet above Lake Superior, while on the north line of the same section it is but little over 500, the river, in the intervening space, having made a wild series of rapids and falls over granitic rocks. On both sides of the river the hills rise boldly, and on the west soon reach an altitude of nearly 900 feet. West of Bad river the Copper and Gabbro Ranges blend into one, having on the south the marked depression in whose western extension lie English and Bladder lakes. The range now has a considerable width, stretching, as we trace it westward from the southern parts of T. 45, ranges 3, 4 and 5 W., more and more into the northern parts of T. 44. All along this portion of its course, the Gabbro Range is broken into innumerable small ridges which show cliffy outcrops, usually of very coarsely crystalline gabbro, facing in every direction, single ledges often having a height of over 25 feet and a length of several hundred.

The Copper Range, so called because the rocks along its course have been found to carry copper, is, for the most part, not distinct topographically from the Gabbro or Greenstone Range. Still, including as it does the northernmost portion of the whole ridge region, the Copper Range presents a continuous steep front towards the lowlands on the north across the whole width of the district. At the mouth of the Montreal river, this steep slope begins directly at the lake shore, where there is a vertical rise of nearly 100 feet, and beyond a steady ascent to an altitude of over 500 feet within three miles. Further west the front of the range recedes rapidly from the lake, and takes a southwesterly course to about the middle of the northern part of T. 45, R. 2 W., whence, to the Brunschweiler river, in the northern part of T. 45, R. 4 W., the course is nearly west. Beyond the Brunschweiler, it seems to become less prominent, and at the same time trends somewhat south of west to the west line of the district. Everywhere east of the Brunschweiler there is a steady rise from the southern edge of the lowlands, at an altitude of 100 to 150 feet to one of about 500 to 600 feet, within three miles. Being obliged to make so rapid a descent, the larger rivers, where they leave the highlands, have produced heavy falls and rapids, and have worn out deep and narrow rock gorges.

In its eastern portions the Copper Range reaches a width of six miles, and at its southern edge an altitude of 700 to 800 feet above the lake. Over most of this broader portion, however, the altitude does not exceed 550 to 650 feet, the surface being generally level and showing only very rarely rock ledges. West of the Potato river the breadth lessens rapidly, and after Bad river is crossed never exceeds, for the Copper Range proper, more than two miles.

For further ideas on the topography of the ridge region, reference is made to the list of barometrical and other altitudes given on subsequent pages, to the general maps of the district (Plates XXI and XXII of the Atlas), and to the detailed descriptions of other portions of this report.

The Lowland Area, lying between the foot of the Copper Range and the shores of Lake Superior, has a surface in general from 100 to 200 feet above the lake. At the southern edge it is somewhat higher than this; while the shore bluffs are seldom over 25 to 50 feet in height, a considerable area about the mouth of Bad river being but a few feet above the lake level. In minor detail, however, the lowland area is much broken up. It is everywhere underlaid by a heavy deposit of red marly clay, mingled with more or less sand, and a few boulders. Through this clay the several main rivers, as well as all the tributaries, down to the smallest, have had but little difficulty in cutting deep and narrow channels. As a result, we find the surface carved in every direction into steep-sided, narrow water courses from 25 to 100 or more feet in depth; the bare clay banks in the cases of the larger streams not unfrequently rising almost perpendicularly from the water's edge. Such a country, to the foot traveler, the only one who can as yet, to any extent, traverse this region, is to the last degree annoying, especially if he is traveling along one of the main streams, as, for instance, Bad river, where, in following the trail, he no sooner succeeds in climbing out of one ravine than he is obliged to descend into another. Following the lake shore itself, a few rods inland, is nearly as bad, each of the numerous little spring brooks that run into the lake following a deep ravine. Of course the same feature makes road and railroad building difficult, as is shown by the great number of bridges along the line of the Wisconsin Central Railroad, two of which, those across the valleys of the White river and Silver creek, are of iron, erected at great cost, respectively over 1300 feet and 600 feet in length, and 100 feet and 85 feet in height. Except about the mouth of Bad river, where there is a considerable area of open marsh, the lowland district does not show any large areas of swamp, though in T. 46, R. 2 W. and R. 3 W., in the Indian Reservation, small swamps are quite numerous.

The Bayfield Ridge. Only the eastern end of the Bayfield Ridge is included within the district now reported on. Most of it is contained in the region examined by Mr. E. T. Sweet, in whose report it will be found described. The top of this ridge has an altitude of from 450 to 600 feet above Lake Superior. The high ground stretches well to the lake shore all around, being especially bold along the coast of the extreme end of the peninsula known to the old French voyageurs as the "Détour," and leaving nowhere more than a very narrow slip of lowland along the shore. As seen from the southeast, this high country stands out very boldly, conveying the idea that it is one of the prominent rock ranges that are so characteristic of the whole basin of Lake Superior. But, on closer examination, it is found to be everywhere heavily covered by drift materials; boulders and sand drift in the interior, and red marly clay nearer the coast. Rock exposures are absolutely wanting, if we except the low cliffs of horizontal sandstone so frequent along the lake shore. On top of the ridge, away from the stream valleys, the surface is generally level, being roughened only by drift knolls and depressions, and altogether without the narrow linear rock ridges that characterize its western extension into Douglas county.

Coast Features. Considered in general, the coast of the mainland portion of the district presents the following prominent features: (1) near the mouth of the Montreal river, about a mile of coast line trending northeast, which is the western end of the long stretch of bold coast that begins at the head of Keweenaw Point; (2) about 22 miles of low coast line, the edge of the level plain that lies north of the Copper Range, trending at right angles to the last course, or about northwest, and ending in the long sand spit known as Chaquamegon Point, the whole stretch standing directly across the depression lying between the Bayfield and Keweenaw ridge belts; (3) the broad but shallow bay, known to the Chippewas as Chaquamegon, or Long Island Bay, which lies directly in the line of depression just mentioned; and (4) the bold coast of the Bayfield peninsula, which has in all a length of about 42 miles, and is bordered for much of its extent by low cliffs of horizontal red sandstone, with deep water close in shore. These cliffs, as also similar ones on the Apostle Islands, have been worn by the waves into a variety of caves and arches, and, clothed as they are to the very edge with heavy forest, constitute not the least attractive portion of the scenery of Lake Superior.

The following details are condensed from notes taken along the coast. Beginning on the east, we find, at the mouth of the Montreal river, cliffs of highly inclined red sandstone surmounted by red clay, rising abruptly about 90 feet from the water. The river enters the lake through a picturesque little bay, at the head of which, a few rods from the lake shore, is a series of bold falls, 90 feet in height, over the nearly vertical ledges of the sand-rock. Westward from the Montreal, the sandstone soon dies away, the red clay forming the whole height of the cliff, which gradually lowers to about 40 to 60 feet. This height continues to Clinton Point, except where a number of very steep-sided and wooded ravines are cut down through the clay. At Clinton Point, and for some distance east, horizontal ledges of sandstone underlie the clay, and in places stretch out for some distance just under the waters of the lake. Westward from Clinton Point, the clay banks become lower, finally disappearing altogether near the east line of Sec. 27, T. 48, R. 2 W., where the open marsh through which Bad river reaches the lake begins. All along on the lake side of this marsh is a narrow sand beach, often heaped into ridges and dunes by the wind and waves. This character continues to the neck of Chaquamegon Point, which is a sand-spit stretching seven miles in the same direction as the more eastern part of the coast, and separating Chaquamegon Bay from the open lake. The width of the point is from 300 feet to over 1000 feet. It is composed wholly of sand, thrown up by the waves, but has a scant undergrowth of grass and stunted trees along the centre for most of its length. In its wider portions the point presents several parallel sand ridges, with the steepest side towards the open lake, but the narrower parts show only one such ridge. During the severe storm of September, 1872, the waves of the lake broke through the point near its eastern end, producing a passage several hundred feet in width, and deep enough for small boats. The same thing has happened before, the channels gradually filling up again. A large inlet existed some twenty years since nearer the head of the point, and its place is now indicated by a level area of sand without vegetation, stretching entirely across the spit.

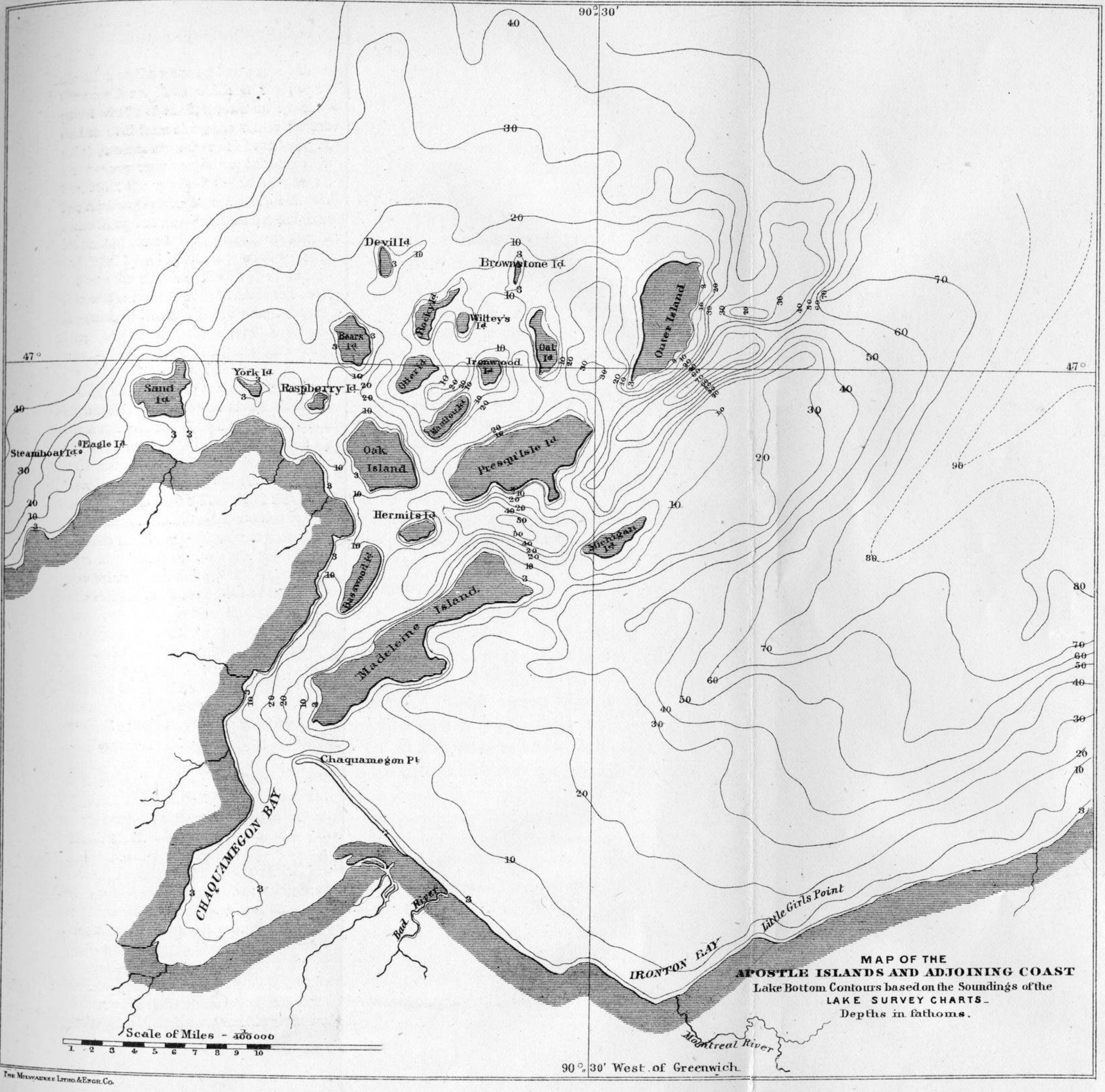
From the mouth of the Montreal to the end of Chaquamegon Point, the three-fathom line of the Lake Survey Chart is not far from shore, and half a mile from shore there is generally from six to seven fathoms of water. At the mouth of Bad river is a sand bar; but just inside the river is broad and deep, and could be improved so as to make an excellent harbor. Steam tugs ascend the river some fifteen miles to the falls, on Sec. 25, T. 47, R. 3 W.

Chaquamegon Bay is about twelve miles long and six wide in the broadest part, the opening between the end of Chaquamegon Point and the Bayfield coast being about three miles across. The deepest water in the bay is to be found on the western side, where there is from four to eleven fathoms in the channel, which runs quite close to the Bayfield coast. All of the eastern part, comprising more than half the whole area of the bay, is shallow, having less than three fathoms of water, while a large area under the lee of Chaquamegon Point, and along the eastern shore, is much shallower than this. At Ashland, the three-fathom line is a mile from shore, and the two-fathom line half a mile, so that long piers are necessary for the steamboat landings. At the head of the bay, where Fish creek enters, there is a still wider belt of shallow water, the two-fathom line being a mile and a half from shore. On the north east, near the neck of Chaquamegon Point, the shore of the bay is low, open marsh, through which enters a wide and deep bayou, with a number of branches, which is known to the Chippewas as the Kaukaugon, and which was, undoubtedly, at one time, the channel through which Bad river reached the lake. Following the shore southwestwardly from here, we find the marsh extending with a low sand beach in front for about seven miles, when low banks of the red clay begin which continue to the head of the bay. At Ashland, the clay bluffs are twenty-five to thirty feet in height and are cut as everywhere by deep, steep-sided, wooded ravines, a number of which are crossed on bridges by the streets of the town. At the mouth of Fish creek, and extending from it around the head of the bay to about the southeast corner of Sec. 24, T. 48, R. 5 W., is marsh.

Here, following now the Bayfield coast, begins a low cliff of red sand-rock ten feet high, and surmounted by five feet of red clay. The sand-rock extends only for some three hundred feet, beyond which the entire bank is made up of clay. All through Sec. 19, T. 48, R. 4 E., and to the sand beach at the creek in Sec. 18, there are low banks of red clay, out of which numerous boulders have rolled, and formed a line along the water's edge. Beyond the creek in Sec. 18 the red clay banks, twelve to fifteen feet high, and with occasional low ledges of sandstone at foot, one to six feet high, extend to Vanderventer's creek in Sec. 7. Here begins a sand beach which continues to and beyond the creek in Sec. 5. On Sec. 5, the coast trends nearly eastward, and we are on the south side of the bulge in the coast which occupies the southern half of T. 49, R. 4 E., and the extremity of which is known as Houghton Point. Here the banks of clay begin again, with frequent low rock ledges at foot, the cliffs evidently extending some distance below the water, which is deep close to the shore. From McClellan to Houghton, in Sec. 27, the rock cliff is 10 feet high, and the ground very steep above. Beyond Houghton, the rock cliff continues to within a fourth of a mile of Sioux river, which comes in through a marsh fronted by a low sand beach. This beach continues to Owen's creek, on the N. W. qr. of Sec. 5, and beyond are clay banks fifteen feet high, the clay soon giving place to the red sand-rock, which, in the northern part of Sec. 33, forms a cliff twenty feet high, with bold ground above. This cliff extends nearly to the town site of Bayfield, being broken only by the short sand beach at the mouth of Pike's creek, S. W. qr. Sec. 27. On sections 22 and 23 the rock cliff is often twenty-five feet in height. At Bayfield the banks are high, but rise more gently from the water. Immediately beyond the Bayfield pier, however, the sand-rock cliff reappears, overlaid by clay, and rising beyond rapidly to over one hundred feet above the water. From Sec. 6, T. 50, R, 3 W., to Sec. 29, T. 51, R. 3 W., there is a beach behind which the ground rises rapidly. Then begin the rock cliffs, which, having a height of from ten to twenty feet, and showing many interesting instances of erosion by waves into caverns, arches and columns, extend along nearly all of the rest of the coast to the limit of the district on the west line of R. 5 W. There are important breaks in the cliff line at Red Cliff, Frog, Raspberry and Sand Bays, where there are sand beaches, and where rivers and creeks of the same name enter the lake.

From Houghton Point to Sand Bay there is deep water close in shore; generally from eight to ten fathoms, and in some cases twenty. Just off the Bayfield pier there are ten fathoms, it being possible for the largest vessels to approach close to the town. Indeed, the harbor of Bayfield and La Pointe is the finest on the American side of the lake, the site being in every way an unusually fine one for a town. There is room for any number of the largest vessels, the whole bay being well protected from all winds except that from the northeast; and from this also the eastern side of the harbor is well sheltered. Moreover, the three channels by which the harbor is approached are all wide and very deep, the north channel showing from twenty-five to sixty fathoms, and there are no dangers at all, the deep water everywhere running close to the shore of the islands. At Sand Bay, there is a bar with about five to fifteen feet of water, connecting Sand Island with the main land, but farther west there are from four to seven fathoms close in shore.

The Apostle Islands, including the smallest islets, are just twenty-four in number. The total land and water area contained within the figure produced by joining the outermost points of the group is about 314 square miles; of this about 77 square miles are land. As a whole, the group trends in an N. E.-S. W. direction, and is the direct continuation of the Bayfield peninsula. The islands are, however, with the exception of Sand Island, all separated from the main land by a channel carrying 10 to 20 fathoms of water, while the channels between different members of the group are often deeper than this, running up to 50 fathoms. The accompanying plate is taken directly from the Lake Survey Chart, No. 3, issued by the Engineer Department, U. S. A., except the lake bottom contours, which have been sketched in from the figures given on the chart referred to. Besides the shape of the bottom, the plate shows the relative positions, sizes, etc., of the several islands of the group. These vary considerably in size, Madeleine Island, the largest of the group, being twelve and one-half miles long, and from a little over one to a little over three in breadth; while



MAP OF THE
APOSTLE ISLANDS AND ADJOINING COAST
Lake Bottom Contours based on the Soundings of the
LAKE SURVEY CHARTS.
Depths in fathoms.

The Milwaukee Litho. & Engr. Co.

the rocky islet between Steamboat and Eagle Islands is only fifteen feet in diameter. Most of the islands are, however, of good size, i. e., from ten to six miles in length, and from one to three in breadth.

Oak Island, which lies directly in the line of the coast of the Bayfield ridge, rises some 400 feet above the level of the lake; one or two others reach perhaps 150 feet; but most of the islands do not rise more than 50 to 75 feet, several not over 10 to 20 feet above the water. Except where clearings have been made, as about the mission on Madeleine Island, all of the islands are densely wooded to the water's edge; for the most part with evergreen timber. All of them have a basement of sand-rock, which in most cases is in sight, especially on the eastern sides, where it frequently rises 10 to 30 feet perpendicularly above the water, and is often worn into many picturesque shapes. Overlying the sand-rock nearly everywhere is a mass of reddish and sandy clay, the same that has already been mentioned as appearing all along the coast of the mainland. On the western sides of the islands, and to some extent also on the eastern sides, this clay frequently hides the underlying sand-rock entirely, rising into very steep bluffs, which, from the bright red color of the clay, are noticeable from a very long distance. Not unfrequently the rain, descending from the surface of the islands, has worn the clay into more or less completely separated towers or buttresses.

A glance at the accompanying map of the Apostle Islands will show that there is a tendency to a linear arrangement, more or less roughly parallel to the general trend of the whole group. This is shown in the linear outlines of individual islands, in the trends of the separate islands, in the trends of groups of the islands, in the positions of the bottom contours, and, in some cases, in the trends of valleys or lines of elevation. The trends of the Bayfield coast of Chaquamegon Bay, and of some of the valleys on the main land, have evidently some connection with the same linear system. The origin of this system, so far as it is possible to assign an origin, is spoken of on a subsequent page. Beyond doubt the islands at one time formed part of the main land. The work of separation has been, of course, in part performed by the action of the waves of the lake; but the main agent has evidently been a more powerful one. The grouping of the islands alluded to above is one based not only on proximity, or the following one another in a straight line, but also, and more especially, upon the existence of shallower water between the members of a group than is found between members of different groups. Madeleine, Michigan and Gull islands are thus shown to be merely portions of one line of elevation, which, moreover, extends far to the northeast under the water surface. Below are given some details with regard to the several islands.

Madeleine Island (Moniquanikang Minis, or Yellow Hammer Island) is the largest of the group, having a length of twelve and one-half miles, and a breadth of from one and a quarter to three and a quarter miles. The surface is level to rolling, reaching in the highest portions an altitude of perhaps 100 to 150 feet above the lake. Coasting the island, the following features are noticed: All along the northwestern side, which is very nearly a straight line, trending northeast, or with the general course of the group, the ground is raised but a little above the lake shore, there being either a gravelly beach or a low bank of red clay along the water's edge, and only very rarely a rock exposure. The harbor of the old French settlement of La Pointe is merely a wide bend in the coast, but is very completely sheltered, and has deep water close in shore. From La Pointe to the southern point of the island are banks of red clay in places over 30 feet in height. At the southern extremity, a sand-bar stretches a quarter of a mile southwestward, just above the surface of the water, and as much farther just under water. This bar is said to have been rapidly wasting for some years past. Turning the point, we find the southeast side of the island made up of several overlapping linear stretches of bold bluff, trending more to the eastward than the northeastern side, and united by curving beaches of sand, with low ground behind. From the sand-spit at the southern point of the island, to the beach in Sec. 27, T. 50, R. 3 W., there are high clay banks, rising 40 to 80 feet above the lake, and having at foot an occasional exposure of the red sand-rock, which in one place, on Sec. 5, T. 49, R. 3 W., rises boldly 25 feet from the water. From the sand beach in Sec. 27, around the point to the beach in the next bay, the rock ledges, 10 to 12 feet high, continue all along, occasionally with a clay bluff above. The latter beach stretches on a curve through sections 13 and 12, T. 50, R. 3 W., and Sec. 7 of T. 50, R. 2 W. Behind the beach is a bayou and a large swamp, which extends some two miles inland, and beyond doubt fills what was once the head of the bay. Moreover, the line of bluffs, which forms the north side of the bay, continues on the same course entirely across the island. From the southeast corner of Sec. 7, T. 50, R. 2 W., all along the north side of the bay to the point on Sec. 35, T. 51, R. 2 W., there are high clay banks. At the point the rock is in sight, and beyond, to the northwest, gradually gives place to the clay, the banks of which at the same time lessen in height.

Michigan Island (Bugadabi Minis, or Hook and Line Island) is a continuation of the line of elevation of which Madeleine Island forms a part. It is three and one-half miles long and one and a quarter broad at its wider or southwestern end, from where it tapers to a point at the northwest end. High bluffs of red clay skirt the island nearly all around, rising sometimes to over 60 feet above the water. At the light-house, on the southern side, the banks are very high. The light is 129 feet above the lake. The only rock visible is on the east side of the point near the northeast end. Stretching from here towards the northeast is a rock reef, more or less covered by sand, over which the water is only a few feet in depth. At the end of the reef is

Gull Island (Giashco Minis), which is only a few rods in length, showing rock at the northern end, with a beach of quite large bowlders. The southeast end is clay. This has been separated from Michigan Island, since the surveys in 1824, '25, '26, by Captain Bayfield, by whom the first accurate map of the Apostle group was made.

Basswood Island (Wigobi Minis) is three and one-half miles long and one and one-half wide at the centre, the shape being an oval one, with the greatest diameter trending about north-northeast or parallel to the coast line of the mainland immediately across the channel. The island rises in the middle to about 100 feet above the lake. The shores are steep all around, being rock-cliff all along on the east side, and clay bank on the west. In places the rock rises some distance above the lake, as shown at the large quarry.

Hermit's Island (Wilson's Island, Ashuwaguindag Minis, or Askew Island) is one of the smaller islands, being two miles long and three-quarters of a mile broad. On the east side the sandstone cliffs, often worn into deep caves, are nearly continuous, whilst the western side is almost wholly clay bank.

Stockton's Island (Presque-Isle or Peninsula Island, Gegawewamingo Minis, or Burnt-wood Island), is one of the larger islands, being seven and one-half miles long and two and one-half wide. It rises about 75 feet above the lake, and has projecting from its southeastern side a narrow peninsula about a mile in length, from which the French name is taken. The southeast side shows sandstone nearly all along, the cliffs in some places rising 30 feet from the water. Beyond the northern point the sandstone lessens in height, gradually giving place to the clay, which forms continuous bluffs all along the western shore.

Outer Island (Gachiishquaguindag Minis) is six and one-quarter miles long by two and one-half wide, trending but little east of north. On the east side the rock cliffs rise from 5 to 20 feet from the water. All along the west side are clay banks 31 to 50 feet high, often worn in a striking manner into projecting buttresses.

Oak Island (Mitigominikang Minis, or Acorn Island) is the highest of the group. A rather unreliable barometrical determination gave 432 feet for the height of the centre of the island. It is three and one-half miles long in a northwest-southeast direction, and two and one-half wide. In the interior a number of ravines indent the surface. One of these, very marked and steep-sided, is 100 feet deep, and trends northeast to southwest. Except on the northwest corner, where there is a clay bank of 75 feet, the immediate shores of the island are not very high. All along the south and east sides are low sandstone cliffs, the north and west sides being, as usual, all clay bank.

Manitou Island (Devil's Island, Tate's Island) is two and one-half miles long in a north 45° east direction, and about a mile wide. The highest parts of the island are not more than 50 feet above the lake. All along the east side are sandstone cliffs 10 feet high. The western side is low clay bank, with a pebbly beach at the southwest corner. From this beach a sand spit runs half a mile northwest, and at the end of the spit is Little Devil's Island, an islet of clay.

Iron Wood Island (Higgins' Island) is roughly circular, with a diameter of one and a quartor miles. It does not rise any where more than 20 feet above the water. On the east the rock cliff is 8–10 feet high, without clay above. On the west are clay banks 2 to 30 feet high, with rock at base in one place.

Cat Island (Hemlock Island) is three miles long in a north and south direction, and one and a quarter miles wide at the broader or southern end, where it rises to a height of about 75 feet. The rock ledges are found on both sides, especially in the narrow northern part, but more continuous on the eastern side, where the cliffs are 15 feet high. The clay is present as usual, and forms a considerable portion of the west coast of the island.

Otter Island (Alabama Island) trends northeast, is two miles long and one and a quarter wide. The highest part is about 60 feet above the lake. Contrary to the general rule, clay bluffs 8-10 feet high are found on the southeast, and sandstone cliff 10 to 12 feet high on the north and northwest.

Rocky Island (Rice's Island) is made up of two parts, one trending a little east of north, two miles long and one wide. The other, a narrow neck extending one and one-half miles to the northeast, with an under water extension half a mile farther than this. The eastern side is a sand beach all along, with a narrow strip of cedar swamp behind. On the west side the clay banks are 10 to 30 feet high, with rock in sight at one place. Although so little rock is seen, the soundings of the Lake Survey Chart show that there is a rocky bottom for some distance around the island. A shoal, with 10 feet of water, connects Otter Island with

Willey's Island (South Twin Island, Shoal Island), which is an oval one mile long and three-quarters of a mile wide. It rises to a height of more than 20 feet, and shows no rock at all, the shores being alternatingly low clay bank and sand beach.

Brown Stone Island (North Twin Island — Cat Island) is a mere rock about a mile long from north to south, and a quarter of a mile wide in the middle, tapering to the extremities. The rock cliff, 15 feet high, is continuous all around except at the northeast corner, where there is a clay bank.

Raspberry Island has an irregular shape and a length of about a mile. The south and east sides show clay banks 10 to 50 feet high, broken by a little sand beach. The rock, contrary to the ordinary rule, appears on the northwest coast. The light at the light-house, on the south side, is 77 feet above the lake.

Bear Island is two miles long by one and three-quarters miles wide, and trends a little west of north. On the east and north the rock ledges rise 15 to 25 feet from the water. On the north, the rock gradually gives place to clay banks, which, with a height of from 10 to 30 feet, form all the western shore. At the southeast corner a sand-spit runs out several hundred feet into the lake.

Devil's Island (Brown Stone Island, Barney and Lamborn's Island, Rabbit Island) is a mere rock, one and one-quarter miles long and half a mile wide. A rock cliff 15 to 20 feet high surrounds the island, which is thus rendered very difficult of access.

York Island has an irregular shape and is about one and one-half miles long, with a width of half a mile at the eastern or broader end. It rises nowhere to a height of more than 20 feet, and shows rock nearly all around, with red clay above.

Sand Island is a large, irregularly shaped island, about two miles in diameter, with a projection one mile long from the northeast corner. There are two sand beaches, each over a mile in length, on the east and north sides. The rest of the island, except on the south, where there are clay banks 25 to 30 feet high, shows sandstone cliffs nearly all around, with more or less clay above. The island is probably nowhere more than 50 feet high. The bar connecting Sand Island with the main land has been mentioned above.

Eagle Island (Steamboat Island) is the westernmost of the group. It is only a few rods long, very level, and shows rock all around, overlaid by 2 to 3 feet of clay.

Steamboat Island is a small clay islet, lying a few hundred feet south of Eagle Island. Between the two lies a still smaller rocky islet, 5 feet high and 15 feet in diameter.

Altitudes. The barometrical observations made in 1873 proved to be of no value on account of the poor instruments furnished the party. Those made in 1876, '77 and '78 do not cover so wide an area as those of 1873, but have been carefully worked up by comparison with the readings of a second stationary barometer, and, in many cases, by comparison of repeated observations made at the same place at times far apart. The aneroids used were carefully compared before and after the work. They are the "Surveying Aneroid," by T. H. Steward, of London, and some five years' experience with them has only served to increase the confidence felt in their results.

Before the lists of barometrical altitudes is given one of elevations along the line of the Wisconsin Central Railway, which, having been obtained by leveling, have, of course, a high degree of accuracy. This list is compiled from a profile and large scale alignment-plat, very kindly furnished by Mr. Colby, the president of the road.

All altitudes in these lists, as also all others given in this report, are referred to the level of Lake Superior, which, according to the latest measurements of the Lake Survey, is 602 feet above mean tide at New York, and 20.5 feet above the level of Lake Michigan, which is thus placed at 581.5 feet above tide.

ALTITUDES ABOVE LAKE SUPERIOR.

Along the line of the Wisconsin Central Railroad, from Chaquamegon Bay to the south line of Town 43.

Place.	Feet above Lake Superior.	
	Grade.	Surface
Chaquamegon Bay	12	0
Ashland depot	30	30
Bay City creek crossing, Ashland	49	20
South line Sec. 34, T. 48, R. 4 W	77	58
South line Sec. 3, T. 47, R. 4 W	116	116
South line Sec. 10, T. 47, R. 4 W	125	123
South line Sec. 15, T. 47, R. 4 W	125	122
South line Sec. 22, T. 47, R. 4 W	125	121
White river crossing, N. W. qr. Sec. 35, T. 47, R. 4 W	125	25
South line Sec. 35, T. 47, R. 4 W	146	145
South line Sec. 2, T. 46, R. 4 W	155	152
South line Sec. 11, T. 46, R. 4 W	169	167
South line Sec. 14, T. 46, R. 4 W	196	195
Summit, N. E. qr. S. E. qr. Sec. 23, T. 46, R. 4 W	210	
South line Sec. 23, T. 46, R. 4 W	199	205
South line Sec. 25, T. 46, R. 4 W	170	169
Maringouin river crossing, N. W. qr. Sec. 36	170	138
Brunschweiler river crossing, S. hf. Sec. 36	173.5	150
South line Sec. 36, T. 46, R. 4 W	183	184
South line Sec. 6, T. 45, R. 3 W	233	231
Twin creek crossing, N. E. qr. Sec. 7	256	230
East line Sec. 7, T. 45, R. 3 W	271	262
Trout brook crossing, W. hf. Sec. 8	315	285
Wadleigh's creek crossing, S. E. qr. Sec. 8	315	285
East line Sec. 9, T. 45, R. 3 W	364	362
Silver creek crossing, S. hf. Sec. 10	388.5	302
East line Sec. 10, T. 45, R. 3 W	411	415
South line Sec. 11, T. 45, R. 3 W	435	435
East line Sec. 14, T. 45, R. 3 W	462	466
East line Sec. 13, T. 45, R. 3 W	517	516
South line Sec. 18, T. 45, R. 2 W	518	521
Beaver creek crossing, N. W. qr. Sec. 19	523	
South line Sec. 19, T. 45, R. 2 W	562	560
South line Sec. 30, T. 45, R. 2 W	615	614
Bad river crossing, S. E. qr. Sec. 31	621	610
Bad river crossing, S. E. qr. Sec. 31	621	610
South line Sec. 31, T. 45, R. 2 W	631	630
West line Sec. 6, T. 44, R. 2 W	637	644
Bad river crossing, S. E. qr. Sec. 1, T. 44, R. 3 W	636.5	624
Bad river crossing, S. E. qr. Sec. 1, T. 44, R. 3 W	636.5	626
South line Sec. 2, T. 44, R. 3 W	655	659
Bad river crossing, N. W. qr. Sec. 11	653	645
Bad river crossing, S. W. qr. Sec. 11	676	664
South line Sec. 11, T. 44, R. 3 W	684	670

ALTITUDES ABOVE LAKE SUPERIOR—(continued).

PLACE.	Feet above Lake Superior. Grade.	Surface
Bad river crossing, N. W. qr. Sec. 14	694	674
Bad river crossing, N. W. qr. Sec. 14	699	682
Bad river crossing, S. W. qr. Sec. 14	715	693
Bad river crossing, S. W. qr. Sec. 14	720	710
South line Sec. 14, T. 44, R. 3 W	737	716
Bad river crossing, N. E. qr. S. W. qr., Sec. 23	774	762
Bad river crossing, S. W. qr. S. W. qr., Sec. 23	795	781
Bad river crossing, S. W. qr. S. W. qr., Sec. 23	804	788
South line Sec. 23, T. 44, R. 3 W	802	810
East line Sec. 26, T. 44, R. 3 W	836	816
South line Sec. 25, T. 44, R. 3 W	850	861
Bad river crossing, N. E. qr. N. W. qr. Sec. 36	849	839
South line Sec. 36, T. 44, R. 3 W	849	847
East line Sec. 1, T. 43, R. 3 W	849	848
Summit, N. E. qr. S. E. qr., Sec. 6, T. 43, R. 2 W	868	
East line Sec. 6, T. 43, R. 2 W	862	860
Bad river crossing, N. W., S. W., Sec. 5	859	850
South line Sec. 4, T. 43, R. 2 W	885	878
Bad river crossing, S. W., S. E., Sec. 9	895	889
South line Sec. 9, T. 43, R. 2 W	896	894
South line Sec. 15, T. 43, R. 2 W	908	905
South line Sec. 22, T. 43, R. 2 W	931.5	930
Summit, near E. line Sec. 27, top of the divide	941	948
South line Sec. 26, T. 43, R. 2 W	937.5	942
South line Sec. 35, T. 43, R. 2 W	928	934

BAROMETRICAL ALTITUDES.

(Those marked thus, * are from the report of E. T. Sweet.)

T. 50, R. 4 W. *	
N. line Sec. 19	393
T. 50, R. 5 W.*	
Roath's, N. E. qr. Sec. 24	547
N. W. qr. Sec. 28	550
T. 49, R. 5 W.*	
Sec. 16	480
T. 48, R. 5 W.*	
Trail, Sec. 35	331
T. 47, R. 5 W.*	
Sec. 11, south br. Fish creek	7
Sec. 9, W. br. Fish creek	7
Cent. Sec. 10	126
Sec. 5, creek	45
N. W. qr. (?) Sec. 6	112
T. 47, R. 2 W.	
Meander corner W. line Sec. 1	65
S. W. cor. Sec. 1	48
Creek, 20 paces south	22
Qr. post, W. line Sec. 12	110
S. W. cor. Sec. 12	150
Qr. post, W. line Sec. 13	145
S. W. cor. Sec. 13	185
Qr. post, W. line Sec. 24	215
S. W. cor. Sec. 24	225
T. 47, R. 1 W.	
¼ mile n. of S. W. cor. Sec. 7	186
¼ mile s. of N. W. cor. Sec. 7	150
¼ mile n. of S. W. cor. Sec. 6	100
Top of Lake bluff W. line Sec. 6	80
T. 47, R. 1 E.	
Montreal river at trail crossing, N. E. qr. Sec. 21	397
Montreal river, S. line Sec. 24	443
T. 47, R. 2 E.	
Mouth of Gogogashugun river, S. E. qr. Sec. 32	503
T. 46, R. 1 W.	
S. W. cor. Sec. 10	523
Potato river, W. line Sec. 15	463
Potato river, W. line Sec. 18	260
Qr. post, W. line Sec. 18	275
S. W. cor. Sec. 18	426
Creek, 145 paces south	408
Qr. post, W. line Sec. 19	480
S. W. cor. Sec. 19	545
Qr. post, W. line Sec. 30	565
S. W. cor. Sec. 30	660
Qr. post, W. line Sec. 31	535
Tyler's Fork, W. line Sec. 31	528

BAROMETRICAL ALTITUDES — (continued).

T. 46, R. 1 W. — (continued).

S. W. cor. Sec. 31	543

T. 46. R. 1 E.

S. W. cor. Sec. 8	548
Qr. post, S. line Sec. 8	558
S. W. cor. Sec. 9	558
Qr. post. S. line Sec. 9	618
S. W. cor. Sec. 10	658
Qr. post, S. line Sec. 10	673
S. W. cor. Sec. 11	686
Qr. post, S. line Sec. 11	674
S. W. cor. Sec. 12	664
Qr. post, S. line Sec. 12	685
550 paces east of last point	718

T. 46, R. 2 E.

Gogogashugun river, S. line Sec. 5	530
Qr. post, S. line Sec. 5	540
Hill, 400 paces west	567
Creek, 600 paces west of qr. post	524
S. W. cor. Sec. 5	551
Qr. post, W. line Sec. 7	842
Qr. post, W. line Sec. 17	805
Trail crossing, N. line Sec. 18	727
Creek, 135 paces west	684
N. W. cor. Sec. 18	746
S. W. cor. Sec. 31	985
Stream, 350 paces east	970
Qr. post, S. line Sec. 31	995
S. W. cor. Sec. 32	1,050
Qr. post, S. line Sec. 32	1,035
Stream, near center of Sec. 32	1,035
Qr. post, N. line Sec. 32	1,065
N. E. cor. Sec. 32	1,085
Qr. post, N. line Sec. 33	1,100
N. E. cor. Sec. 33	1,060
Gogogashugun river, N. line Sec. 34	975
Bluff top, 200 paces west	1,060
N. E. cor. Sec. 34	1,010
Qr. post, W. line Sec. 26	1,065
N. W. cor. Sec. 26	1,015
Qr. post, N. line Sec. 26	1,026
N. W. cor. Sec. 26	1,040
Qr. post, W. line Sec. 24	965
N. W. cor. Sec. 24	940
Montreal river, N. line Sec. 24	910

T. 45, R. 3 W.

W. qr. post Sec. 14	520
N. W. cor. Sec. 23	525
W. qr. post Sec. 26	545
N. W. cor. sec. 23	633
W. qr. post Sec. 26	730
N. W. cor. Sec. 35	837
W. qr. post Sec. 35	830
S. W. cor. Sec. 35	845

T. 45, R. 2 W.

Tyler's Fork, S. E. qr. Sec. 2	512
Tyler's Fork, W. line Sec. 15	486
Tyler's Fork, W. line Sec. 16	416
Creek, S. line S. W. qr. Sec. 26	738
S. W. cor. Sec. 26	800
Creek near qr. post, S. line Sec. 27	700
S. W. cor. Sec. 27	763
Qr. post, E. line Sec. 33	685
S. E. cor. Sec. 33	763

T. 45, R. 2 W. — (continued).

Qr. post, S. line Sec. 33	753
S. W. cor. Sec. 33	733
Creek, W. line Sec. 33	648
Qr. post, W. line Sec. 27	783
Creek, W. line S. W. qr. Sec. 22	610

T. 45, R. 1 W.

S. W. cor. Sec. 6	613
Qr. post, W. line Sec. 18	763
S. W. cor. Sec. 18	752
Qr. post, W. line Sec. 19	776
S. W. cor. Sec. 19	744
Tyler's Fork, S. line Sec. 21	780
Bluff top, just west	810
S. E. cor. Sec. 21	820
S. E. cor. Sec. 23	1,000
Qr. post, S. line Sec. 24	1,025
S. E. cor. Sec. 24	1,080
100 paces s. of cor., crest of Penokee Range	1,100
500 paces n. of cor., crest of Penokee Range	980
Crest of Penokee Range, 700 paces S. of N. qr. post Sec. 25	1,125
W. qr. post Sec. 25	1,125
Crest of ridge, 200 paces S.	1,145
Center Sec. 26	1,040
W. qr. post, Sec. 26	990
S. W. cor. Sec. 26, crest of ridge	1,190
S. qr. post, Sec. 27	1,020
S. W. cor. Sec. 27	860
W. qr. post, Sec. 27	840
W. qr. post, Sec. 30	868
S. W. cor. Sec. 30	863
S. W. cor. Sec. 31	840
Qr. post, S. line Sec. 31	910
S. W. cor. Sec. 32	1,040
Qr. post, S. line Sec. 32	1,110
S. W. cor. Sec. 33	950
Qr. post, W. line Sec. 33	870
Center Sec. 33	930
Qr. post, S. line Sec. 33	865
Tyler's Fork, S. line Sec. 33	860
Qr. post, W. line Sec. 34	860

T. 45, R. 1 E.

Qr. post, E. line Sec. 1	1,050
S. E. cor. Sec. 1	1,080
Qr. post, S. line Sec. 1	1,100
S. W. cor. Sec. 1	1,020
S. W. cor. Sec. 10	940
Qr. post, S. line Sec. 10	1,100
Crest Penokee Range, 300 paces east	1,150
S. W. cor. Sec. 11	1,180
Qr. post, W. line Sec. 11	1,120
500 paces S. of N. E. cor. Sec. 11	1,090
Qr. post, W. line Sec. 15	1,140
S. W. cor. Sec. 15	1,030
Qr. post, S. line Sec. 16	1,030
S. W. cor. Sec. 16	1,125
S. qr. post, Sec. 17	980
S. W. cor. Sec. 19	1,080
Qr. post, S. line Sec. 19	1,040
Potato river, S. line Sec. 19	930
S. W. cor. Sec. 20	960

BAROMETRICAL ALTITUDES — (continued).

T. 45, R. 1 E. — (continued).

Qr. post, W. line Sec. 20	980
Qr. post, W. line Sec. 21	1,155

T. 44, R. 3 W.

S. W. cor. Sec. 2	725
Qr. post, W. line Sec. 2	830
N. W. cor. Sec. 2	845
S. W. cor. Sec. 11	860
Qr. post, W. line Sec. 11	655
Qr. post, S. line Sec. 11	735
Center Sec. 11	650
S. W. cor. Sec. 12	815
Qr. post, W. line Sec. 12	655
Center Sec. 12	695
Qr. post, S. line Sec. 12	795
600 paces south	900
Center Sec. 13	833
Qr. post, W. line Sec. 13	880
Center Sec. 14	740
Bad river, N. line Sec. 14	665
Qr. post, W. line Sec. 14	735
Shaft-house Penokee mine, Sec. 15	1,000

T. 44, R. 2 W.

S. W. cor. Sec. 1	945
Qr. post, W. line Sec. 1	810
Center Sec. 1	940
250 paces south, crest of Penokee Range	1,070
Carrie's creek, S. line Sec. 2	850
Qr. post, S. line Sec. 2	890

T. 44, R. 2 W. — (continued).

S. W. cor. Sec. 2	800
S. W. cor. Sec. 7	840
Qr. post, S. line Sec. 7	860
Crest of ridge, 400 paces south	980
Qr. post, S. line Sec. 8	830
Creek, 622 paces north	650
Center Sec. 8	705
Qr. post, W. line Sec. 9	738
Carrie's creek, 465 paces north	635
N. W. cor. Sec. 9	695
Center Sec. 9	795
S. W. cor. Sec. 10	1,060
Crest of ridge, 200 paces north	1,085
Qr. post, W. line Sec. 10	925
Qr. post, S. line Sec. 10	1,070
Crest of ridge, 300 paces north	1,190
Center Sec. 10	1,010
Qr. post, W. line Sec. 11	975
189 paces south of qr. post, N. line Sec. 11, crest of ridge	990
N. W. cor. Sec. 16	895
60 paces south, top of Mt. Whittlesey	940
262 paces south, creek	765
Creek, north line Sec. 17, 300 paces W. of N. E. cor	710

T. 44, R. 1 W.

N. W. cor. Sec. 5	1,040
Crest of ridge 400 paces south	1,165
Qr. post, W. line Sec. 6	1,100

DRAINAGE SYSTEM.

The highest land in Wisconsin, omitting one or two isolated points, is only 20 to 40 miles south of Lake Superior, where a large area lies at an elevation of from 900 to 1,200 feet above Lakes Michigan and Superior, or between 1,500 to 1,800 feet above the sea. As a result, we find, to the south of this high land, which constitutes the water-shed between the streams tributary respectively to Lake Superior and the Mississippi, a long and very gradual descent; while on the north we have one which is correspondingly short and rapid. On the top of the water-shed, as already shown, is a large region of tamarack and cedar swamps, and small lakes, among which the head waters of the north-flowing and south-flowing streams interlock in an intricate manner, the same swamp area in some places being drained in both directions.

On tracing out the dividing ridge between the two systems, we find that it covers the extreme southern part of our district in a quite irregular east and west line. To the south of the line, so far as the present district is concerned, with the exception of the few small brooks and lakes in the northwest corner of T. 43, R. 5 W., and the adjoining corner of T. 44, R. 5 W., which connect with Lake Numakagon, and so through the Numakagon river with the St. Croix, the drainage is altogether into the Chippewa. On the north side of the dividing line, the streams are tributary to either the Montreal or the Bad. Having to descend from 800 to 1,000 feet in so short a distance, it follows of course that they are very rapid streams, with many chutes and falls. Moreover, since the greater part of the descent is accomplished within the limits of what has already been designated as the Ridge Area, whose width is only a small portion of the whole distance to the lake, it becomes all the more evident that waterfalls and rapids must abound. In fact, between the southern edge of the Penokee range, and the southern edge of the lowlands, a distance of only six to twelve miles in a straight line, the rivers fall from 600 to 900 feet, the single falls running from 20 to 90 feet in height.

Besides the streams named, there are also numbers of short and small creeks, which run directly into the lake from off the lowlands, or from the highlands of the Bayfield peninsula. Taking these into account, we may conveniently group all the streams of the region, the Apostle Islands being almost entirely streamless, into the four following systems, which are named in the order of their importance, viz.: (1) the Bad River System; (2) the Montreal River System; (3) the Lake Shore System, and (4) the Chippewa River System. With regard to the last two, there is no need of adding anything to the information that can be obtained from the accompanying maps. A special description of the Bad and Montreal rivers, and their tributaries, is given below.

Bad river, the Mauvaise rivière of the early French explorers, is known to the Chippewas as the Mashkeg zibi, or Marsh river. The former name it appears to owe to the large amount of suspended matter in the water of its lower portions, which, flowing as they do for many miles between banks of red clay, naturally carry a great deal of clayey material to the lake. Since nearly all of the tributaries of Lake Superior are rapid streams, flowing over rock bottoms, this is an unusual peculiarity, and one possessed only by the streams of the Wisconsin shore, amongst which Bad river is much the largest and most important. The Indian name refers to the fact that the river reaches the lake through a large area of open marsh, also a feature peculiar to this stream. Bad river drains in all an area of about 1,000 square miles, of which 815 miles lie within the district. Its branches stretch far to the east and west of the main stream, Tyler's Fork and Potato river reaching into range 2 east, while the head-waters of White river stretch to range 8 west, a total east and west distance of about fifty miles.

The main trunk of the system heads in a large swamp area in T. 43, R. 1 E., and R. 1 W.[1] In the S. E. quarter of Sec. 9, T. 43, R. 1 W., two head streams unite, one coming from the north, the other from the south. The latter, which is the principal one, heads in the northwestern part of T. 43, R. 1 E., and pursues a course south of west through the swamp in T. 43, R. 1 W., to Sec. 21, T. 43, R. 2 W., where, receiving the drainage from the south of a string of small lakes, it turns north to the junction mentioned. The Wisconsin Central crosses this branch in the S. E. qr. of Sec. 16, and again in the S. E. qr. of Sec. 9, at which places, respectively, the water surface stands

[1] Through some oversight the engraver has omitted the uppor portion of Bad river from Atlas Plate XXI.

at 895 feet, and 888 feet above Lake Superior, and the stream is about 20 feet wide. After the junction of the two branches, the course of the river is northward for a mile, and then west two miles to the west line of T. 43, R. 2 W. At the railroad crossing in the S. W. quarter of Sec. 5, it is 851 feet above the lake. After passing the town line, there is a turn to the northward through the extreme northeastern corner of T. 43, R. 3 W., and thence to the lake the course of the river is in general northward, though there are numerous minor deviations.

At the crossing in the N. E. qr. of the N. W. qr., Sec. 36, T. 44, R. 3 W., the water surface is at 839 feet attitude, having fallen about 10 feet to the mile from the first crossing. Up to this point, the stream has been comparatively slow moving, flowing most of the time through marsh. Just beyond, however, a more rapid descent begins, there being in the northern part of Sec. 36 an 8-feet fall over granite. In Sec. 23, the railroad crosses three times in the S. W. qr., the water at the crossings being at 788, 781, and 762 feet atlitude, respectively. The first of these is only two miles from the crossing in Sec. 36, showing thus a fall of over 25 feet to the mile. In the S. W. qr. Sec. 23, the fall is 26 feet, in about two-thirds of a mile. A short distance below the last named crossing, the river passes through a gorge in pinkish granite, narrowing in places to a width of only about 10 feet and falling about 20 feet in the 30 rods, there being three leaps with rapids between. At the first crossing in Sec. 14, the attitude is 710 feet, the river having fallen 52 feet in three-quarters of a mile, including the falls just described. Another crossing, only a few hundred feet along the railroad, shows a fall of 17 feet in less than a quarter of a mile. All along here, to the crossing of the gorge at the south side of Penokee Gap, the river is 60 to 100 feet in width. At the gorge, it is contracted to 20 feet and the altitude of the water surface is 682 feet. Here the river has come in contact with the Huronian series, and is forced to flow along the strike, having worn itself a channel in the limestone which forms the south wall of the gorge. The passage northward through the Penokee Range is now made, the river widening, but preserving a rapid current in the valley known as Penokee Gap, which has a width of from 50 to 300 paces, there being a bottom land of some width on the west side of the river, where also the cliffs are boldest and highest. At the crossing on the north line of Sec. 14 the water surface stands at 670 feet, and half a mile down the stream, in Sec. 11, at 664 feet. Just beyond the last crossing and around a curve in the river, there is a fall over ledges of diorite of about 12 feet in 10 rods. In the northern part of Sec. 11, there is a change to a northeasterly course, which continues through Sec. 1, T. 44, R. 3 W., and the southern parts of sections 5 and 6, T. 44, R. 2 W., when there is a turn to the north along the east line of Sec. 31, T. 45, R. 2 W., the river all along being about 100 feet wide, deep, and comparatively slow-moving. On the north line of Sec. 31 the altitude is about 600 feet.

In the S. E. qr. of sec. 30, there is a passage through a deep and narrow gorge in granite, with a succession of chutes and falls. The whole fall in Sec. 30 is about 100 feet, the river flowing in the northern part of the section through a valley some 200 feet in depth, though without rock ledges near the stream. From here the river, widening, continues northward with a swift current, but not broken by rock rapids, to the northern part of Sec. 19, then, bending to the east, through the northwestern part of Sec. 20, on the north line of which section it has an estimated altitude of about 430 feet. In the southern part of Sec. 17, the river contracts, the current grows swifter, and, finally, turning to the north, makes a perpendicular leap of 25 feet into a narrow rock walled gorge. The fall is a picturesque one, the river being divided into two channels by a high mass of rock, the western channel carrying the most water. Along the slanting bottom of this gorge, with a width of about 25 to 40 feet, the river rushes in a northeasterly direction for 1,100 feet, falling in this distance about 40 feet, to the mouth of Tyler's Fork, which enters from the east, and is the first important tributary received. Immediately at the mouth of the latter stream, the gorge turns abruptly at right angles, trending now northwest. Directly in the angle of the convex or eastern side of the bend, Tyler's Fork enters Bad river by a fall of 45 feet over the wall of the gorge, here about 65 feet deep. The top of the wall is thus cut into by the former stream, upon which there are, a few rods above, two falls of 10 feet each, with intervening rapids, making the total fall at the mouth of the stream between 60 and 70 feet. Beyond the mouth of Tyler's Fork, the Bad river gorge, trending now northwesterly, deepens, soon reaching 100 feet, with overhanging walls of boulder-conglomerate and vertically placed sandstone. About a thousand feet below the fall of Tyler's Fork, the rock ledges disappear, and the river flows through a ravine walled by high banks of red clay, above which the ground rises rapidly on both sides of the stream. No data are available for the altitude of the river surface in this portion of its course. It is estimated, however, that at the foot of Tyler's Fork fall, the elevation is about 320 to 330 feet, whilst the total fall within Sec. 17 can hardly be short of 125 to 150 feet. This would make the altitude at the north line of Sec. 17 about 250-300 feet. Beyond Sec. 17 the river has not been followed closely, but flows with a current gradually decreasing in rapidity, and with a tortuous course, through the red clay of the low lands to the mouth of the Maringouin, in Sec. 25, T. 46, R. 3 W. This is about six miles, measured along the stream from the north line of Sec. 17, T. 45, R. 2 W., and, as the altitude here can not be more than 90 to 100 feet, the fall in this distance is at least 30 feet to the mile.

The Maringouin comes in from the west, being the first important tributary received from that direction. At the junction both rivers are broad and deep, with a slow-moving, muddy current, and a wide bottom land. From here, through T. 46, R. 3 W., to the fall in the southern part of T. 47, R. 3 W., while preserving the general northerly direction, the course of Bad river is exceedingly tortuous, as is usually the case with a slow-moving stream. The bottom land all along here is quite wide; from one-fourth to one-half mile. The river, however, quite frequently touches one side or the other of its valley, flowing at the foot of steep bluffs of bare red clay and sand, which rise 60 to 100 feet above the water. The third tributary of importance, the Potato or Opinike river, comes in on the east side two and a quarter miles down the stream from the mouth of the Maringouin. The falls in Sec. 25, T. 47, R. 3 W. are over the edges of layers of red sandstone and shale, which, dipping southward at an angle of about 38°, produce a series of small falls of one or two feet, for between a mile and a half and two miles along the river. Below the falls Bad river is again sluggish, deep and tortuous, flowing in T. 47, R. 3 W., 13 to 14 miles in making 6 miles. Bold clay banks flank one side or the other, nearly to the mouth of White river, which comes in from the west on the east side of Sec. 28, T. 48, R. 3 W. Here the country is open, and now, made still broader by the accession of White river, Bad river turns to the eastward and passes through marsh to the lake, which it reaches near the middle of the west line of Sec. 17, T. 48, R. 2 W. At the mouth there is a bad sand bar, but this could readily be improved, and since there is deep water immediately outside, whilst the river is deep inside, an excellent harbor could be made. Small tugs have frequently ascended to the falls. There are four principal tributaries of Bad river, which, named in the order of the distances of their mouths from the mouth of the main stream, are as follows: *White river*, or the Mashkeg Fork, entering from the west; *Potato river* or Opinke zibi, from the east; *Maringouin or Mosquito river*, from the west; and *Tyler's Fork*, from the east.

White River has a total length of about 40 to 45 miles. Heading at Long Lake, in T. 44, R. 7 W., Bayfield county, it pursues a generally northeasterly course to the west line of our district, which it crosses on the west line of Sec. 30, T. 46, R. 5 W. From here the course, with many windings, is, in general, northeasterly through the clay banks of the lowlands. For the most part, the river runs in a valley 80 to 100 feet deep and very steep-sided. At one place only are there any rapids or rock exposures. This is at Welton's dam, Sec. 6, T. 46, R. 4 W., where the current is obstructed by the edges of southward-dipping layers of sandstone, exactly as at the falls of Bad river, Sec. 25, T. 47, R. 3 W. The total fall of White river from Long Lake is about 700 feet, most of which is, of course, in the upper portions.

Potato River has a total length of about 30 miles, in which distance it falls 900 to 950 feet. The principal head stream starts in the northwest part of T. 45, R. 2 E., flowing thence a southerly course along the southern foot of the Penokee Range. In Sec. 30, T. 45, R. 1 E., it turns north, and on the east side of Sec. 19 passes the Iron Range. Where first crossed by the east line of Sec. 19, the river is about 30 feet wide and 920 feet above Lake Superior. The Iron Range is passed in a narrow valley 150 feet deep, with perpendicular cliffs of gneiss, silicious slate and magnetitic schist on the east side of the river. From here the general course of the stream is northerly to Sec. 7 of the same town, where enters the other main fork, a stream which flows south of east along the north slope of the Penokee Range, just as the first named fork flows along its southern slope. From the junction of the forks, the Potato flows in general more to the east of north than before, showing many chutes and rapids, to about the center of Sec. 15, T. 46, R. 1 W. Here begins the general westerly course, which, with numerous minor deviations, is preserved to the junction with Bad river. In Sec. 15 the Little Potato comes in from the northeast, and on the west line of the same section the altitude of the river surface is about 443 feet. Through Sec. 16, the river flows in a valley cut 60 to 80 feet in the red lacustrine clay, alternately approaching one side or the other of the valley, and having a narrow bottom 4 to 6 feet above the stream. There are no rapids or rock ledges crossing the stream in Sec. 16, on the west line of which section the water surface has descended to only 428 feet altitude. In Sec. 17, however, 700 paces down the stream from the line, rock ledges and rapids begin, which are soon followed by a series of cataracts. The head of the rapids is at a point about 1,400 paces east and 300 north of the southwest corner of Sec. 17. At 800 east and 280 north of the same point, there is a very heavy rapid, below which the river rushes along underneath a cliff of diabase, on the south side, to a point 500 feet down stream, where there is a fall of 25 feet over the same rock. On both sides of the west line of Sec. 17, at about 700 paces north of the southwest corner, is a series of bold falls, having a total descent of not less than 75 to 80 feet, in a distance of 500 feet along the stream, with two leaps of 25 feet and 32 feet, respectively. These falls are over vertically placed ledges of conglomerate, sandstone and shale. Below, again, the current is slower, with bold banks on either side of a narrow bottom-land. For about half a mile these banks are of red sandstone, overlaid by red clay, but beyond this of red clay only. On the west line of Sec. 18, the altitude of the water surface is not over 260 feet, the total descent within sections 17 and 18 being about 170 feet. For the rest of its course the river is slow-moving, and very tortuous, with high banks of red clay on either side of a narrow bottom land, to the junction with Bad river, in the east half of Sec. 24, T. 46, R. 3 W.

The Maringouin River was first so called by Colonel Charles Whittlesey in Owen's "Geological Survey of Wisconsin, Iowa and Minnesota," on account of the number of mosquitos he found on its banks, "maringouin" being the term used for these insects by the French *voyageurs*. Many of the maps, and most of the inhabitants of the region have, however, corrupted this title to "Marengo."

The Maringouin is the tributary next in importance to White river, which it equals in length, being full 40 miles long from source to mouth, and which it nearly equals in the size of the area drained. It heads in the southeastern part of T. 44, R. 5 W., and the southwestern part of T. 44, R. 4 W. Thence the course is in general northeasterly to the Huronian belt of rocks in the northern part of Sec. 23 of the latter town.

Here the river is deflected for some distance along the northwestern strike of the Huronian, which forms the wall of the north side of the gorge, through which the river flows; the other wall being a pinkish Laurentian granite. Into the up-stream end of this gorge, about 20 rods south of the north line of Sec. 23, and 100 rods east of the northwest corner of that section, the river descends in a series of three falls, having in all a height of about 65 feet, within a few rods. The two upper ones are respectively 15 and 25 feet high, 50 feet apart along the stream, and fall towards the northwest. The third starts directly from the foot of the second, but falls westward, the three constituting a curve around a jutting mass of the pink granite. At the foot of the falls is a pool about 50 feet by 30, with a vertical wall of granite 47 feet high on the southern side. On the north side of the gorge, through which the river flows in Sec. 14 and into Sec. 15, there is a ridge 250 feet high, composed of the Huronian rocks.

The west northwest course is pursued through the southern part of Sec. 15 to Sec. 16, when there is a turn to the north, the Iron-Bearing or Huronian rocks forming a high ridge on the left bank of the stream. From here northward through T. 44, R. 5 W., and T. 45, R. 5 W., the Maringouin has not been followed closely. In the former town the course is almost due north to the north line of Sec. 4. In T. 45, R. 5 W., however, the course is much more devious, there being several long excursions back and forth along the strike. In the northern part of this town, the river passes through the lowlands with the usual clay banks and low bottom-land. Here the course of the stream veers gradually to the eastward, in which direction it continues, after leaving T. 45, R. 5 W. at the extreme northeast corner, to its junction with Bad river. All along this part of the river the clay banks and low bottom continue, the water becoming more and more highly charged with suspended matter as the mouth is neared. At the railroad crossing in the northwest quarter of the northwest quarter of Sec. 36, T. 46, R. 4 W., the valley of the Maringouin is 700 feet wide at the top and 30 feet deep, the river, with a width of not more than 20 paces, standing at an altitude of 138 feet.

In the final easterly stretch, the Maringouin receives a number of tributaries from the south. These come from off the northern face of the Copper Range, and as they near the Maringouin flow in ravines cut deeply into the red clay. A number of these ravines are crossed by the Wisconsin Central Railway, which runs for some miles in an easterly direction as it ascends the steep northern face of the Copper Range. Twin creek, Trout brook and Wadleigh's creek flow in narrow ravines 25 to 30 feet in depth, whilst the Silver creek ravine is 85 feet deep. All these streams have a heavy fall, rising at a height of from 600 to 700 feet above the Maringouin, and, with one exception, at a distance of only about seven miles. The largest of them is Brunschweiler's river, which sets back much farther southward than the others, heading in some small lakes on the edge of a large swamp area in the northern part of T. 43, R. 4 W. From here northward to Bladder lake, in sections 11, 12, 13 and 14, T. 44, R. 4 W., the creek is sluggish. Bladder lake is merely an irregularly shaped expansion of the Brunschweiler, surrounded by hills which show bare ledges of a very coarse gabbro. Where it leaves the north end of Bladder lake, the Brunschweiler is only about six feet wide, and here begin at once the chutes and rapids which extend along the whole course of the creek, with only small intervening still spaces, until after the Copper Range is passed in Sec. 15, T. 45, R. 4 W. Bladder lake could readily be raised for a number of feet, by making a dam at the outlet, and, on account of the peculiar conditions, the expense would be but slight. The water-power is a very valuable one. Below Bladder lake, and to the passage of the Copper Range, the Brunschweiler flows in a narrow valley, with steep hills showing bare ledges of gabbro on either side. These hills frequently close together, producing narrow gorges, with vertical walls rising from the water's edge. At the passage of the Copper Range, near the northern line of Sec. 22, T. 45, R. 4 W., is a series of falls and chutes, the last on the river. The descent here is about 30 feet in six or seven rods.

Below here to the junction with the Maringouin, near the center of Sec. 32, T. 46, R. 3 W., the usual clay banks, muddy water and slow current, are met with.

Tyler's Fork, the last of the important tributaries of Bad river, and the only one of them that does not reach the lowlands before joining the main stream, has a total length of about 30 miles, and a total fall of nearly 700 feet. It heads in the large swamp near the middle of T. 44, R. 1 E., and flows thence south of west to Sec. 28, T. 44, R. 1 W. From here it flows northward to the Penokee Range, which it passes in Sec. 33, T. 45, R. 1 W. This passage is mapped on Plate XIII of this volume.

Where the river first strikes the Huronian, it is about 15 paces in width, sluggish, and standing at about 860 feet above the lake. A short distance beyond, however, at a point 150 paces north of the east quarter-post of Sec. 33, the first rock is seen, and the river, just before flowing north, is suddenly deflected for 25 paces along the strike direction of the slate, N. 66° E. Turning then again abruptly, at right angles, a fall of about 5 feet is made at 190 paces north of the quarter-post. At 220 paces, the stream is again forced to follow the prominent strike lines, and now flows in a S. 66° W. direction, through a rock gorge 25 to 45 feet deep, and 20 to 30 feet wide at the river level, for a distance of about 140 feet. At the end of this gorge, another abrupt turn at right angles is made, and the rock, lying thus athwart the stream, produces two falls, in all about 15 feet high. Even the falls themselves show the influence exerted by the strike upon the course of the water, for part of the upper leap is made to fall across the rest, and the whole stream between the upper and lower leaps is forced to follow the strike direction for a few rods. From the foot of the lower fall, a narrow gorge, this time across the strike, extends some 40 paces along the river with 30-feet walls on either side, and a width of about 15 to 20 feet. Some 45 paces below this gorge, there is another low fall, but for most of the distance through the rest of Sec. 33, and to the falls near the middle of Sec. 28, the stream is sluggish, and passes through alder swamps and old beaver dams. The falls in Sec. 28 are made up of a series of low plunges, over black slate, the descent being some 20 feet in 200 paces. At the north line of Sec. 20, the river surface stands at 760 feet above Lake Superior.

Beyond Sec. 28, T. 45, R. 1 W., the general direction of Tyler's Fork is a little west of north to the north line of the town, the river having in this distance a fall of some 200 feet, but no notable cataracts. Where the north line of T. 45 is crossed, the river is in swamp, and so continues, changing at the same time to a westerly course, to the west line of T. 46, R. 1 W., where the water surface has an altitude of 528 feet. Here the course changes to southwest, the marsh continuing through Sec. 1 and into Sec. 2 of T. 45, R. 2 W. The southwesterly course is continued through Secs. 11 and 10 without rapids and with a strong current. From the southern part of Sec. 10 to the southwest quarter of Sec. 15, the course is nearly due south. At the south line of Sec. 10, the altitude is 512 feet. In the southwest quarter of Sec. 15, there is a turn at right angles to a generally west course, and at the crossing of the east line of Sec. 15 the altitude is 485 feet. The total descent in this section is thus 28 feet, the current becoming swifter, though as yet no rapids or rock ledges have appeared. In Sec. 16, 529 paces below the east line of the section, begins the series of rapids, which, with a few short intervening spaces, continue to the mouth of the river, ending with the wild series of falls mentioned in descending the gorge of Bad river. On the west line of Sec. 16, the river surface has descended to 416 feet altitude. The heaviest rapids are in Sec. 17. There the course of the river is about north 25° west for some 1,200 feet, when it makes a short semicircle to the westward. In this curve are the three falls, respectively 10, 10 and 40 feet, by which the descent into the Bad river gorge is made. The entire descent of Tyler's Fork in Sec. 17 is between 80 and 90 feet.

Montreal River, the Wasijiwang zibi of the Chippewas, drains a much smaller area than Bad river, but, though not carrying so much water as the lower Bad, is often as broad a stream, especially after the reception of its main branch, the Gogogashugun. The total area drained by the Montreal, in Wisconsin, is about 177 square miles. Since it forms, for a large portion of its course, the boundary between Wisconsin and Michigan, a large part of its drainage area lies within the latter state. The main tributary of the Montreal, the Gogogashugun, is nearly as large a stream as the upper Montreal itself, and receives a much larger share of the entire drainage area of the Montreal, as far as Wisconsin is concerned.

The Montreal heads in T. 43, R. 3 E., in a tangle of swamps and small lakes, among which its head-waters interlock with those of the Flambeau, the main tributary of the Chippewa. From here the course is a northerly one through T. 43, R. 3 E., and T. 44, R. 3 E.— in which town it passes through Pine Lake — the current slow, the river narrow, and the banks generally alder, tamarack or cedar swamp. In the northeast part of Sec. 33, T. 45, R. 3 E., it meets the state line, and from this point to the mouth is itself the state line. Through the remainder of T. 45, R. 3 E., the course is north of west to the northeast corner of Sec. 6, and thence through the southwest corner of T. 46, R. 3 E., to the Penokee Range, which is passed in Sec. 24, T. 46, R. 2 E. There is no remarkable gorge or fall here, the river flowing with a quite rapid current through a wide valley, and making only two small rapids over the upturned edges of a dark slaty rock. On the north line of Sec. 24 the river is about 910 feet above the lake. The same west-of-north course is continued through T. 46, R. 2 E., in Sec. 11 of which town there is a series of three falls over green diabase and diabase-amygdaloid. The uppermost of the three descends in all some 25 feet in three leaps, with chutes between; the other two, each made up of a succession of leaps and chutes, are respectively about 35 and 15 feet in perpendicular height. Below these falls to the north line of T. 46, rock ledges and small rapids continue. Just after crossing the line the general course of the river changes to the eastward, in which direction it continues, with minor deviations along the strike directions, to the mouth of the Gogogashugun in Sec. 32, T. 47, R. 2 E. Here the water surface has descended to 503 feet above Lake Superior. From here, the course is, in general, north two miles, then west three miles, and north two, to the south line of Sec. 13, T. 47, R. 1 E.; thence northwest to the centre of Sec. 14, west to the southeast quarter of Sec. 15, southwest and south to near the centre of Sec. 22, and westerly to the falls in the southwest quarter of the northwest quarter of Sec. 21. The minor deviations are, however, very many, the river frequently doubling on itself, producing loop-like forms in its course.

From the mouth of the Gogogashugun to the crossing of the old Flambeau trail, in the northeast quarter of Sec. 21, the Montreal flows a rapid current in a steep-sided valley, 80 to 100 feet deep, frequently approaching the bluffs on one side or the other, but is wholly without rock rapids. On the south line of Sec. 24, T. 47, R. 1 E., the altitude is 440 feet; and at the crossing of the Flambeau trail 383 feet. Below the trail the river continues to run between steep banks, 50 to 80 feet high, but flows faster, almost continuous rapids, with several two-feet falls, extending from 80 paces below the trail to the main falls. These are right in a sharp bend of the river[1] and descend, in two leaps, with chutes between, a total perpendicular distance of 78 feet. The lower fall is 40 feet high. From its foot the river rushes through a tortuous and narrow gorge, the overhanging walls of boulder conglomerate in one place rising over 200 feet above the water. From the mouth of this gorge, near the center of Sec. 20, there is a nearly straight N. 30° W. course to the lake, sandstone ledges frequently showing in the side and bottom of the river. About twenty chains from the lake shore there are falls, in all 90 feet in height, over the vertically placed sandstone ledges. From the foot of the falls to the lake the river is deep and still, with walls of sandstone and red clay 90 feet high on

[1] See special maps of the Lower Montreal, Plates XVIII and XIX of this volume.

either side. Across the mouth is a pebble beach, between which and the west wall the river water escapes to the lake in a narrow channel.

The total fall of the Montreal is about 1,000 feet in a total length of about 50 miles.

The **Gogogashugun river** ("river crossed by a fallen, swaying tree") is the main tributary of the Montreal, and may quite properly be regarded as one of the two forks that unite to form the Lower Montreal. In Foster and Whitney's report, the Upper Montreal and Gogogashugun are called respectively the Pine and Balsam rivers. The name here given to the latter is taken directly from the Chippewas, who recognize as the "Shingopes" or Balsam only one of the head-streams of the Gogogashugun. The total length of this stream is between 25 and 30 miles, in which distance there is a fall of nearly 500 feet. It heads in the swamp in the southeast corner of T. 44, R. 1 E., passes Island Lake in the southwest part of T. 44, R. 2 E., and eastward to the southern part of Sec. 21, in the same town, whence the course is nearly due north to the junction with the Montreal. South of the Iron Range, the stream is mostly sluggish, and bordered by alder, tamarack and cedar swamp. The Iron Range is passed in the southern part of Sec. 27, T. 46, R. 2 E., on the south line of which section the water surface is 975 feet above Lake Superior. At the passage, there are several falls over the same slates that form the barrier at the gorge of Tyler's Fork. The stream,[2] "on coming in contact with the barrier, follows the strike for several rods in a narrow trough, when it divides. One branch, turning abruptly across the beds a few feet and then returning along the strike a short distance, again turns across the beds and follows a narrow channel entirely across the schists. The main branch keeps onward along the strike for a short distance beyond the point of division, and then turns at right angles and plunges down a narrow channel across the beds, until it is joined by the smaller branch some distance below." Soon after passing the Iron Range the river passes through a large alder swamp (Sec. 21), beyond which, in Secs. 16 and 17, begins a series of rock exposures and small rapids, which end in a succession of low falls just south and north of the north line of Sec. 8. At the crossing of this line, the river is at 530 feet altitude. Below, there are no rapids or falls to the junction with the Montreal, where the altitude is 503 feet.

Artesian Wells. This subject may be properly alluded to here, since these wells are fed by underground currents of water. No attempt, so far as I am aware, has ever been made to obtain an artesian flow within the district, but a few words of caution on the subject may not be amiss. In all of that portion of the district lying without the "Lowland Area," any attempt to obtain a flowing well would of course be wholly futile; nor is it likely that any such attempt would be made, on account of the forbidding nature of the rocks. In that region, however, which is underlaid by the red marly clays, all around Ashland, for instance, the conditions are such as at least warrant an experiment; for here we have a series of stratified, impervious clays, including inter-stratified sandy layers, and not improbably rising slightly southward, towards the mountainous interior. The last point is the doubtful one. The same red clays yield flowing wells over a large area in eastern Waushara and adjoining counties in eastern Wisconsin. They have there, however, a

[2] From a description of the passage of this river through the Iron Range, furnished by Professor Chamberlin.

distinct slant eastward, and a larger spread upon which to collect the surface water; which, of course, is the ultimate source of all subterranean water.

VEGETATION AND SOILS.

These are treated here only in their most general relations, as affecting the physical aspect of the country, and as dependent upon, or connected with, the underlying geological structure.

The whole region is densely wooded, forming but a small part of the great northwestern forest, whose well known general characters hold here also. So dense is the timber growth that not only is traveling rendered to the last degree difficult, foot traveling being the only kind possible, but it is a rare thing that one can see more than a few rods, or attain a point of observation from which any wide view, or good general idea of the topography, can be obtained. The traveling is rendered yet more difficult by the frequent areas of fallen timber, known as "windfalls." These are well enough known in all of the Wisconsin forests, but never become so well known as to be welcome to the "packer" through the woods. They are like great swaths, having been prostrated by hurricanes, and are often sharply defined from the standing timber around. The trees at times lie all in one direction, but in other cases are wholly without such arrangement, having been prostrated by a tornado. The great windfall of September, 1872, so far as my knowledge goes, is as much as forty miles in length, though it is reported to have a greater length than this. It crosses the Chippewa river in Sec. 23, T. 40, R. 5 W., with a width of about one and one-half miles. Beyond this point it trends east of north to the Wisconsin Central Railroad, about three miles south of Penokee Gap, where it has a width along the railroad of about two miles. From here it passes, with a width of never less than a mile, and with not a tree standing, directly through the hard wood timber of the Penokee Range, in Sec. 7, T. 44, R. 2 W., and thence northward to and beyond the junction of Tyler's Fork and Bad river. The latter stream enters it also in Sec. 31, T. 45, R. 2 W., where it lies on both sides of the river. When last traversed in 1877, this windfall had been partly burnt over, but was, for the most part, made more impenetrable than ever on account of the new and dense growth of bushes and small trees. In crossing it on the Penokee Range, it was found necessary to cut the way with an axe for nearly a mile and a half.

The prevailing trees of the district are of evergreen varieties. In the lowland areas north of the Copper Range, the prevailing growth noticed was of balsam, hemlock, spruce and birch, with some white cedar and occasional areas of pine, or scattering pine trees. On the northern flank of the Copper Range, and generally in the valleys of the ridge district, hemlock appears to prevail. On the summits and slopes of the higher ridges, however, and in the vicinity of the Montreal river, over wide areas of elevated country, sugar maple predominates. The whole length of the Penokee Range is marked by a belt of sugar tree, always very sharply defined from the evergreens of the lower levels on either side, and running from one or two hundred paces to a mile in width. The maple trees are generally of much larger size than those of the evergreen varieties, and where they grow there is much less undergrowth, the traveling being, consequently, much more agreeable. In the swampy region south of the Iron Range, the timber is mostly balsam, cedar, spruce and tamarack of small size, with scattering large pine trees and occasional tracts of white pine.

Of the soils, it may be briefly said that they belong to four general varieties: a red marly clay; a "loamy" soil; a swamp or wet land soil; and an alluvial or river-bottom soil.

The *red marly clay* soil extends over all of the lowland area, stretching also well up on the Copper Range, to a height of between 500 and 600 feet above the lake. It also covers all of the Apostle Islands and all of the country along the Bayfield coast, from which it stretches in places some miles inland, the highest portion only of the eastern end of the Bayfield Ridge being free from it. This soil is directly derived from the great thickness of Quaternary (post-glacial) lacustrine clay which, interstratified and mingled in places with more or less sand, overlies so considerable an area along the south shore of Lake Superior. It is the same in age and general nature as the marly clay soil of the shores of Lake Michigan, though for much of our district it is, perhaps, more thoroughly clayey. It generally carries a very light coating of vegetable accumulation, and is everywhere covered with a thick growth of evergreen timber, for the most part not of large size. In places this clay is mingled with enough sand to make it good for agricultural purposes; but as a general rule it is so purely clayey and tenacious, baking under the sun to a very hard, almost stony consistency, that it is a much less valuable soil than that next to be described. It is, however, always charged with a considerable quantity of lime and magnesia carbonate, and by thorough working may be made gradually available. The following are analyses by Prof. W. W. Daniells, of samples of this clay collected in the immediate vicinity of the village of Ashland:

	I.	II.	III.	IV.	V.
Insoluble residue........	.....	.....	.....	.....	76.37
Silica..................	58.09	64.56	.....	.....	61.86
Iron sesquioxide	4.44	4.11	.....	.....	.....
Alumina...............	25.32	18.86	.....	.....	.....
Calcium carbonate......	4.31	6.40	11.93	10.09	7.15
Magnesium carbonate...	4.01	3.53	.....	.....	.....
Water.................	4.09	2.56	.....	.....	.....
Totals	100.26	100.02			

The *loamy soils*, which are the best in the district, are found on the higher lands for the most part, or the tops of the ridges that characterize what has been called the "Ridge Area." They support always a heavy growth of hard wood, chiefly sugar tree, and are excellently adapted for all such crops as are able to withstand the rigors of the Lake Superior climate. The whole length of the Penokee Range is characterized by such a soil, but wider areas are found on the Gabbro and Copper Ranges near the Montreal river, where excellent hard wood land covers nearly the whole width of the elevated country between the Iron Ranges and Lake Superior.

The *swamp or wet land soils* are especially characteristic of the country south of the Iron Range, where more than half the surface is occupied by tamarack and cedar swamps. Besides these true swamps there are other areas hardly wet enough to be so called, which yet support a more or less distinctly swamp timber growth, chiefly of cedar. Such areas abound in the country south of the Iron Range, and are frequently met with also in the valleys between the more northern ridges.

The *alluvial or river bottom soils* have not a wide distribution; they are, indeed, only of any importance in the valley of the lower Bad river below the mouth of the Maringouin. Much of this "bottom," which reaches sometimes half a mile in width, is an excellent soil, being a fine river silt mingled with much vegetable mould. This is especially the case below the lower falls. In some of the branches of Bad river, where they pass through the red clay, it was noticed that the bottom was almost wholly sand, and a very poor soil, and this was attributed to the washing out of the clay by the current, the sand being left to form the bottom.

Agriculture is as yet only a matter of experiment, not more than three or four farms having been tried before the recent completion of the Wisconsin Central road, and those only intermittently, and on a small scale.

CHAPTER II.

THE LAURENTIAN SYSTEM.

Every where south of the Penokee Range, the country is underlaid by the rocks of this system. This area includes all of T. 43 that lies within the district; all of T. 44 in ranges 1, 2 and 3 east; nearly all of T. 44, R. 1 W.; the southern portion of T. 44, ranges 2, 3, 4 and 5 west; all of T. 45, ranges 2 and 3 east; the southeastern half of T. 45, R. 1 E.; the southeast corner of T. 45, R. 1 W.; the southeast corner of T. 46, R. 2 E., and the small part of T. 46, R. 3 E., that lies west of the Montreal river; in all about 550 square miles — but a small proportion of the great Laurentian area of Northern Wisconsin.

The northern boundary of the Laurentian area is very sharply marked, not only topographically, by the abruptness of the southern face of the Penokee Range, but geologically also, since the southernmost rocks of the Huronian system are nearly continuously exposed, while the Laurentian exposures are more frequent near the boundary line than elsewhere. The only exception to the general rule of the continuity of these exposures is in T. 44, R. 4 W., where not only the exposures are wanting, but the Penokee Ridge itself has disappeared. Even here we are able to mark out the line with as great certainty, since the magnetic belt of the Huronian, one of its lowest members, has been traced in detail by Mr. C. E. Wright, with the aid of the magnetic needle.

The topographical characters of the Laurentian area have already been indicated. It is merely necessary to repeat here the main facts. The region is an elevated one; as a whole much the most elevated portion of the district, since it lies at an altitude of 850 to 1,200 feet above Lake Superior. The surface is, in general, without sharp or prominent ridges, and is largely occupied by tamarack and cedar swamps, between which rise the low and rounded hills of drift materials. Some of these low ridges are of rock, and then show numerous rounded ledges or "*roches moutonnées*" of pinkish-weathering granite or gneiss. As a rule, however, exposures are rare, the immense drift accumulations, and large swamp areas, constituting an effectual covering to the underlying rocks. The exposures are most frequent immediately under the southern side of the Penokee Range and near the

LAURENTIAN ROCKS.

R.D. Irving.

The Milwaukee Litho.&Engr.Co.

Fig 1. Chloritic Hornblende Gneiss (1466); Penokee Gap. × 25.

Fig 2. Apatite-bearing Gneiss (1414); Penokee Gap. × 125.

rivers. Further southward the drift becomes heavier and heavier, reaching its greatest development on the summit of the watershed.

The rocks of the Laurentian area, so far as the exposed portions are concerned, are of dark colored and altered (chloritic) hornblende-gneisses and pink quartzose granites. The hornblende-gneiss is always very plainly laminated, frequently highly schistose, and the whole internal structure of the rock, as seen under the microscope, shows conclusively its original clastic condition. The granites are generally without such distinct bedding, but appear, nevertheless, to be true metamorphic granites. No eruptive granite, recognizable as such, has been observed.

It is not possible, without overstepping the limits of our district, to reach any important generalizations with regard to the Laurentian series. It is evident enough that the rocks are of a true sedimentary origin, and that they have been folded in an exceedingly intricate manner. The strike directions run from slightly north of west to about north 50° east. Judging from the very constant southwesterly courses of the various branches of the Chippewa just south of the southern limit of our district, the northeasterly strike direction must be the prevailing one.

It is not known that the Laurentian rocks of our district include any useful mineral substances. So far as known, they are entirely destitute of metallic ores. Since this is the case with the same series in its known extension into the upper peninsula of Michigan, it is not thought likely that any important discoveries will be made in the future in Wisconsin.

LOCAL DETAILS.

Along Bad river, in T. 44, R. 3 W., south of the Penokee Range, several ledges of granitic rocks are to be seen, and one or two in the northern part of T. 43, R. 2 W. The southernmost of these is on the railroad line. It is a pinkish granite, but was not closely examined. In Sec. 36, the great windfall of 1872 crosses the river and railroad. The open space left by the fallen trees, being on quite high ground, affords one of the rare chances for a wide view to be obtained in this region. Along the course of the windfall, which is here about one mile and a half wide, numerous low, rounded knobs, or "*roches moutonnées*," of pinkish-weathering granite are to be seen. One of these, near the south line of Sec. 36, is a gray, fine-grained, gneissoid granite, having a distinct bedding in a direction a few degrees north of east, and a vertical dip. In the northern part of Sec. 36, the granite causes a fall in Bad river.

Just west and north of the centre of Sec. 23, T. 44, R. 3 W., Bad river passes through a narrow gorge, in pink-weathering granite. The gorge is about 30 rods in length, the river here flowing about 20 degrees north of east, and there are falls and rapids, amounting in all to about 20 feet perpendicular descent. On the north side, the rocks are about 10 feet high, and at the eastern end of the gorge, about 100 feet south of the river, is a smoothed and rounded *(roche moutonnée)* wall of pink granite, about 50 feet long and 25 feet high. Through a part of this, there is now a railway cutting whose centre is just about 200 feet west of the centre of Sec. 23. The rock (24.2040) at this place is medium-grained, bright pink in color, and very highly quartzose; sp. gr., 2.65. Besides the predominating pink to grey translucent quartz, there is much pinkish orthoclase which is bright surfaced, and for the most part quite fine, though occasionally the facets reach one-eighth of an inch in diameter. The mica is always sparse and, macroscopically at least, often wanting. No bedding structure whatever is visible, though strong joints occur. Thin seams of an aphanitic dark greenish-gray to black rock (2,041) traverse the face of the exposure. At the west or upper end of the gorge, the granite (2,042.20) is medium-grained, showing a grayish-white ground mass of milky quartz, mingled with a good deal of white and pink bright-faceted feldspar, and mottled with fine shining black mica. The same black seams (2,043; sp. gr., 2.73), weathering to a light earthy-green, are seen here again. These veins are very sharply defined from the adjoining granite, and have a width of 2 to 3 inches. Near the lower of the two principal leaps in the gorge, the granite (23) is medium-grained, light-gray, and highly quartzose, but here shows a distinct stringy arrangement to the fine and sparse black mica. Twenty feet below the lower fall, on the north side of the river, the granite (25; sp. gr., 2.62) contains more feldspar than usual, this ingredient appearing in abundant white shining facets. A deeply weathered crust contrasts this rock also with the more quartzose kinds.

Following Bad river northward, we find no further exposures until **Penokee Gap** is nearly reached. In this vicinity, in the southeast quarter of the northwest quarter of Sec. 14, T. 44, R. 3 W., are some large natural exposures of hornblende-gneiss, on and near the river, as also in the two large railway cuttings through the same rocks. In the southwest quarter of the same quarter-section are other Laurentian exposures. For a further understanding of the relative positions of these ledges, the reader is referred to the large detailed map of the vicinity of Penokee Gap, Atlas Plate XXIII.

Underneath the southern end of the truss bridge over the gorge of Bad river (the southernmost of the bridges shown on the map referred to) a crystalline limestone, the lowest member of the Huronian series, is in sight. Eighteen steps south of this rock, along the railroad track, is the beginning of the first cutting in the Laurentian gneiss. This cutting is about 44 steps long, with the rock 10 to 15 feet high on the eastern side. Throughout the whole length, a very marked bedding structure is apparent, some portions being even highly schistose. The dip is 73° to the southward, while the Huronian rocks a few feet off incline to the north. The strike is a few degrees south of west or oblique to that of the Huronian beds; a very satisfactory demonstration of unconformability being thus afforded. The whole face of the exposure presents a dark-colored appearance, owing to the large amount of hornblende that is present either in the original or altered form. Strong master-joints, trending north 15° west, and showing large smooth, iron-stained surfaces, traverse the rock. Less prominent joints trend at right angles to these. At the north end of the cut, the gneiss (1,405; sp. gr., 2.69) is dark gray, speckled with white, compact, minutely crystalline, and without subordinate lamination, but showing distinct layers a few inches in thickness. The mineral ingredients apparent are: gray *quartz*, which predominates; very fine faceted bright *feldspar*, abundant; black *hornblende* (and probably mica), very fine, and scattered throughout, producing the dark color. Little strings and minute bunches of pyrite are frequently visible. The weathered surface is pinkish-white. Seven steps farther southward come in 3½ feet, in very distinct layers, 1 to 6 inches wide, of a glistening black kind (1,406; sp. gr., 2.92), in which there is present a great deal of fine black mica (biotite). Long blades of apatite crowd both the quartz and feldspar of this rock, as seen in the thin section. Next to this is a band, 2 feet wide, of a light gray highly quartzose kind (1,407; sp. gr., 2.55), which is exceedingly fine-grained and compact, with a conchoidal fracture, and is ribboned with light reddish-stained seams. This rock has almost the appearance of a quartzite, contrasting much with the surrounding darker-colored material. Under the microscope, it is seen to be chiefly made up of much rounded quartz granules, which run from .037 m. m. to .140 m. m. in diameter. In the gray portion of the rock these are mingled with numerous biotite-scales (.09 to .15 m. m. long), most of which lie parallel to the schist plane. In the pink or reddish bands, the entirely separated and very much rounded quartz grains are imbedded in a pink mossy matrix, composed chiefly of hardly translucent orthoclase.

Next to the foregoing are ten inches of dark-green, greasy-surfaced chloritic schist (1,408; sp. gr., 2.72), with interlocking laminæ. This is really only a highly altered form of the normal rock (1,411) of the cutting; the unusual amount of alteration being due, probably, to the close lamination and high content of hornblende. The slice shows a greatly predominating amount of a greenish-brown, scaly to highly fibrous material, which in part is feebly dichroitic, but is for the most part without dichroism, and is evidently chlorite, in different stages of alteration from hornblende. A little quartz is contained. Beyond, to about 17 steps from the beginning, are further alternations of the light-colored quartzose kind (1,407) and the green chloritic schist (1,408). At 18 paces are thin layers (1,409), made up of light pinkish-gray, highly quartzose seams, and very thin laminæ, composed almost entirely of lustrous black hornblende, the leaves of which reach 5 m. m. in length. Beyond, again, comes in the comparatively unaltered blackish gneiss (1,410, 1,411; sp. gr., 2.75 to 2.78), which seems to be the normal rock of the ridge. A large sample (1,411) from this place is described in detail by Mr. Julien in Appendix B., to which reference is made. It is only necessary to state here, that it is a nearly black, rather fine-grained, compact rock, finely banded with seams which are alternatingly rich in quartz and hornblende; that it consists essentially of orthoclase, plagioclase, quartz, hornblende, chlorite and magnetite, and is properly a chloritic hornblende-gneiss, the chlorite being merely a pseudomorphous alteration-product of the hornblende. Towards the south end of the cutting the quartzose seams often predominate over, and are wider than those rich in hornblende, and the rock consequently takes on a lighter hue.

It is evident enough that all of the rock at this place is essentially the same, the variations being due either to the predominance of one or other ingredient in different layers, or to the amount of alteration, which is, naturally, greatest at the northern end of the cutting, or near the surface of the northern slope of the hill.

Passing directly west from the cutting just described, Bad river is met at about 100 steps, just at a sharp bend. On the opposite or western side of the river, the same hornblendic gneiss rises precipitously from the water, forming a rocky knob over 50 feet high, the exposures covering an area of about 100 paces from east to west, and 50 paces from north to south. In outward appearance the rock from all portions of this knob (1,465, 1,466 — sp. gr., 2.96 — from the foot of the cliff on the river, at about 35 paces west of station 115, Atlas Plate XXII; 1,462, 1,463, 1,464, respectively from 40 paces south of, 15 paces south of, and at, station 112) is quite uniform and essentially the same as the normal rock in the cutting, the only apparent difference being a more uniform black color, due to a greater amount of the hornblendic ingredient. The slice (1,466) bears out the conclusions drawn from the outward appearance of the rock, showing to the naked eye the dark-colored ingredient, in scales up to 0.5 and 2 m. m., as the predominating one. With the loupe this constituent is seen to be partly deep-green (chlorite) and partly brownish-green (hornblende). Under the microscope (×75), the hornblende is in pale brownish-green plates of very irregular shape, often confusedly intermingled with each other, and with the chlorite scales, which are very highly dichroitic and show the prismatic cleavage distinctly. The chlorite has a bluish-green color, and shows generally some traces of the dichroism and cleavage of the hornblende from which it is altered. Orthoclase is the next ingredient in abundance, while the plagioclase and quartz are much less plenty than in the rock examined by Mr. Julien. Minute fissures 0.1 m. m. wide traverse the slice, and in their neighborhood a considerable quantity of red ochreous matter prevades the feldspar to a distance of 1.5 m. m. All of the rock of these ledges is very distinctly gneissoid, with a nearly E.-W. strike, and a dip of 85° S. A westward continuation of the same hornblendic gneiss is seen in a small knob 30 paces north of station 106, where it is very fine-grained, and compact, with a uniform dark-gray color (1,461).

South of the railway cutting above described, another, at a distance from the first of 110 steps, measured along the track, represents a more southern belt of rock. This cutting is 44 steps long, with rock on the east side rising to a height of 3 feet, and showing a dip of 76° S., the strike being the same as in the more northern cutting. The rock is almost essentially the same. At the north end of the cutting it (1,413) is very finely banded light and dark, and is the same as the rock examined by Mr. Julien (1,411). At 8 steps further south the grain is very much finer (1,414; sp. gr., 2.79), the slice showing the ingredients quite uniformly intermingled, with a predominating amount of much rounded grains of quartz and orthoclase. At 18 paces the rock (1,415; sp. gr., 2.83) becomes soft and highly schistose, the layers showing a greasy, shining, brownish-green surface, due to a large proportion of partly altered mica, which is arranged along certain laminæ. Under the microscope the principal ingredients are seen to be fibrous hornblende, for the most part somewhat altered, and yellowish-brown mica. Fine magnetite is scattered through the section. At 38 paces, in the normal, compact, black rock, are white bands, 1 to 1½ inches wide, composed chiefly of very fine-granular quartz (1,416).

At 18 paces beyond the end of the exposure in the cutting, the normal dark-colored gneiss is seen, some yards east of the track, interbedded with light-colored, very quartzose seams several feet in width. The rock of these seams (1418) is pinkish-gray, fine-grained, of a gneissoid texture, and composed almost wholly of grains of quartz and pink and white orthoclase .04 to .4 m. m. in diameter. Under the microscope the orthoclase is milky from partial alteration, and a few plagioclase grains are seen.

For 40 paces further the rocks are concealed, and then 30 feet of the dark-colored gneiss, (1419) with light-colored bands, (1426) show in a "borrowing" to the east of the railroad.

At the quarter post on the west line of Sec. 14, in the bed of a small stream, are large ledges of a medium-grained pinkish granite. (1400).

West of Bad River. In **T. 44, R. 4 W.**, several granite ledges have been noted. Pinkish-weathering granites occur on the head-waters of the Brunschweiler river in sections 27 and 28. At the southwest town corner (S. W. cor. Sec. 31), are ledges of a dark gray, fine-grained, compact, gnessoid rock, which microscopically shows predominating gray quartz, fine white feldspar, some dark-colored mica, and probably also hornblende.

Several ledges on the west line of Sec. 30, T. 44, R. 4 W., show a rather fine-grained pinkish-gray gneissoid granite, with very fine-scaled black mica arranged in lines.

In the vicinity of the **falls of the Maringouin**[1] in the N. W. qr., Sec. 23, T. 44, R. 5 W., are a number of exposures. The falls, which are about 50 paces south and 500 west of the northwest corner of Sec. 23, are themselves over granite; and the same rock shows for some distance below on the south side of the stream, whilst above, the course of the river is through granite for about a quarter of a mile. At the top of the cliff at the falls, on the west bank of the river, the granite (88, sp. gr., 2.62) is medium-grained and flesh-colored, the principal ingredients being apparently quartz and pinkish orthoclase, with which are associated some whitish feldspar and blackish-green mica

[1] As Mr. C. E. Wright has made a detailed examination of this vicinity in his investigation of the iron bearing rocks west of Penokee Gap, I have made no microscopic examination of the granite here exposed.

arranged in bunches. The rock is without sign of gneissoid arrangement of the ingredients. Specimens taken from half-way down the cliffs (89, p. gr. 2.76), and from the water's edge (90), show the same characters, but contain a little greenish chlorite. Twenty rods above the falls the rock (91) contains an abundance of light-colored shining mica, as well as a fine dark-colored ingredient. Forty rods above the falls the granite (92) is medium-grained and compact, having a white-and-black-mottled appearance. The white ingredient is largely orthoclase, whilst the black is in part hornblende. Pyrite, in minute bunches, is scattered through the rock. One-fourth mile above the falls the granite (93) is the same as that at the falls, showing, however, some tendency to a gneissoid structure. The micaceous ingredient appears to be in part chlorite.

In the N. E. quarter of Sec. 21, and the N. W. quarter of Sec. 22, are ledges of granite, and near the common northern corner of these sections the southern beds of the Huronian System are exposed. The granite here is brick red, mottled with greenish-black, rather fine-grained, and consists chiefly of red cleavable orthoclase, with black hornblende and some quartz.

East of Bad River. In the western part of **Sec. 11, T. 44, R. 2 W.**, 1000 steps south and 125 steps east of the northwest corner of the section, and in the immediate vicinity of ledges of the crystalline limestone and white quartz, which form the two lowest members of the Huronian, is a low exposure (30, of Atlas Plate XXIV) of a dark gray, fine-grained, compact, gnessoid rock (2072; sp. gr. 2.82), in which are perceptible, macroscopically, fine granular quartz, very fine-faceted glassy white feldspar, and large flaked, black, shining hornblende, the single blades of which reach sometimes a length of an eighth of an inch. The hornblende is especially abundant in certain laminæ, some of which appear almost wholly composed of it. The thin section of one of the laminæ rich in hornblende shows to the loupe a white cloudy background thickly strewn with green flakes, many of which are one-twentieth inch in length, and little white translucent spots (quartz). Under the microscope ($\times$ 88) the green scales are seen to be chiefly hornblende, with very strong dichroism from pale greenish-brown to deep bluish-green, and with plain prismatic cleavage. Some of the scales have a feeble dichroism, deeper green color in ordinary light, and lack the cleavage. These are evidently chlorite, from which to the hornblende there is every degree of alteration. Other thinner and smaller scales of chlorite are scattered through the ground-mass, which appears to be chiefly altered orthoclase. The clear grains of quartz and rare scales of muscovite complete the list of constituents.

Two hundred steps east of the northeast corner of Sec. 4, T. 44, R. 1 W., a number of ledges of rock are found crossing the section line. These finally end, at 250 steps east of the corner, in an east-facing precipice 50 feet in height. The rock of these ledges is apparently quite uniform (2,085, 2,086), and presents a massive appearance, being entirely without apparent bedding or lamination lines. Macroscopically, the rock is dark greenish-gray, and fine-grained, but highly crystalline. Glistening facets of gray feldspar and black hornblende are distinguishable. A brownish-white earthy crust, one-sixteenth of an inch deep, covers the exposed surfaces. The thin section shows hornblende as the main ingredient, in blades more or less shattered, and often showing very plainly the prismatic cleavage. The blades often reach .5 m. m. in width. Much altered orthoclase, rare quartz, chlorite altered from the hornblende, and small muscovite blades are the other constituents.

On and near **Potato river**, Sec. 19, T. 45, R. 1 E., are quite large exposures of fine-grained, greenish and black Laurentian rocks, which, in part at least, are highly schistose and altered chloritic gneisses, analogous to those on Bad river. On the river, the southern edge of the Laurentian exposures is 560 paces north of the southeast corner of

Sec. 19, and they continue, with some interruption, to 765 paces; where, on a steep cliff-side rising 75 feet from the river, the exact contact with the siliceous schists of the Huronian is most beautifully shown. The greenish Laurentian rocks are in part massive and in part highly schistose, the schistose planes striking N. 60° E., and dipping south 55°–60°. On all of the Laurentian exposures the rock is exceedingly fine-grained to aphanitic, often quite soft, has a greenish cast, and weathers with a light-greenish earthy surface. A specimen (2,127; sp. gr., 2.78) taken from near the junction with the Huronian slate, is greenish-gray, schistose, quite soft and very fine-grained, but showing under the loupe a few scattering crystals of hornblende. Under the microscope, the slice shows scattering and much broken crystals of hornblende, which have a length of .2 to .4 m. m., show the cleavage very distinctly, and lie in every direction. In and about these, magnetite, or other black opaque mineral, is abundant, becoming especially thick in places where the hornblende crystal has been almost wholly decomposed. The predominant mineral of the rock is chlorite, which, in very fine interlacing scales, forms the greenish ground-mass in which the foregoing are imbedded. In this ground-mass, interlocking with the chlorite scales, are also many of only partially altered hornblende. The quartz and feldspar are quite subordinate.

The same rock exactly (2,126), shows where the section line climbs the steep eastern bank of the river, at 720 paces north of the southeast corner. At 560 paces north of the corner, and 10 west of the section line, a ledge with a width from north to south of 30 paces, rises precipitously from the east bank of the river. At the northern end of this ledge the schistose structure is highly developed, and the rock (2,123) is the same as before. Further south on the cliff face, dirty-pinkish amygdules of calcite one-sixth to one-eighth of an inch in length, are abundant, and the weathered surface of the rock has a curiously pitted appearance, from the removal of the amygdules. At the southern end of the exposure the rock is without the schistose character, but is otherwise evidently the same.

Besides the above described exposures, there are other small ones on the south line of the section running from 94 to 134 steps west from the southeast corner, and from 65 to 105 steps west of the river. The rock here (2,122; sp. gr., 2.71) is ill-exposed, and no reliable strike lines were obtained. It is very fine-grained, dark gray, and has a slightly shimmering surface, from abundance of fine mica scales. The texture is schistose, and the weathered surface dirty greenish-white. U. M.,[1] it is seen to be quite different from the more northern exposures on the Potato, just described. The main ingredient is quartz, in rounded grains, many of which are .02 to .1 m. m. in diameter, and are porphyritically imbedded in a finer brownish ground-mass, in which the mica is a principal constituent. A few crystals of plagioclase are contained.

Sixty-five steps north of the southeast corner of **Sec. 1, T. 45, R. 1 E.**, is a low ledge of chloritic gneiss, striking S. 80° W., and dipping 50° N.

At the falls of the **Gogogashugun river,** in the southern part of Sec. 27, T. 46, R. 2 E., the Laurentian exposures are large and interesting. The Laurentian gneiss shows from a short distance north of the center of the south line of the section, to the junction with the Huronian at 200 paces north. The following description is from notes taken by Professor Chamberlin at this place: "The gneissoid rock, where seen near the junction with the schist, is for the most part of a greenish cast, but in the vicinity developes the more usual gneissoid appearance. It closely resembles the uppermost Laurentian at Penokee Gap. Quartz, feldspar and a green mineral are the main constituents. Its dip, at the junction, is 49°, N. 23° E.; strike, N. 67° W. It is unquestionably Laurentian, as it was seen in actual contact with the siliceous schists, which dip from 45° to 79° N. W. and strike N. 55° E. A hand specimen showing the two was obtained." This

[1] U. M., signifies "under the microscope."

specimen (2,202; sp. gr., 2.75) shows a dark greenish-gray, very fine-grained rock, the ingredients being indistinguishable macroscopically, though fine shining facets can be distinguished with the loupe. The slice is light gray, thickly streaked with green, the schistose structure being highly prominent. U. M., fine grains of quartz and orthoclase form the ground-mass. The grains reach sometimes a diameter of .025 m. m., but for the most part are not over .009 to .01 m. m. Very fine-scaled chlorite is the chief admixture, but here and there may be seen a shattered hornblende blade of some size, whilst many smaller hornblende fibres are seen throughout. Magnetite occurs in numerous small, irregular grains, and the whole rock is very close to that seen at the same horizon on the Potato.

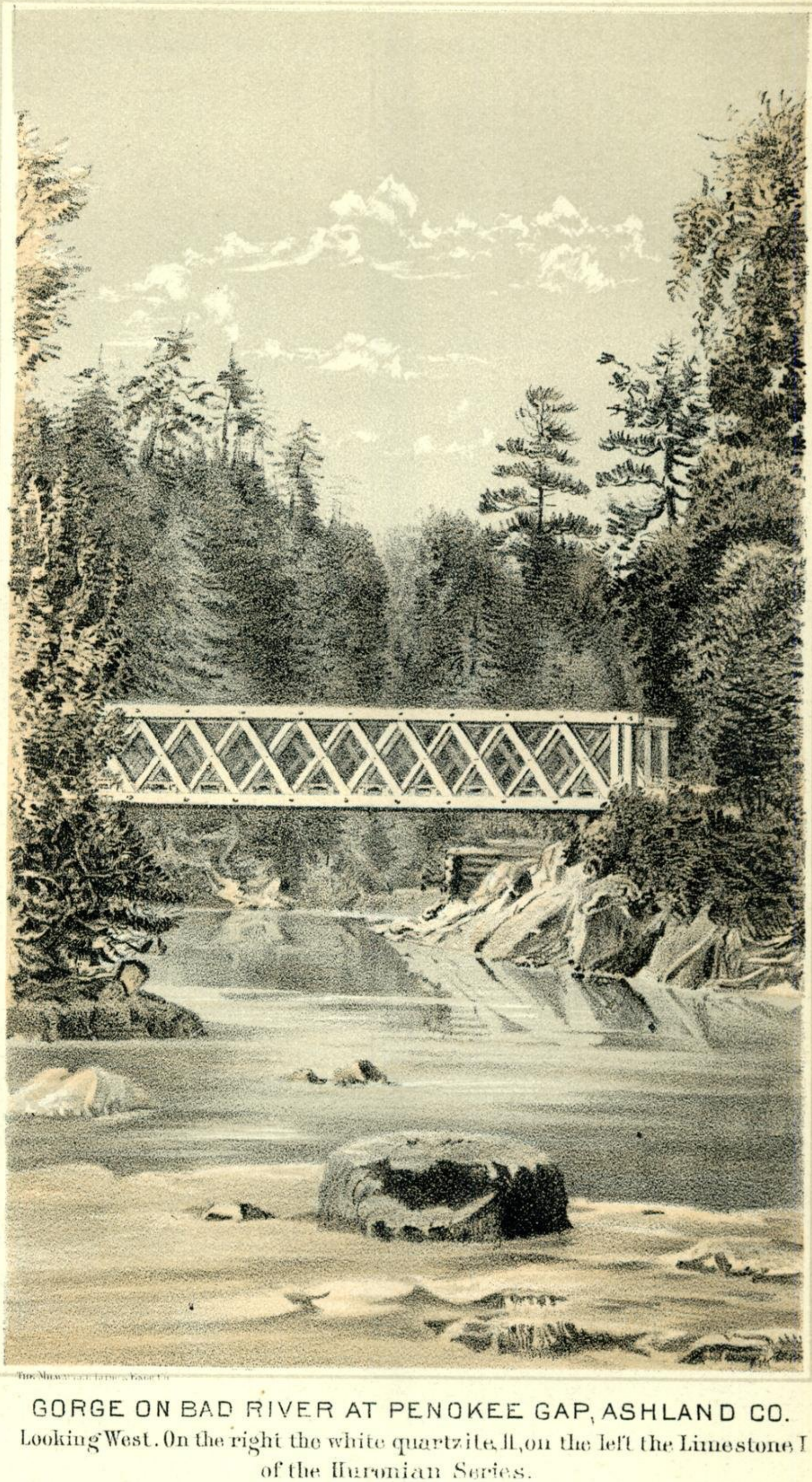
CHAPTER III.

THE HURONIAN SYSTEM.

SURFACE EXTENT AND TOPOGRAPHICAL FEATURES.

The Huronian rocks lie together in a narrow belt, from half a mile to three miles in width, which stretches entirely across the district, from the west line of T. 44, R. 5 W. to the Michigan boundary at the Montreal river, in Secs. 24 and 13, T. 46, R. 2 E. The total length of the belt in this distance is about forty-six miles. The wider portions are towards the east, the western part narrowing in places to as little as a mile or even half a mile in width, as in the sections just south of Bladder lake. The total area underlaid by these rocks is just about one hundred square miles.

For a more definite idea of the position and extent of the Huronian area in the several townships crossed by it, we may begin at the western limit of the district, on the west line of T. 44, R. 5 W. Here, in sections 18 and 19, we find the belt trending north of east, with a width of about a mile. The same course and width are preserved, with some minor bendings, until the Maringouin river is reached, about half way across the township. Now begins a gentle curve, with the convex side towards the north, the general course of the formation being thus gradually brought around to the southeast, in which direction it continues to Secs. 20 and 29, T. 44, R. 4 W., where the width is about a mile. The course is next northeasterly to the southeast quarter of Sec. 14, T. 44, R. 4 W., just south of Bladder lake, where the width is contracted to as little as half a mile, the southernmost beds of the Huronian lying within this distance of large ledges of the coarse gabbro which constitutes the southern portion of the Keweenawan series. On the east line of Sec. 14, an abrupt turn to the southeast is made, and in the north part of Sec. 24, still another, the formations now trending some 60° east of north. This direction continues, the width at the same time rapidly increasing, through the western part of T. 44, R. 3 W. South of the eastern end of English lake begins a nearly due east course, which continues for some six miles, or half way across T. 44, R. 2 W., the width increasing from two to two and a half miles. In sections 3 and 10, and parts of the adjoining sections of the latter town, an exceed-



GORGE ON BAD RIVER AT PENOKEE GAP, ASHLAND CO.

Looking West. On the right the white quartzite, II, on the left the Limestone I of the Huronian Series.

ingly abrupt turn to the northeast is made, and from here the course is N. 66° E. to near the east line of T. 45, R. 1 W., and thence N. 60° E. to the Michigan boundary at the Montreal river, in the eastern part of T. 46, R. 2 E., the breadth of the formation in all this portion of its course, running from two and a half to three miles. Minor undulations occur in this portion of the belt, but no such abrupt turns as observed in its western extension.

The southern boundary of the Huronian, or its line of junction with the Laurentian, is a very sharply defined line, on account of the bold topography and frequent rock exposures of the Penokee Range. Even in that portion of the Huronian belt where the Penokee Range disappears, and the rocks are entirely concealed by drift and swamps, the magnetic attraction exerted by the iron-bearing member of the formation, one of its lower layers, serves to fix very closely the southern boundary. On the accompanying atlas plates, this boundary line is laid down so accurately, and the facts upon which it is based are there detailed so fully, that no further explanation is needed here.

In addition to the facts given on the maps and in the details of the following pages, it is merely necessary to say here, with regard to the northern boundary, that it does not follow the strike of the Huronian beds, but cuts across them in a more or less irregular way. The width of the Huronian does not vary on account of the thickening or thinning or disappearance of any of its subordinate layers, but the wider portions include higher layers, which are wanting in the narrower portions. The irregularity, then, of the northern boundary is due to a non-conformity of the overlying rocks with the Huronian. It should also be said that these overlying rocks, chiefly gabbros, are of an igneous origin, and have certainly, in some places, and quite possibly, also, in others not yet recognized, penetrated the Huronian, producing peculiar irregularities in the line of junction.

The main topographical features of the Huronian belt have already been given in another connection. It is only necessary to notice here somewhat more definitely the relation existing between the geological structure of the series and the topography of the strip of country underlaid by it. The Huronian series includes a succession of beds, always markedly schistose and at times highly slaty, which are, for the most part, inclined at a high angle to the northward. At the base or southern side of the belt are narrow layers of crystalline limestone and quartzite, succeeded by a broad band of siliceous slate, some 400 feet in width, above which there is again a much broader band, generally as much as 800 feet wide, of magnetic and specular schists. Above these again is a series of alternating layers of mica slates, diorites, quartz slates and quartzites — the latter comparatively inconspicuous — which reach a thickness of several thousand feet. A close connection may be traced between the nature of these beds and the features of the surface.

The existence of the Penokee Range, which marks the lower side of the Huronian belt for the greater part of its extent, and which has already been described in some detail, is determined by the broad bed of magnetitic quartzites and siliceous magnetic and specular schists above referred to. These, by virtue of the superior hardness and power of resisting chemical action conferred on them by their siliceous ingredient, have remained standing, while the softer beds to the north have been worn, for the most part, into deep valleys, in which streams run parallel to the trend of the Penokee Range, being impelled to their courses by the strike of the underlying rocks. In places, the more massive diorites and quartzites of the northern portion of the series rise from the valley in abrupt ledges, but they never constitute a continuous ridge like the Penokee Range, on account of their smaller breadth and inferior resisting power. On the northern side of this valley the Huronian beds often extend well up the river on to the Copper Range, being protected here by the massive rocks of the Keweenaw series, which bound them on the north. The south slope of the Penokee Range, again, is made up of the siliceous schist which underlies the harder rocks that form the body of the range, and, being itself generally a quite soft and easily eroded material, the southern slope is often precipitous, or at least very bold. This is especially true of the middle portions of the range, from a few miles west of Bad river nearly to Tyler's Fork. Further east this layer becomes more quartzitic and harder, and forms itself the body of the ridge, the overlying beds at the same time losing their comparatively great resisting power by a change in composition. In some places in the eastern extension of the Huronian belt, both the siliceous schist and the overlying beds are softer than the Laurentian below, and the crest of the ridge is made up of rocks of the latter series.

A variation in the degree of northerly dip of the beds of the Huronian has also very measurably affected the surface features. From a point on the ridge a few miles west of Bad river to the Montreal, the angle of dip is always very high, 55° to 75°; while further west it lessens to 45°, 35°, 25°, and even to 20° or 15°. In these places, the result is a longer front slope to the ridge, and a very steep, frequently bold and precipitous southern face, made up usually of heavily bedded quartzitic iron ore overlying the siliceous schist, which now loses its prominence and forms only the foot of the southern face. The entire absence of the Penokee Range in T. 44, R. 4 W., is perhaps to be attributed in part to a lessening in dip, though probably chiefly to a change in the character of the lower layers of the series.

LITHOLOGY AND STRATIGRAPHY.

The Huronian series consists of a succession of more or less highly schistose to slaty beds, which reach a total thickness in the widest part of nearly 13,000 feet. These layers all stand inclined at a high angle to the north, and stretch across the country in outcrops generally parallel to the southern limit of the formation, some of the more prominent ones preserving their characters across the whole width of the district, a distance of about forty-five miles. Inclining, as they always do, to the north, these beds are without folds, and the series is only limited in that direction by the overlapping of masses of igneous rocks belonging to an unconformable system — the Copper-bearing or Keweenawan[1] series — the unconformity being one, however, recognizable only on a comprehensive survey of the region, and not by any observed contact between the two formations. The absence of any folds in so highly altered and inclined strata is easily explained, if we regard them as forming part of a great bend underneath the trough of Lake Superior and reappearing on the north side of the lake with a reversed inclination. These points have been brought out on a previous page, and need only to be alluded to here.

The degree of northward inclination of the Huronian beds is, for most of the course of the formation, from 55° to 75°; most usually between 65° and 75°. To the west of Sec. 16, T. 44, R. 3 W., however, the degree of inclination is nearly always much less, becoming at times as low as 20°. The bends in the course of the formation have already been noted in a general way. Some of these are exceedingly abrupt, as, for instance, on Sec. 10, T. 44, R. 2 W.; at the crossing of the creek in sections 8 and 17, T. 44, R. 2 W.; and at several places in the western extension of the formation. These bends are well marked out in the rock exposures, and are noted in detail on the accompanying maps.

At the passage of Bad river, the strata are crossed by a fault, trending about N. 17° W., the layers on the west side of the fault being thrown 800 feet to the northward of those on the east side; or, regarding the throw as a vertical one, the western side has been elevated or the eastern depressed a vertical distance of over 1,700 feet; the apparent lateral throw, on this supposition, being explained by the inclined position of the strata. This fault is marked in the topography by a corresponding

[1] See Part I of this volume.

set-off in the Penokee Range, which on the west side of the river is well to the northward of its position on the east side. It is also well marked by large rock exposures on either side, and also by an abrupt break in the line of magnetic attraction caused by the magnetic belt of the formation. The facts with regard to it are all detailed on Atlas Plate XXIII, and also in the descriptions of the following pages.

The following tabulation indicates the succession of layers of the Huronian series in the vicinity of Bad river, so far as made out, with the average thickness, surface breadth, and other prominent points of each layer. Several of the lower layers, including a total thickness of some 1,500 feet, have been traced across the entire width of the district. The higher layers, on account of their comparative softness and susceptibility to chemical changes, have been for the most part deeply eroded, and are, moreover, largely buried beneath accumulations of drift materials, so that the exposures are comparatively few and distant, and the task of making out the succession becomes much more difficult. On the general map of the district, Atlas Plate XXII, the upper portions of the Huronian are marked by one color, and the statement is made in the legend that the layers making up this portion of the series are not constant in their characters. This statement is broader than it was meant to be, and, moreover, this map was drawn before the study of the collections and notes made in the field was completed. It is entirely true that some of the layers are composed in their western extensions of rocks differing considerably from those composing them across most of the district; but had the printing of this map been delayed a few months, an additional color could have been inserted for the great mica-schist member, XXI, lying at the top of the series, for the whole distance from the Montreal river to English lake, beyond which, to the west, it is cut out by the overlying Keweenawan gabbro. The alternating quartz-schists and black slates, XIV to XVIII, have also been recognized from Bad river eastward for twenty miles, and we cannot doubt that a removal of the overlying drift would disclose nearly, if not quite, as constant layers in the upper portion of the series as below.

The numbers of the following synopsis are those used on the plates of the atlas.

Synopsis of the Stratigraphy of the Huronian of the Penokee Region, Wisconsin.

Formation.	*Average thickness. Feet.*
I. Tremolitic crystalline *limestone*	90
II. (A) Arenaceous white *quartzite*, often brecciated, 35 feet; (B) *magnetitic quartz-schist* 5 feet	40

Synopsis of Stratigraphy of the Huronian of the Penokee Region — (continued).

Formation.		*Average thickness. Feet.*	
III.	*Siliceous slaty schists;* including quartzite, "argillitic" mica-schist, and novaculite; all having much quartz, and none ever showing any amorphous material	410	Palms
IV.	*Magnetic belt;* including: *(a)* banded magnetic quartzite — gray to red quartzite, free from or lean in iron oxides, banded with seams, from a fraction of an inch to several inches in width, of pure black granular magnetite, only rarely mingled with the specular oxide; *(b)* magnetitic quartzite. the magnetite in varying proportions, pretty well scattered throughout, and mingled with the specular oxide in proportions varying from nothing to a predominating quantity; *(c)* magnetitic quartz-slate, the magnetite pervading the whole, and mingled with the specular oxide as before; *(d)* slate like *(c)* but largely charged with tremolite or actinolite; *(e)* arenaceous to compact and flaky quartzite, free, or nearly so, from iron oxides; *(f)* thin-laminated, soft, black magnetitic slate; *(g)* hematitic quartzite, the iron oxide the red variety; *(h)* garnetiferous actinolite-schist, or eclogite; *(i)* diorite, which is restricted to the western end of the Huronian belt. Kinds, *(a)* to *(d)*, all carry much pyrolusite, or other manganese oxide. These varieties have no persistent stratigraphical arrangement, and are named here in order of relative abundance. Total thickness, about	780	Ironwood
V.	*Black feldspathic slate;* consisting of orthoclase grains imbedded in a paste of biotite, pyrite, limonite and carbon	180	Tyler
VI.	Unknown, always drift-covered	880	
VII.	Dark gray to black, aphanitic *mica-slate,* having a wholly crystalline base of quartz and orthoclase, with disseminated biotite scales	120	
VIII.	Unknown, but probably in large part the same as VII	290	
IX.	Chloritic, pyritiferous, massive *diorite*	150	
X.	Black, aphanitic *mica-slate,* like VII	25	
XI.	Covered, but probably mica-slate	280	
XII.	*Black mica-slate;* aphanitic; at times chiastolitic	225	
XIII.	Chloritic *diorite-schist*	35	
XIV.	*Black mica-slate,* like XII, often chiastolitic	375	
XV.	to XVIII. Alternations of black *mica-slates,* with *quartzites* and quartz-schists	675	
XIX.	*Greenstone-schist;* aphanitic; the hornblende and plagioclase much altered	260	
XX.	Covered, but probably like XXI	525	
XXI.	*Mica-schist;* from aphanitic to medium-grained; including bands of light-gray quartz-schist, the mica becoming subordinate; all varieties having a background of quartz; the mica wholly biotite; penetrated by veins and masses of very coarse, pink to brick-red biotite granite; total on Bad river, 4,960 feet. Seen further east, higher layers, 2,500 feet; in all	7,460	
	Total	12,800	

The most complete section of the Huronian thus far obtained is in the vicinity of Bad river, in sections 2, 11 and 14, T. 44, R. 3 W., where the exposures are numerous, though even here quite large unfilled blanks remain. All but the highest layers in the series are represented in the Bad river section, and the investigations have there been carried into greater detail. In the following pages, therefore, the several layers, which are taken up in order, beginning with the oldest or southernmost, are first described as they are seen in the Bad river section, after which they are traced as far east and west as possible. West of Bad river, the detailed examination of the lower layers of the iron-bearing series was undertaken by Mr. C. E. Wright, and the detailed descriptions of the various ledges will be found in his report in a subsequent part of this volume. This portion of the series having, however, been examined by my party in the preliminary reconnoissance of the first year of the survey, I have given the prominent facts with regard to each of the layers in their western extensions for the purpose of comparison.

In referring to the detailed descriptions of the following pages, the inquirer is requested to have before him the several Atlas Plates accompanying this report. These maps include, besides a general map of the district, others, on a large scale, giving the details of the Huronian series.

Formation I. Crystalline Limestone.

This rock, a tremolitic crystalline limestone, forms the lower layer of the Huronian wherever it is seen. The exposures are somewhat distant from one another, and in places it is undoubtedly absent, the underlying formation coming into contact with the higher beds. Nevertheless, the limestone appears to be persistent for a large part of the whole length of the Huronian belt. The layer is always a thin one, probably never exceeding a width of 100 feet or a thickness of 90 feet.

On Bad river, in the vicinity of Penokee Gap, northwest quarter of Sec. 14, T. 44, R. 3 W., the limestone forms the southern wall of a narrow gorge through which the river flows in an easterly direction. More exactly, this exposure is at about 550 paces[1] south and about 800 east of the northwest corner of Sec. 14, or midway between stations 122 and 123 of Atlas Plate XXIII, and only 18 paces north of the Laurentian gneiss exposed in the railway cutting described on a previous page. The limestone shows along the river for a distance of about 75 feet, and has a width across the strike, which is about 5° north of east, of some 36 feet. Since the opposite wall of the gorge is formed of a hard quartzite, it appears probable that the whole width of the river should be added to the above figure. Adding also half the distance to the nearest gneiss exposure, we have a probable total horizontal

[1] 2,000 paces to the mile.

HURONIAN ROCKS.

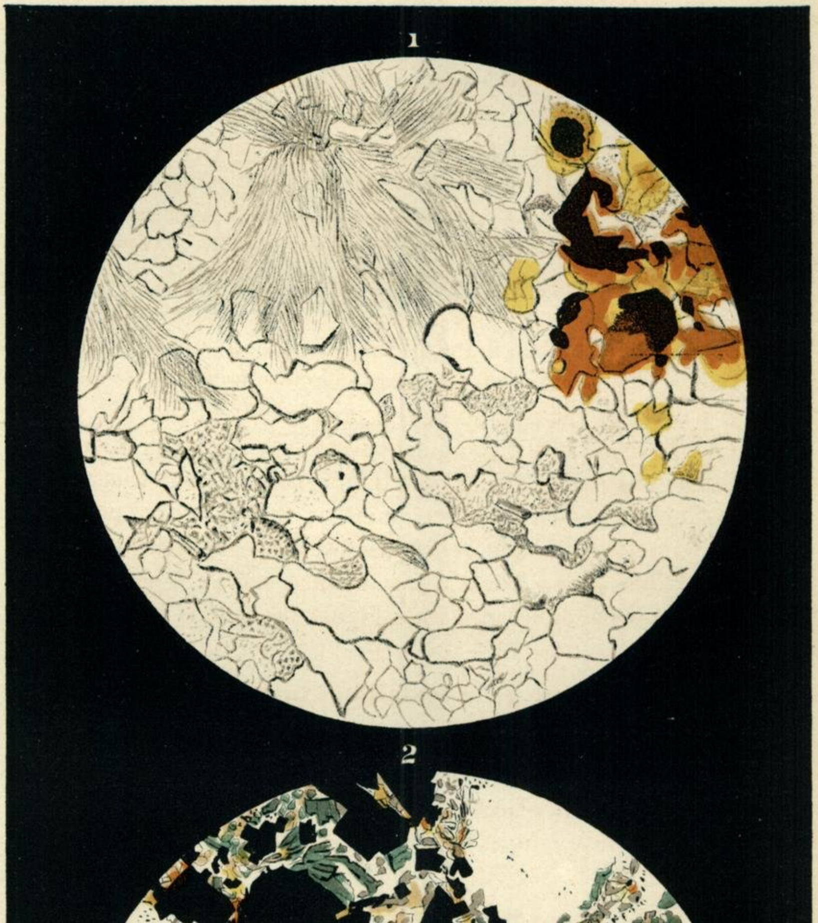


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Fig. 1. Crystalline Limestone (1421), Formation I; Penokee Gap. × 180.
Fig. 2. Magnetitic Schist (1455), Formation II B; Penokee Gap. × 30.

width of about 75 feet, which corresponds, with a dip of 65°, to a thickness of about 68 feet.

As exposed at this place, the limestone (1421; sp. gr., 2.82) is light bluish-gray, and finely crystalline to aphanitic, showing numerous exceedingly minute glistening particles of pyrite, which are, in places, represented by ochreous spots. The weathered surface is a dirty brownish-white, with a raspy feel, and is traversed by numerous minute furrows, due to the dissolving out of seams of calcite. A partial analysis of this rock by Mr. E. T. Sweet shows: calcium carbonate, 50.52; magnesium carbonate, 33,41; iron, 1.19; insoluble, 13.85; undetermined, 1.03= 100. Of the undetermined portion, at least half is probably sulphur belonging to the pyrite present. In Mr. Julien's report, Appendix B, is given an account of the microscopic characters of this rock, and no further description is needed here. It should be said, however, that Mr. Sweet's analysis, the results of which have since been confirmed by a further test, prove that either many of the grains are those of dolomite, or that the calcite is a highly magnesian variety. In Fig. 1, Plate XIII A., I have given a sketch of a section of this rock as it appeared under a power of 180 diameters. The drawing serves to show the main features of the rock, viz.: the much rounded and irregularly shaped calcite; the isolated blades and feathery tufts of tremolite; and the particles of pyrite surrounded by ochreous matter resulting from their decomposition.

East of Bad river. The limestone is generally concealed, eastward of Bad river, beneath the detritus at the foot of the southern slope of the Penokee Range, and the nature of the rock is such that it would naturally only be exposed where eroded into a cliff side. The approximate position of the eastern extension of this rock is indicated sufficiently on Plates XXIV to XXVI of the Atlas.

On the southwest quarter of the northwest quarter of Sec. 11, T. 44, R. 2 W., the limestone is seen in one or two quite small exposures (No. 29 of Plate XXIV), in the immediate vicinity of ledges of Laurentian gneiss, and of beds II and III of the Huronian. As seen here (2,077) it is white to straw-colored, somewhat arenaceous and highly schistose.

On the northeast quarter of Sec. 33, T. 45, R. 1 W., a low cliff, six feet in height, of the limestone, faces westward towards the valley of Tyler's Fork. At this place (2,087), it is quite impure, very dark gray in color, aphanitic, and studded thickly with very minute but macroscopically distinct and quite perfect octahedral crystals of magnetite.

At some point along the course of the Huronian belt between Tyler's

Fork, Sec. 33, T. 45, R. 1 W., and Potato river, in Sec. 19, T. 45, R. 1 E., the limestone and overlying quartzite run out; for at the passage of the latter stream, the exact contact between the Laurentian and III of the Huronian is seen. East of the Potato, however, they come in again, the limestone being seen as a dark colored impure rock in contact with a light gray, medium-grained granite of the Laurentian, in the north part of Sec. 15, T. 45, R. 1 E.

West of Bad river. Here the exposures of I are not very numerous, but are distributed so generally along the course of the Huronian belt as to indicate the nearly complete continuity of the layer.

There is quite a large ledge, some fifty paces in diameter, in the low ground at the foot of the south slope of the Penokee Range in the northern part of Sec. 24, T. 44, R. 4 W., where the rock is quite similar to that seen at Penokee Gap.

Through the rest of T. 44, R. 4 W., the whole Huronian series is concealed, and in the vicinity of the Maringouin river, sections 23 and 16, T. 44, R. 5 W., the Laurentian granite and III of the Huronian occur in such relative positions as to indicate the absence of the limestone. Just beyond, however, on the south line of sections 15 and 16, T. 44, R. 5 W., are several ledges of dolomitic limestone, those on Sec. 14 occurring at the base of the steep southern face of a bold ridge, 250 to 300 feet in height.

Further west no indications of the existence of this layer have been obtained.

Formation II. Arenaceous Quartzite.

This layer is also a thin one, never exceeding 50 feet in thickness, and has been traced from a mile or two west of Bad river to a point some six miles east. It is altogether probable that it extends further in both directions, but in T. 44, R. 5 W., where I is present, it is directly overlaid by III. It is quite possible, however, that the limestone in the western extension of the Huronian belt represents both I and II of the Bad river section.

On Bad river. At Penokee Gap, southeast quarter of the northwest quarter of Sec. 14, T. 44, R. 3 W., II forms the north wall of the gorge, of which I forms the south wall, as already described. The exposure has a width of 42 feet, and length along the strike of about 75 feet, and forms the northern abutment of the bridge by which the railroad crosses the river. A few steps west and north of this ledge, however, at the base of a hill composed of III, the uppermost part of II is in sight in contact with the next formation. From these data the entire width of II is placed at 50 feet, corresponding to a thickness of about 45 feet. As seen on the river side and for the greater part of its thickness, II is a pure white, non-schistose, fine-grained, highly granular to arenaceous quartzite (1422). Over much of the exposure, dark gray blotches reaching two inches across, and bounded by straight lines, give a peculiar brecciated appearance. On close inspection, these are seen to consist, like the rest of the rock, chiefly of fine granular quartz, but now mingled with a small quantity of very fine magnetite.

The uppermost portion of II, as seen in contact with III, a short distance west of the railroad track, and just on the north edge of the wagon road (Atlas Plate XXIII), has a marked character of its own, which is also recognizable for as much as a mile along the strike, and is therefore marked on Plate XXIII as a separate layer, II B. This rock (1,424; sp. gr., 2.96) has a dark color, mottled with oval-shaped, white blotches up to one-fourth and even one-half inch in length. Dark-colored, highly glassy, amygdaloid-like spots, one-tenth to one-twentieth inch in diameter, are also plentiful. The high specific gravity and dark color are explained by the very large amount of magnetite that adheres to the magnet when the rock is quite coarsely powdered. Under the microscope, the magnetite is seen to be the chief ingredient of the matrix, in which it lies in sharply and linearly bounded sections, which are often perfectly square. With it is fine granular quartz, and minute, greenish, feebly-dichroitic scales. The larger oval patches are chiefly aggregations of fine quartz grains, whilst the glassy quartz patches referred to are seen to be single individuals, most of which polarize brilliantly, and all of which are crowded with liquid inclusions. From the relations in which this quartz stands to the other ingredients of the rock, it is evidently much the most recent constituent.

Both II A and II B are well exposed at several other points in the immediate vicinity of Penokee Gap, of which the following are the most important: (1) About 100 steps west of the ledges at the railroad, just described, and between stations 114 and 115 of Atlas Plate XXIII, a mass of II A projects into Bad river, immediately at the corner of a sharp bend, the rock here (1423) having the same characters as before described. (2) At the foot of a cliff of III, forming the north side of a ravine, a short distance west of station 95, Plate XXIII, both II A and II B are in sight. At the foot of the cliff, 13 feet of II A are seen, with the characters already described. Next above it are 16 feet of II B, the lower 9 feet of which is dark greenish-gray (1,455) to nearly black, having a high specific gravity from the large content of magnetic iron, which ingredient is plainly visible macroscopically in minute lustrous octahedral crystals. Under the microscope, this rock is seen to be the same as that near the gorge of Bad river (1424) except that it is very much richer in magnetite, the crystals of which are, moreover, much more perfectly shaped in this rock. The same oval aggregations of quartz grains, single quartz patches, and greenish dichroitic scales, are visible. Fig. 2 of Plate XIII A of this volume, shows the appearance of a thin section of this rock magnified 30 diameters. The dusty clouding of the quartz is resolved with a power of 200 to 500 diameters into distinct cavities, many of which hold a bubble. The remaining 7 feet of II A grades into a grayish quartzite, and this into the thin laminated slaty schist III.

East of Bad river. East of Penokee Gap, II is seen at several points on the south foot of the ridge, but the best exposures are at Mt. Whittlesey, in the extreme northeast corner of Sec. 17, and northwest corner of Sec. 16, T. 44, R. 2 W. Mt. Whittlesey is a spur of slate (III) on the south side of the Penokee Range, at the point where the latter is crossed by the valley of a small creek.

The exposures are large, both towards the south and towards the west, on the side of the valley just named, II showing in a continuous vertical wall for several hundred feet. The whole face of the exposure presents a dirty white to brown (iron-stained) color, mottled with sharply angular dark gray to black spots, a strikingly brecciated appearance being thus produced. Dashes and lines of the darker color also occur, conforming with the general bedding of the overlying slate. On closer inspection the rock here (2,056, 2,057) is seen to be a very fine-grained, highly arenaceous quartzite or sandstone, often so friable as to crumble readily between the fingers. The darker colored patches are made up chiefly of the same material as the rest of the rock, but include also a considerable quantity of very fine magnetite.

Exactly the same rock (2,073) shows again in a small ledge, near others of I and III, and of Laurentian gneiss, on the southwest quarter of the northwest quarter of Sec. 11, T. 44, R. 2 W. (No. 28, Atlas Plate XXIV).

West of Bad river, II has been recognized at several points for some two miles along the Penokee Range, but not further west. The underlying limestone is, however, found in many places as far as the west line of the district, and, being of greater thickness than on Bad river, may include here both I and II. On Sec. 16, T. 44, R. 5 W., I appears to be directly overlaid by III.

Formation III. Siliceous Slate or Schist.

This layer is one of the best marked and most persistent of the whole Huronian series, having been traced the entire length of the Huronian belt. At the western end of the Penokee Range it is found forming the base of the southern slope. From here eastward it rises higher and higher on this slope, forming frequent bold and even precipitous exposures. At Bad river it reaches nearly, and at Mt. Whittlesey, Sec. 16, T. 44, R. 2 W., quite, to the top of the ridge. Further east it forms more and more the bulk of the range, reaching at many places east of Tyler's Fork well down the northern slope, the summit here lying within the Laurentian area. Even the isolated ridges of T. 44, R. 5 W., beyond the western end of the Penokee Range, form no exception to this rule, the siliceous schist lying in the low ground to the southward. The cause of this peculiar change is probably to be found in the fact that the overlying magnetic belt becomes less quartzitic and durable towards the east, the slaty layers of III at the same time undergoing a directly opposite change. The most frequent exposures are, however, in the western portions of the belt, where the rock is less quartzose and resistant, a fact explained by the durability of the overlying magnetic belt.

The rocks of III are somewhat various in composition and physical properties, and yet all show the characteristic highly slaty or schistose structure and common light color as compared with all other known members of the series. The most important varieties, as marked by their macroscopic characters, are (1) a thinly schistose to highly slaty, light gray to leaden gray, greasy-surfaced, and easily scratched kind; the surface often showing the sheen of mica, though generally aphanitic, and weathering to a light straw-color; (2) a kind shading into the last, but often distinctly marked from it by a lighter or darker greenish tint, greasier surface and greater softness; (3) a much harder, light gray, less thinly laminated, and more distinctly quartzose kind, grading in one direction into a light gray vitreous quartzite, and in another into the rock known as novaculite; (4) a red, shaly to slaty, and more distinctly argillaceous kind. Between these types there are all sorts of gradations, and different kinds are frequently inter-laminated. Microscopic examinations show quartz to be a constant constituent of all varieties, though in some of the more highly slaty and softer kinds evidently preponderated over by the other ingredients. In no section examined has any amorphous clay-like base been noticed. Mingled with the quartz in the softer kinds is more or less feldspathic material, and brownish mica (biotite). Many of these softer kinds would have been taken, not long since, for talcose and chloritic, but the absence of talc and chlorite in many cases is proved not only by the microscope but by analysis. The following, by Prof. W. W. Daniells, shows the composition of a leaden-gray to light greenish-gray, soft kind, from the railway cutting at Penokee Gap:

Silica	71.97
Alumina	19.21
Iron sesquioxide	4.65
Potash	0.72
Magnesia	0.97
Lime	0.38
Water	0.76
Total	98.66

Talc has not been observed in any of the thin sections examined. A chloritic ingredient occurs sparingly in some of the greenish kinds, though others more deeply tinted and not examined microscopically, may contain a larger amount. In most varieties all traces of a clastic condition have disappeared, but in a number of cases rounded grains of quartz are studded thickly over the thin section. Magnetite occurs in some sections in quite perfect octahedral crystals, but as a whole this layer is remarkable for the absence of magnetite, when compared with the other members of the series. From the overlying magnetitic schists it is generally sharply defined, a gradation having been observed at one place only.

From the facts thus given it will be seen that all the varieties of rocks of this member fall under the two classes of mica-schist, and quartzite. The former are of the kind called by Mr. Hawes,[1] in the New Hampshire reports, "argillitic mica-schist," to which they are allied in the absence of amorphous base, the abundance of quartz and fine mica, the presence of a feldspathic constituent, and of chlorite as an accessory, as well as in macroscopic characters. In view, however, of the numerous gradation varieties that exist, and of the very evident inclusion of all the varieties in one well-marked formation, it has seemed best to retain the more general term of siliceous schist, which was used in the early reports of the survey.

The horizontal width of this layer at the passage of Bad river, Sec. 14, T. 44, R. 3 W., is 450 feet, which indicates a thickness of about 410 feet. The corresponding figures for other prominent points at which the whole width is in sight, are as follows: at Mt. Whittlesey, 450 and 400 feet; at the passage of the Potato river, Sec. 19, T. 45, R. 1 E., 475 and 425 feet; at the passage of the Gogogashugun, Sec. 27, T. 46, R. 2 E.,

[1] See Geology of New Hampshire, Part IV, p. 218.

317 and 290 feet; in the north part of Sec. 24, T. 44, R. 4 W., 600 and 400 feet; and near the Maringouin river, Sec. 23, T. 44, R. 5 W., 300 and 200 feet.

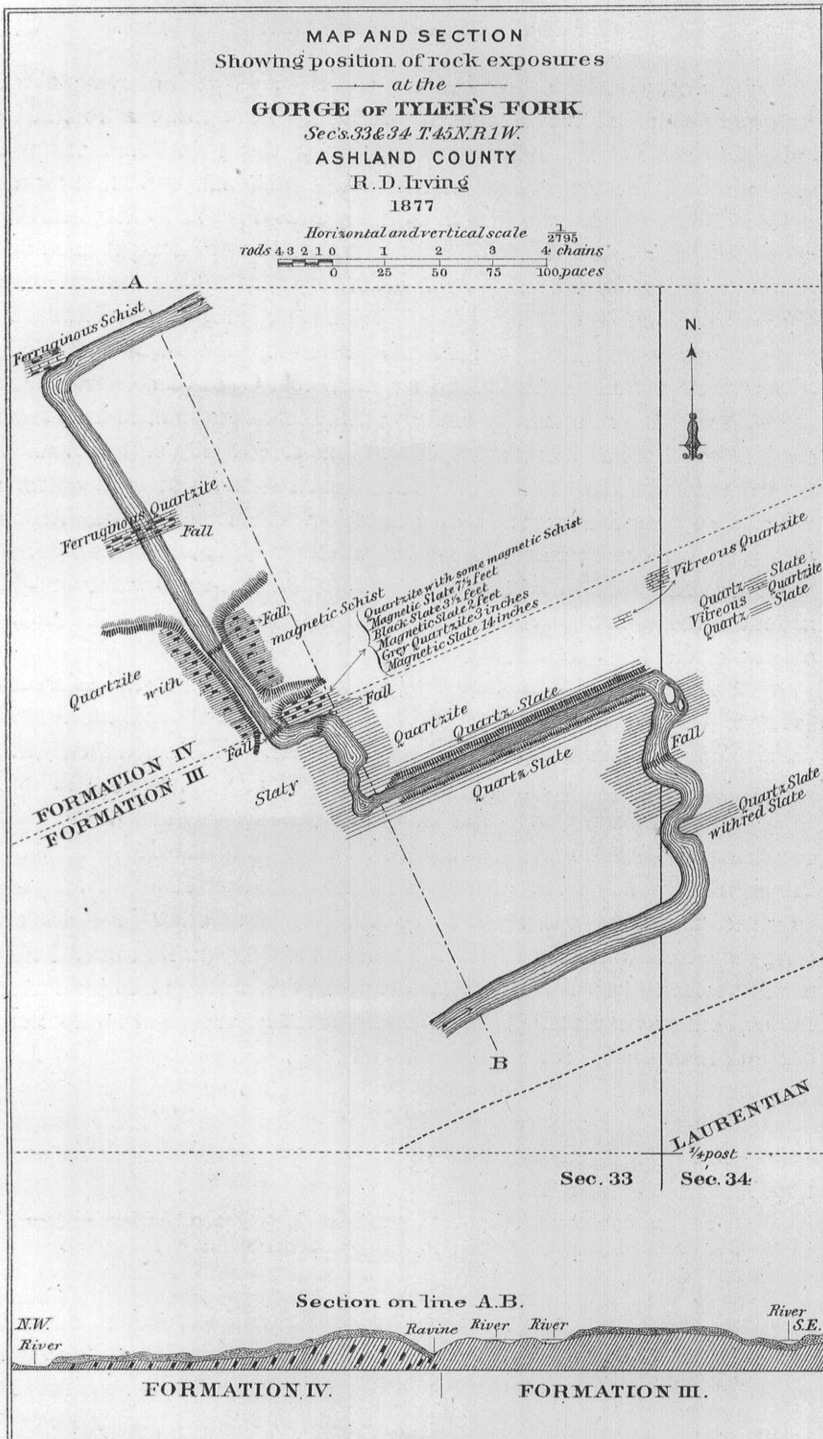
On Bad river. At Penokee Gap, the whole width of III is in sight on the west side of the fault, smaller exposures occurring on the east side. Immediately north of the magnetitic quartzite II B, described on a previous page as showing just west of the railway track, at station 123, Atlas Plate XXIII, rises a bold knob, 140 feet high, which includes the whole width of the siliceous schist, the contacts with the overlying and underlying beds being in sight on the northern and southern slopes of the hill, respectively. Through the eastern point of this knob passes a railroad cutting, and the rock is more or less completely exposed all over the hill. Immediately in contact with II B it is thinly laminated, with wavy and contorted layers, weathering to a straw color. The same layers are opened upon in the railway cutting, where the unweathered rock is seen to be light to dark grey in color, the darker colored, frequently greenish kind, alternating in very thin seams with the lighter colored and more distinctly quartzose kind. In some places a distinct greenish tint is visible, and nearly all parts show something of a sheen from the mica present. Magnetic iron is visible with the magnifier on the edges of some laminæ, and in the thin section is seen to be in perfect octahedra, sparsely scattered. All the rock in this cutting may be classed readily enough with the argillitic mica-schists, the variations being due to relative amounts of quartz and mica, and the presence or absence of chlorite (1425, 1426, 1427 and 31). The lamination throughout is very distinct, the layers running from a few lines to three or four inches in thickness. The dip is 65° to 66°. An analysis of the rock from this cutting (31) is given on the foregoing page. The rest of the hill shows essentially the same rock, except that near the junction with the overlying quartzite a distinct gradation into the latter is observable.

Another large area of slate is shown on Atlas Plate XXIII, occupying the square between stations 86, 87, 95 and 96. Here is again a hill with steep faces toward the south and east. The cliff facing towards the south shows II and II A at base. The rock here (1457) dipping 54° north, is a dark grey, hard, sharp-edged, and quite quartzose kind, in layers one to one and a half inches in thickness. The sheen of finely scaled mica is evident on the schist planes. The rest of the rock (1448, 35 paces north of station 86; 1449 near station 87; 1450, 25 paces east of 87) is of the prevailing thin-laminated, straw colored to grey, greasy-surfaced, argillitic mica-schist type. The dip varies from 54° to 65°.

On the east side of the river and fault line at Penokee Gap, the upper layers of III are exposed in the ravine between stations 302 and 301, Plate XXIII, having been thrown 900 feet south from the position of the same layers on the west side of the fault, near station 145. The decided north-of-west tendency seen in the strike on the east side of the fault, and the south-of-west tendency on the west side, are worthy of notice.

East of Bad river. Mt. Whittlesey, at the corner of sections 8, 9, 16, 17, T. 44, R. 2 W., is almost wholly made up of III, and the exposures are large. The slate inclines due northward, at an angle of from 56° to 65°, is mostly very thin-laminated and much contorted, assuming, on the jagged precipice facing south, many imitative forms. Most of the rock (2053) is straw-colored to grey, and is like the typical argillitic mica-schist of the Penokee section (1425). Some of the thicker layers approach novaculite, and in the upper portions north of the knob known as Mt. Whittlesey, more distinctly quartzose kinds come in (2058, 2059, from exposure No. 49, Atlas Plate XXIV). These are light grey, and schistose, but very hard, and under the microscope are seen to be composed of quartz grains 0.2 mm. in diameter, and imbedded in a fine brownish-tinted matrix, which is an aggregate of quartz grains. Scales of biotite 0.02 mm. in length are plentifully scattered through the matrix, whose brown color is due to their presence. The quartz grains are full of linearly arranged liquid-filled cavities. Immediately south of the section corner a large northward-dipping surface shows a dark-colored kind carrying a good deal of magnetite. The interesting relation of the east-and-west-striking slates of Mt. Whittlesey, to the northeast-striking magnetitic schists, shown in the creek just west, is made sufficiently plain on Atlas Plate XXIV. The bend indicated is a sharp one; it is not impossible that a fault may exist here, though the facts do not demand it. There is evidently a connection, however, between the position of the gorge which here passes the Penokee Range and the sudden bend in the strata, just as there is such a connection between the fault at Penokee Gap, and the gorge at that place.

Passing over a number of intervening ledges we note next the large exposures at the passage of Carrie's creek, northeast quarter of Sec. 11, T. 44, R. 2 W. The exposures are on both sides of the creek, those on the west being the most extensive. Here is a cliff facing east towards the creek, and another facing southward, about 400 paces south of the quarter-post on the north line of the section. The usual thin-laminated, contorted, straw to grey-colored rock, is everywhere seen. The facts with regard to strike and dip are sufficiently well given on the map.



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Very large exposures of III are found again on the side of the Penokee Range in the northeast quarter of the southeast quarter of Sec. 1, T. 44, R. 2 W., and extending beyond the town line into Sec. 6, T. 44, R. 1 W., for several hundred feet. The slate rises here to the very summit of the ridge, and shows prevailing the thin-laminated contorted kind, as at Mt. Whittlesey. At the top of the cliff, however, in Sec. 6, T. 44, R. 1 W., about 200 paces south, and 200 east of the west quarter-post, are seen a number of layers of a pink to brick-red clay slate, which has not been noticed farther west, but is to be seen at a number of points in the eastern extension of the belt. This rock (2083, 2084) is obtainable in large flat slabs, and is the most completely slaty of any noticed in this formation. Closely examined it is seen to be distinctly quartzose, though readily cut by the knife, and studded with minute shining points, which under the loupe resolve themselves into very perfect octahedrous of magnetite. Under the microscope these are seen to be imbedded in a cloudy, white, difficultly resolvable ground-mass, which is wholly crystalline, and appears to consist chiefly of quartz and feldspar.

At the passage of Tyler's Fork, southeast quarter of the northeast quarter of Sec. 33, T. 45, R. 1 W., are again large exposures of III, which here is considerably changed in character as compared with the more western exposures, being, as a whole, much more distinctly quartzitic, besides including a considerable portion of vitreous quartzite, or quartz-schist. Plate XIV of this volume serves to show the positions and extent of the exposures at this place. The total width is about 330 feet, which corresponds to a thickness of some 300 feet, the whole thickness not being exposed. The southernmost ledge in sight puts into the river at a point 150 paces north of the quarter-post on the east line of Sec. 33. Here the following section was measured, beginning on the south:

(1) Four feet of dark grey, aphanitic, argillitic mica-schist (2091); much more quartzose than at Penokee (1425); in very thin, regular layers measuring four-tenths to two inches; dipping northward 60°.

(2) One foot of same, layers thinner.

(3) One foot of light grey, aphanitic, quite hard and sharp-edged, micaceous quartz-schist (2092), in layers measuring three-tenths to five-tenths inch.

(4) One foot reddish, aphanitic, fine-grained rock (2093), exactly similar to that on Sec. 6, T. 44, R. 1 W. (2083, 2084), the surface thickly studded with very minute glistening magnetite octahedra; inter-stratified with a few light grey layers like the rest of the rock, and showing a very distinct cross-lamination, like that of an ordinary unaltered sandstone.

Just above on the west side of the river, the thin-laminated light-grey slate includes much hard, conchoidal-fracturing novaculite (2090).

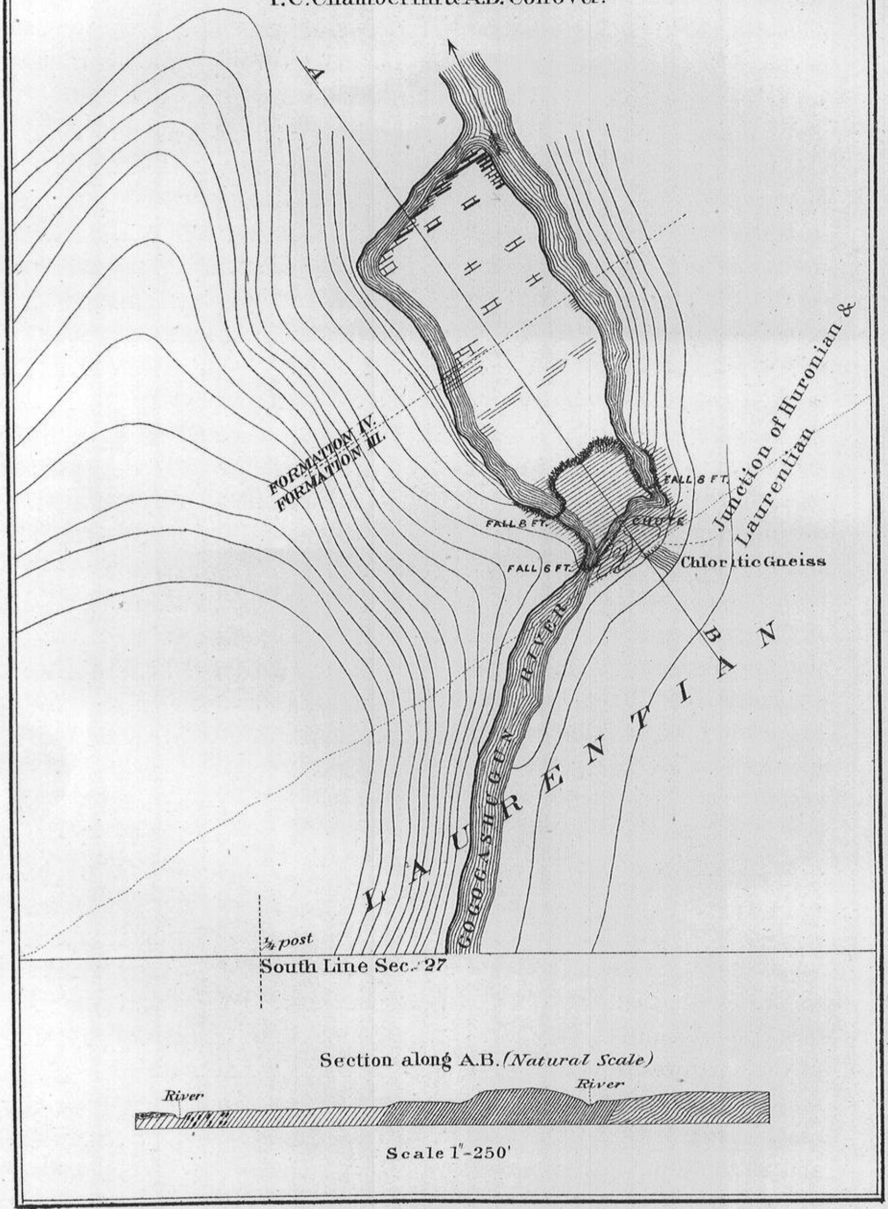
Twenty-five to fifty steps further north, broad bands, one to six feet in width, of a hard, brown-stained, vitreous quartzite begin to appear. Further north all of the slate, though still distinctly laminated, becomes more quartzose, and the quartzite bands increase in number and width. One of these, forming a knob at 250 paces north and 45 east of the quarter-post, is 15 feet in width, and bounded above and below by thin-laminated light grey quartzitic slate. The river here runs for several hundred feet through a narrow gorge in this slate, following the strike in a S. 66° W. direction. On each side of the gorge the slate exposures rise 30 to 40 feet from the water's edge, showing a very distinct lamination, but approaching to true quartzite in character (2095). Following this gorge to its end, at 160 paces north and 128 west of the quarter-post, we find the river turning at right angles directly across the strike. Following this new direction we come upon higher beds in the series, and find that the rock has completely changed to a light greenish-grey, very close-textured, nearly vitreous and much jointed quartzite (2109, 2110, 2094), in very distinct layers one-half inch to ten inches in width, dipping 72° to 75° to the northward, and weathering with a brownish surface. The same character continues to the upper edge of the formation. The falls of the river shown on Plate XIV are over this quartzitic rock. Just north of the first fall at this place, the junction of III and IV is very handsomely shown, the vitreous quartzite (2111, 2112) continuing unaltered to the very junction.

On the Potato river, in the northeast quarter of the southeast quarter of Sec. 19, T. 45, R. 1 E., the exposures of III are again very large and interesting. Following the river down from the southeast corner of Sec. 19, we find numerous exposures of the Laurentian chloritic gneiss extending to a point about 225 paces south of the east quarter-post of the section, the river in this distance flowing nearly along the section line. At this point the gneiss terminates abruptly against III of the Huronian. The junction between the two formations is beautifully shown on a cliff rising some 75 feet from the river. From here the river runs northwestward nearly across the strike of the slate, which continues to show for its whole width in a cliff a short distance back from the water's edge. All of the phases already described as belonging to III are here displayed, much of the rock showing a very slaty character, large flat slabs detaching readily from the cliff side. On the north the formation is also abruptly terminated by IV, the junction being plainly in sight. The whole width exposed is about 475 feet, making a thickness of about 425 feet. The dip is 68° to the north, the strike N. 70° E.

On the Gogogashugun river, Sec. 27, T. 46, R. 2 E., the whole width

PLATE XV.

Map showing the
POSITION OF THE ROCK EXPOSURES
on the
GOGOGASHUGUN RIVER
Sec. 27 T. 46 R. 2 E.
by
T. C. Chamberlin & A. D. Conover.



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of III is again in sight, the contact with the Laurentian and overlying No. IV, both being visible. Professors T. C. Chamberlin and A. D. Conover made a detailed examination of this place in 1877. From the notes of the former I take the following with regard to the formation at present under discussion: "The siliceous schists are highly laminated in some portions, while in others beds from 3 to 12 inches in thickness are observable. In color they range from grey to purple. The latter are usually clay-like in texture, and in some cases apparent pipestone. The layers of this class are interleaved with the more quartzose kinds. Mica-like scales are common in some portions, also iron pyrites, often in perfect cubes of small size. The schists are fine-grained, close and compact, rarely showing any distinct granular texture. The dip ranges from 45° to 73°, strike N. 55° E. Some of the layers are somewhat undulating, and some thicken and thin perceptibly. At some points, especially toward the upper portions, the layers become somewhat ferruginous. When fully exposed they seem to resist the action of the elements well, but under moss and shallow earth are more decomposed, though not markedly so. The resistance of the schists causes the cascade. The stream, in passing the barrier, follows the strike for several rods in a narrow trough, when it divides. One branch, turning abruptly across the beds a few feet and then returning along the strike a short distance, again turns across the beds and follows a narrow channel entirely across the schist. The main branch keeps on along the strike for a short distance beyond the point of division, and then turns at right angles, and plunges down a narrow channel across the beds until it is joined by the smaller branch some distance below. The whole width of the siliceous schist is 317 feet." From the foregoing description it is evident that the formation here shows its usual characters, and this conclusion is borne out by a close examination of the specimens collected (2211).

West of Bad river. West of Penokee Gap, exposures of the slate are almost constantly in sight, the characters being in general the same as already described. Specimens collected indicate that chlorite is somewhat more frequently present, but that the rock is, in general, essentially the same as in the more eastern portions. The following are the localities of some of the most prominent exposures: northwest quarter of the northwest quarter of Sec. 15, T. 44, R. 3 W., six rods south of the section corner, a very heavy exposure; northeast quarter of the northeast quarter of Sec. 17, T. 44, R. 3 W., a large ledge some 100 paces long and 20 to 30 in width, overlaid by a large mass of quartzite, the whole dipping northward at a considerably lower angle than usual; south line of Sec. 18, T. 44, R. 3 W., about 700 paces west of the southeast corner, near the foot of the south face of the Penokee Range; Sec. 19, T. 44, R. 3 W., near the west line of the northwest quarter of the section; northwest quarter of Sec. 24, T. 44, R. 4 W.; northeast quarter of Sec. 23, T. 44, R. 5 W., at the foot of a high bluff; and in a similar position on the south line of Sec. 16, T. 44, R. 5 W. Details with regard to these ledges and others will be found in Mr. Wright's report.

Formation IV. The Magnetic Belt.

This belt of rocks constitutes the most marked and continuous of the whole Huronian series, having been traced from the Michigan boundary westward to its final disappearance near Lake Numakagon, in T. 44, R. 6 W., a distance of about fifty miles. The constant exposures along much of the belt, with the magnetic observations made, have rendered this tracing possible. Quite a variety of rocks are here classed together, because the subordinate layers recognized at one place are not found in another. The way in which these layers give place to one another, the common quartzose character of the whole, and the general impregnation with the magnetic and specular oxides of iron, which at times pervade the whole thickness, though at others restricted to a narrow part, show that all should be regarded as parts of one great division of the series. The propriety of this is further indicated by the sharp definition of the whole belt on the south, and, less evidently however, on the north also.

The following is a brief summary of the different kinds of rocks observed in this formation, the order being that of relative abundance: *(a) banded magnetitic quartzite*— gray to red quartzite free from or lean in iron oxides, banded with seams from a fraction of an inch to several inches in width of pure, black, granular magnetite, which is only rarely mingled with the specular oxide; *(b) magnetitic quartzite* — the magnetite in varying proportions, pretty well scattered throughout, and mingled with specular oxide in proportions varying from nothing to a predominating quantity; *(c) magnetitic quartz-slate* — in layers two to four inches thick, with inferior lamination well marked, though without corresponding cleavage — highly jointed, the fragments sharp-edged and hard, the magnetite pervading the whole mass and associated with a varying quantity of specular oxide, as before; *(d) slate, like (c)*, but largely charged with actinolite or tremolite; *(e) arenaceous to compact and flaky quartzite*, free, or nearly so, from the oxides of iron; *(f) thin-laminated, soft, black magnetitic slate; (g) hematitic quartzite*, the iron oxide the red oxide; *(h) garnetiferous actinolite-schist*, or *eclogite-schist*, often almost entirely free from magnetite; and *(i) diorite*, this being restricted to the western end of the Huronian belt in T. 44, R. 5 W., and R. 6 W., where, however, it occurs in heavy bands.

The iron oxides impregnate some of these bands at times in such quantity that they become iron ores. The economic value of these schists as ores is treated of on a subsequent page.

The whole width of IV is not far from 850 feet, where affected by the prevailing high northern dip, corresponding to a thickness of 750 to 800 feet. In the western portion of the belt, where the dip is generally less, this width, of course, increases; and in sections 16 and 14, T. 44, R. 5 W., intercalated bands of diorite appear to increase considerably the actual thickness.

On Bad river, at Penokee Gap, and in the immediate vicinity, nearly the whole thickness of IV is in sight; bold cliffs of magnetic schist rising from either side of the gap through which the river passes (Atlas Plate XXIII). The following subdivisions of this formation are plainly visible here, beginning with the lowest or southernmost:

	Feet.	*Feet.*
IV A. Quartzite, width	....	50
IV B. Magnetite-schists, including —		
(1)[1] Banded magnetitic quartzite	20	....
(2) Slaty quartzose and actinolitic or tremolitic magnetite-schists	200	....
(3) Banded magnetic quartzite	580	....
Total width of IV B	——	800
IV C. Garnetiferous actinolite-schist or eclogite-schist		10
Total		860

These divisions are taken up in order in what follows, the exposures of each division as they are seen on the west side of the fault line being first noted, and afterwards those on the east side. For a full understanding of these details, reference must be constantly made to the large map of the vicinity of Penokee Gap, Atlas Plate XXIII.

The quartzite IV A shows on the west bank of Bad river, a short distance south of station 145, where it is seen in contact with (1) of IV B. It is seen again on the north slope of the hill of III, previously described, 40 paces south and 50 east of station 142. The rock here (1,500) is fine-grained, highly arenaceous, yellowish to gray, entirely without magnetic or specular iron, and traversed by numerous white quartz veins. Nearly the whole width is in sight. Another exposure is just south of station 97, at the foot of a steep cliff of magnetite-schist; 29 feet of the upper part is in sight, and the rock (1,458) closely

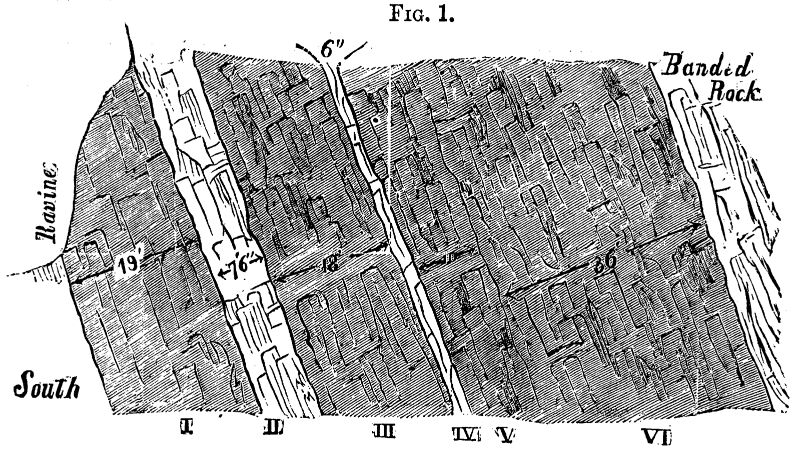
[1] The separations between these divisions of IV B are indicated on the map by white lines in the brown.

similar to that already described. Further west, along the same ravine side and near station 88, it is seen again, presenting now a somewhat different appearance (1,451), since the arenaceous texture is lost, and minute, lustrous octahedra of magnetite occur sparsely scattered. East of the fault-line IV A, having been carried 800 feet southward, appears in several places at the foot of the cliffs on the north side of the ravine near station 301, with the same characters as before (1,403).

The lower banded magnetitic quartzite, IV B (1) is in sight on the bank of Bad river, near station 145, in nearly its full width of 20 feet. The rock here is a dark gray quartzite, with some ferruginous matter throughout, and banded with seams and gashes of lustrous, black, highly granular, pure magnetite, which run from one to four inches in width, and conform with the bedding. A sample from one of these seams, collected in 1873, yielded 68.04 per cent. of metallic iron. On the weathered surface near the water's edge, the contrast between the white-weathered quartzite and the jet-black magnetite is striking. The cliffs already described as showing IV A, near stations 88 and 97, show also, immediately overlying it, the layer at present under discussion.

The slaty magnetite-schists, IV B (2), are best seen on the cliff-side just north of station 102, where some 90 to 100 feet of the upper portions are laid bare. The cliff here faces both east towards the river, and south towards a branch ravine, and is from 20 to 40 feet in height.

FIG. 1.



SECTION OF WEST CLIFF, PENOKEE GAP.

Fig. 1 illustrates a measured section made here in 1873, of which the following are the details, beginning at the edge of the ravine on the south:

		Ft.	In.
I.	Tremolitic magnetite-schist; slaty, highly jointed; coming out in sharp-edged lozenge-shaped fragments; the non-separable laminæ, from a line to an inch in thickness, strongly marked from each other by lighter and darker shading, the lighter bands being the more quartzose; on the darker laminæ a pale metallic lustre; streak, light gray to nearly black or purplish-black; containing, as shown by samples from across the whole thickness, the following ingredients: iron sesquioxide, 42.90; iron protoxide, 19.17; silica, 31.84; alumina, 0.38; lime, 1.37; magnesia, 1.29; manganese oxide, 1.13; phosphoric acid, none; sulphur, none; water, 0.38=98.46; magnetic oxide, 50.67; specular oxide, 11.40; metallic iron, 44.94—a composition which, taken together with microscopic observations, indicates the following mineral ingredients, named in order of relative abundance: magnetite, quartz, hematite, tremolite, pyrolusite; specimens attractable by the magnet in coarse fragments, often showing polarity; thickness..............	19	..
II.	Dark gray quartz-schist, containing 23.38 per cent. magnetite, and no specular iron; thickness..	7	6
III.	Magnetite-schist, similar to I, sample from across whole width containing: metallic iron, 49.4; silica, 27.0; phosphorus, none; thickness...	18	..
IV.	Gray quartz-schist, nearly free from iron; thickness....................	..	6
V.	Magnetite-schist, like I and III, but lighter gray in color, and less finely laminated, the sample, taken as before, yielding: iron sesquioxide, 34.77; iron protoxide, 15.82; silica, 42.90; alumina, none; lime, 1.33; magnesia, 2.62; manganese oxide, 1.73; phosphoric acid, none; sulphur, trace; water, 0.47=99.74; magnetic oxide, 50.59; specular oxide, none; metallic iron, 36.64—a composition which indicates the same mineral ingredients as in I, except that the quartz predominates and the hematite is wanting; thickness..........................	10	..
VI.	Magnetite-schist, like I and III; composition, as shown by analysis of sample taken from all across the bed, some 30 feet above the base of the cliff: iron sesquioxide, 43.89; iron protoxide, 19.48; silica, 30.73; alumina, none; lime, 1.91; magnesia, 1.63; manganese oxide, 0.87; phosphoric acid, 0.02; sulphur, none; water, 0.55=99.08; metallic iron, 45.87; magnetic oxide, 62.75; specular oxide, 0.61; and by analysis of another similar sample from near the foot of the cliff: metallic iron, 44.03; silica, 34.06; all of which indicates the same composition as in I, except that the hematite is quite subordinate, and a small quantity of apatite is added. Tracing this bed down the hill-side a distance of some 20 feet vertically, and about 10 feet below the upper surface, a lenticular mass of bright-lustred specular iron is met with, having a maximum width of about 4½ feet, and length in sight of about 20 feet. This yielded on analysis: iron sesquioxide, 49.16; iron protoxide, 9.07; magnetic oxide, 29.23; specular oxide, 29.00; metallic iron, 41.46; thickness......................	36	..
	Total..	91	0

The upper surface of VI of the above section joins the upper banded schists IV B (3).

The lower portions of these beds are seen in the vicinity of stations

97 and 98 and northward from them. The exposures are, however, not nearly so large as those just described. The characters are just such as shown by the preceding detailed section. Near station 88, the specimen (1,452) described by Mr. Julien in Appendix B, was taken from a slaty variety.

East of the fault line, this division of IV is pushed far to the southward, and not so largely exposed as the overlying beds. A number of exposures are, however, to be seen on the north side of the ravine near station 301 and east from there, with characters just like those of the ledges on the west side of the fault.

The upper banded magnetitic schists, IV B (3), constitute the greater part of Formation IV, as seen at Penokee Gap. It is possible that some bands of the more slaty kind occur in this division, in the vicinity, but, if so, they are of inconsiderable thickness. The exposures of this division are large on both sides of the fault, and especially so on the west, where they make up much of the west cliff of the Gap. The section above given of the preceding or slaty division ends in contact with the banded rock some twenty paces south of station 101, Atlas Plate XXIII, and from here large exposures of the latter rock continue northward, forming the bald cliff so noticeable from the railroad track below. As seen here, this division of IV is similar to IV B (1), already briefly described, the mass of the rock consisting of a dark gray to red and jasper-like quartzite, only slightly ferruginous, with seams of lustrous, black, and rich magnetite, one-eighth inch to three and four inches in width. These seams have a general direction with the bedding of the rock, but are quite irregular, expanding, contracting, and even terminating suddenly. Not unfrequently branches start off across the bedding, returning to their former directions at some inches to the right or left. Traced along the dip, the seams soon die out, being succeeded by others, overlapping on one or other side. On a fresh fracture, or on a surface newly stripped of soil, these seams do not present any marked contrast with the surrounding rock, but on the exposed surfaces, often smoothed by glacial action, the quartz-rock is weathered to a light gray, and contrasts finely with the black magnetite bands. Fig. 2 is a sketch of an area 4×5 feet, on the surface of the bald cliff

FIG. 2.

BANDED MAGNETITIC QUARTZITE, PENOKEE GAP.

alluded to above, and serves well to indicate the general character of this rock.

On the top of the same cliff, another small area was measured; the following are the details:

	Inches.
1. Dark-gray to reddish quartzite, with numerous very thin and irregular seams of magnetite, none of which exceed a thickness of one-eighth inch...	25
2. Regular seam of pure, fine-grained, black magnetite, without appearance of specular oxide; strongly jointed, containing 62.21 per cent. of iron	2
3. Like 1	30
4. Like 1, but the magnetite seams much more persistent and regular...........	26

A sample taken from all across the face, including both magnetite seams and inclosing rock, yielded nearly 40 per cent. of metallic iron, while the rock picked free from the iron seams yielded 19.2 per cent. Both of these figures are probably 10 per cent. or more too high for the general run of the rock.

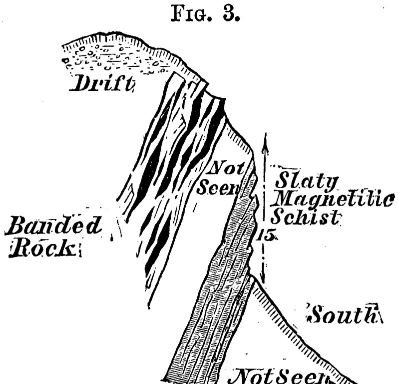
A number of other exposures of this division occur on the west side of the fault, showing essentially the same characters as those described. On the east side of the fault are also large ledges, the most prominent rising directly from the edge of Bad river, and filling most of the triangular area lying between stations 125, 151 and 152, Atlas Plate XXIII. As here seen the rock is essentially the same as on the west side of the fault, though, on the whole, probably less ferruginous. It should be remembered always, that, having been thrown vertically for a distance of some 1,700 feet, the layers on the east side represent the condition of those on the west side in depth.

The uppermost member of IV as seen at Penokee Gap, the garnetiferous actinolite-schist, is narrow, having a total thickness of not more than 10 feet. It occurs, however, on both sides of the fault, and, from its peculiar characters, aids greatly in determining the exact amount of dislocation. On the eastern side of the fault it forms a steep slope some 10 to 20 feet high all along the north side of the Penokee Range between stations 32 and 36, a distance of four hundred paces, for most of which it is exposed. As seen here this rock (1,404, near station 32; 1,444, 1,445, at station 33) is a dark gray to nearly black, fine-grained to aphanitic schist, with a very much iron-stained surface, and shows layers marked by darker and lighter grays. The lighter layers are coarser than the rest, and in them can be seen with the loupe thickly crowded, minute, garnet-like crystals. Under the microscope the section shows an exceedingly fine, greenish ground-mass of radiating actinolite, scattered through which are pretty frequent irregular pieces of magnetite, to which the dark color of the rock is evidently in part due. For satisfactory resolution of the actinolitic ground-mass a power of over 100 diameters is requisite. In the darker layers the garnets are sparse or wanting, while in the others they are crowded together so as almost to exclude the matrix. The garnets run from 0.05 to 0.8 mm. in diameter, and are much fissured, though but little decomposed, remaining for the most part dark between the crossed nicols. Dashes of bright color are, however, seen, which may be actinolite needles, also small areas of color adjacent to the fissures, which belong to some decomposition product. Magnetite is also included in some of the larger garnets.

On the east side of the fault this bed is again seen, the exposures occurring on the bank just east of the railroad track, and some thirty paces south of station 150. The layers seen here are mostly higher than those exposed on the west side of the fault, and somewhat different in character. The extreme southern end of the exposure shows, however, precisely the same rock as seen at stations 32, 33, etc. Northward from here the rock grows coarser in grain, the garnets becoming rarer. Under the microscope this variety (1,502) shows beautifully radiating tufts of actinolite, much coarser than before, the spaces between the tufts being often filled with a brownish ochreous matter. The garnets are rare, and are at times pierced entirely through by needles of actinolite. Still higher in the layers the grain of the rock becomes yet coarser, the actinolite being now distinctly perceptible to the unaided eye, while the garnets are still rarer (1,501). Figs. 1 and 2 of Plate XIII B, show the appearance under the microscope of thin sections of this rock, the former being from a specimen (1,404) taken near station 32, the latter from one (1,502) taken 35 paces south and 20 east of station 150. At 30 paces south and 20 east of station 150, Formation No. V, a black slate, is seen in contact with IV C.

East of Bad river. The course of the magnetic belt is slightly north of east through the northeast quarter of Sec. 14, a number of ledges of magnetitic schist showing on the north side of the stream which flows westward through the southern part of the quarter-section. About 600 paces west and 600 south (estimated) from the northeast corner of Sec. 14, the section of Fig. 3 was observed on the north side of the ravine through which flows the stream just mentioned The slaty layers of the lower part of this figure are

FIG. 3.



Section on N. E. Qr. Sec. 14, T. 44, R. 3 W.

richer in iron than usual. A sample taken from a thickness of 5 feet yielded on analysis: iron sesquioxide, 67.06; iron protoxide, 8.38; silica, 18.47; alumina, 6.30; lime, 2.48; magnesia, 2.28; manganese, oxide, 1.05; phosphoric acid, 0.13; water, 0.45=100.60; magnetic oxide, 27.00; specular oxide, 48.44. About forty rods east of this point on the same hillside, another sample, representing a thickness of 10 feet, of about the same horizon, yielded 44.43 per cent. of iron.

On the east line of Sec. 14, judging from the magnetic observations, the northern line of IV is about 200 paces south of the corner.

In Sec. 13, after continuing a short distance in the direction just named, the belt seems to curve gently to south of east, the northern border crossing the east line of Sec. 13 at 300 paces south of the southeast corner. In this section exposures are almost continuous along the crest of the Penokee Range, and the summit of its northern slope. At the time of my last visit, 1877, quite a little test-pitting had been done on the northwest quarter of this section. The principal work was at a point some 840 paces east and 350 south of the northwest section corner. The rock exposed here is of the banded variety, is largely charged with reddish jasper, and highly polished by glacial action. The ore-streaks are broader than usual, reaching one and a half feet, and are chiefly of the specular oxide, some yielding a very rich steely specular ore (2,045), which is, however, magnetic, and yields a purplish powder. We have here evidently a continuation of the upper banded magnetitic schists of the Penokee Gap section.

On the northeast quarter of Sec. 13, a mural exposure, chiefly of the slaty kind, was noticed near the top of the southern slope. A sample from the best consecutive 40 inches yielded 46.26 per cent. of metallic iron. Twenty feet higher in the layers the banded schist was in sight, with quite numerous seams of rich specular ore. The best 5 feet contained upwards of 45 per cent. of iron.

In Sec. 18, T. 44, R. 2 W., the magnetic belt curves again to north of east, its northern border passing out near the northeast corner of the section. The Penokee Range here is quite narrow and steep-sided, and a number of low mural exposures occur at the top of the south slope, as also others on the crest and northern slope. The whole section is in windfall, and numerous small exposures have been made by falling trees. A thickness of 10 feet, measured at the top of the south slope, on the northwest quarter of the section, yielded 37 per cent. of iron. The exposures are chiefly of the banded variety, though the slaty kind is also seen.

In Sec. 17 the course is nearly due east half way across the section, when a sharp curve is made to the northeast, the whole belt crossing into Sec. 8, the next to the north. In the southeast corner of the latter section, another abrupt turn is made, now to a due east course, the southern border of the belt crossing the east section line 100 paces north of the southeast corner. In Sec. 17 there are almost constant exposures from the northwest corner along the crest of the Penokee Range, half way across the section. Most of these are of the banded variety, which, judging from the exposures, seems here to make up even a larger part of IV than at Penokee Gap. Some slaty material, and that richer than usual in iron, is to be seen. Ledges 55 and 56, Atlas Plate XXIV, are on the north side of a ravine opening south of east. The lowest layers seen there are grayish quartzite (2,049), almost without ferruginous admixture. Further up the hill and higher in the strata, narrow purplish bands come in, and the rock is very jaspery. Still higher a thin-laminated magnetitic slate (2,051) is seen, in part quite rich, with a width of some twenty feet. The magnetite throughout contains not a little of the specular oxide. At the north quarter-post of Sec. 17, are still higher layers, in which the purplish ferruginous matter is pretty uniformly distributed in a granular quartzite.

At the gap through the Penokee Range near Mount Whittlesey, there are a number of exposures of IV, both in the creek and on the hill-side above. The southernmost of these is in Sec. 17, 29 paces south of the section line. The others are in Sec. 8. On all, the rock is a dark gray quartzite, with but little ferruginous material (2,059½, 2,060), and that in narrow seams. These ledges strike N. 56° E., and only 250 paces east are large exposures of east-and-west slate belonging to III, proving very nicely the abrupt bend made here by the whole formation.

On the summit of the Penokee Range north from Mt. Whittlesey are a number of ledges, one mound-like in form, and of quite large size. The rock seen here and also in some old pits near by is the same as that exposed in the valley just west. The strong attractions noted further down the north slope of the range seem to indicate a larger content of iron in the upper layers of IV than in the lower exposed portions.

Across Sec. 9 the magnetic belt bears a little north of east, its southern border gradually changing from the north to the south side of the south section line. Exposures are constant all across the section both on the crest of the ridge and on the upper part of the southern slope. Beginning just south of the south quarter-post of Sec. 9, and running along the section line and just north of it, to beyond the southeast section corner, is an almost continuous series of bold exposures. These are mostly of a peculiar brownish-grey, very highly granular, magnetitic quartzite (2,064), quite different in appearance from anything in the Penokee Gap section, to the banded quartzite of which it most nearly approaches. The bands, however, are only occasionally as sharply defined as in the latter rock, being generally merely lighter and darker shadings. These bands are quite irregular, and show much contortion. Interstratified with this coarser prevailing rock, at least two layers of thinly laminated, black, slaty magnetitic schist (2,061), with a width of about five paces, were made out. A large portion of the unusually high crest of the Penokee Range in the northern part of Sec. 9, is made up of this banded rock, the northern slope showing exposures of a more massive magnetitic quartzite, quite lean in iron.

On the east line of Sec. 9, some three hundred paces north of the southeast corner, a number of old test-pits expose rather poorly the uppermost layers of the magnetic belt. A sample selected from the whole length of one of these pits, a distance of fifty feet across the strike, yielded 41.19 per cent. of iron. As seen here, the magnetic rock is very highly slaty, and the usual quartzose ingredient is replaced by a softer clay-like material. From the appearance of some especially slaty and quite lean fragments obtained from the northernmost of these pits, it is evident that we are here very near the junction with the next formation of the Huronian series (V).

Entering Sec. 10, the magnetic belt bears slightly north of east for nearly half a mile. It then turns abruptly almost at right angles, trending at first a few degrees east of north to near the middle of the section, and then about northeast, the southern border of the belt passing out of the section about two hundred paces north of the east quarter-post. The same high crest noted in Sec. 9 extends more than half way across Sec. 10, and shows here again on its northern slope a number of exposures of the peculiarly banded rock seen in Sec. 9. On the steep northern slope of the ridge in the northeast quarter of Sec. 10 are large exposures, having a length of some twenty rods, of dark grey quartzite very lean in iron. About five hundred paces west of the east quarter-post of Sec. 10, a width of about fifteen feet of the slaty magnetitic schist is in sight.

Entering Sec. 11, our belt holds on its northeast course, soon passing into Sec. 2, the east line of which is crossed by the southern border of the belt at 200 paces north of the southeast corner. In the northwest quarter of the northeast quarter of Sec. 11, and the southwest quarter of the southeast quarter of Sec. 2, Carrie's creek passes the Penokee range. For some distance on each side of the valley in which the creek flows, exposures are numerous. At the north quarter-post of Sec. 11, and from there running some forty rods westward and twenty eastward along the course of the Iron Range, is a steep north-facing ledge of nearly non-ferruginous dark grey quartzite. This is on the north slope of the ridge, and is evidently a continuation of the similar rock seen in a similar position across much of Sec. 10. The same kind of rock, with a few magnetite seams, is exposed for some 150 paces south of the quarter-post. In Carrie's creek, 125 paces south of the north line of Sec. 11, and 250 east of the north quarter-post the same dark grey quartzite, now, however, more highly charged with magnetite, is exposed, with a width of thirty feet.

On the east side of Carrie's creek, and running along the north line of Sec. 11 for several hundred paces eastward, are numerous small exposures of the same rock. These strike north 60° east, and since the section line crosses them diagonally, a considerable thickness is here exposed. At about 500 paces west of the northeast corner of Sec. 11, thinly laminated, very highly magnetitic schists (2,081) are exposed, which are of course lower in the series than the quartzites just mentioned.

Crossing the southeast quarter of Sec. 2, the magnetic belt continues on its northeast course to about the middle of Sec. 1, when it curves to a more nearly easterly direction. On the southwest quarter of this section, a bold exposure, on the north slope of the ridge, shows a thickness of some sixty feet of both slaty and banded magnetitic schists. A sample from across the lower 20 feet, which showed the banded variety, yielded: iron sesquioxide, 40.42; iron protoxide, 12.33; silica, 39.17; alumina, 1.14; lime, 1.37; magnesia, 1.90; manganese oxide, 0.55; phosphoric acid, trace; sulphur, none; water, 2.16=99.04; magnetic oxide, 39.73; specular oxide, 13.02, metallic iron, 37.89. The ore seams, sampled independently of the rest of the rock, yielded 47.29 metallic iron. One seam, though looking somewhat richer than the general run, yielded only 47.26 per cent. Farther north and down the slope of the ridge a bold face of black slaty magnetic schist is in sight. A sample taken here across a thickness of twenty feet yielded only 12.99 per cent. of metallic iron. Other exposures of similar character occur along the ridge in the same section.

Entering Sec. 6, T. 44, R. 1 W., with the south border about 150 paces south of the west quarter-post, the magnetic belt swings around again more to the northeast. In this section the Penokee Range is especially high and narrow, with a very steep northern slope. Outcrops are not numerous. One small one showed a bright specular ore, banded with jasper. A sample from a thickness of four feet yielded only 25.64 per cent. of metallic iron.

In the northeast quarter of Sec. 6, the course of the belt makes another turn eastward, and in the northwest quarter of Sec. 5, it turns again to the northeast, maintaining this course across the southeast quarter of Sec. 32, T. 45, R. 1 W., and Sec. 33 of the same town to Tyler's Fork in the northeast quarter of the latter section. On the east line of Sec. 32, 250 paces north of the southeast corner, is a large north-facing ledge of the peculiar rough-textured banded quartzite, so largely exposed near the south line of sections 9 and 10, T. 44, R. 2 W. On the southwest quarter of Sec. 33 is an exposure on the north slope of the ridge, 200 feet long and 20 feet high, with a thickness of 20 feet in sight, of a banded magnetitic quartzite, the ore streaks being unusually abundant, rich, and easily separable from the adjoining rocks. These ore seams, averaging one to one and one-half inches thick, can be broken out in large slabs two to three feet in length, and yield a nearly pure, compact, purplish magnetite. A sample including both rock and ore seams yielded only 25.81 per cent. of metallic iron. A sample made from all along one of the ore seams yielded: iron sesquioxide, 65.91; iron protoxide, 27.49; silica, 4.68; alumina, none; lime, 1.79; magnesia, none; manganese oxide, 0.56; phosphoric acid, none; sulphur, trace= 100.43; magnetic oxide, 88.57; specular oxide, 4.83; metallic iron, 67.66.

The exposures at the gorge of Tyler's Fork, northeast quarter of Sec. 33, have already been partially described, and a map given on Plate XIV. Referring to this plate it will be seen that just at the junction between the magnetic belt and the formation below (III), the river makes a heavy fall. Then, turning, it runs about five rods along the strike, and makes another fall, at the same time turning again at right angles. From here down for 150 feet it passes through overhanging walls 30 feet high, of ferruginous quartzite, below which for several hundred feet are several other exposures of the same rock. The section of the magnetic belt seen here may be briefly summarized as follows, beginning below:

	Ft.	In
Thin-laminated, black magnetitic slate	1	2
Slightly ferruginous gray quartzite	..	4
Magnetitic slate, thin-laminated, very regularly slaty, dip 66° N., strike S. 53° W	4	6
Not well seen	4	..
Jaspery magnetitic slate or schist, including black slaty layers as above, and intersected by white quartz veins; including also ferruginous seams, yielding 40 per cent. of metallic iron	21	..
Dark gray magnetitic quartz-schist or quartzite, with occasional seams richer than the rest, but as a whole containing but little iron oxide, grading below into the thin-laminated jaspery schist, and above into a massive quartzite. Forty feet from the base is a persistent seam of siliceous red hematite, 20 inches wide, a sample from which yielded 41.29 per cent. of metallic iron	160	..

	Ft.	In.
Covered	100	..
Dark gray magnetitic quartz-schist	26	..
Covered	340	..
Dark gray magnetitic quartz-schist	20	..
Total	677	00

The section of IV thus described shows a much smaller content of iron oxides than noted at any point in its more western portions. It is generally true, moreover, that from here eastward there is a continual decrease in the iron content, this decrease being accompanied by a lessening in magnetic attractions. As far as the Potato river quite strong attractions occur, but they are usually restricted to a much narrower belt than before; while east of the Potato river the amount of deviation of the needle rapidly lessens, disappearing altogether before the Montreal is reached.

Eastward from the gorge of Tyler's Fork the course of the magnetic belt is about N. 65° E., through the northern part of Sec. 34, the southern of Sec. 26, the northern of Sec. 25, T. 45, R. 1 W., and the southern of Sec. 19, T. 45, R. 1 E., to the Potato river on the east line of the latter section. In this distance the exposures are rare and small, the only one of any size occurring directly on the meridian line near the southwest corner of Sec. 19, T. 45, R. 1 E. Here is a face towards the north 10 feet high, and 150 to 200 feet in length, of the banded magnetitic quartz-schist. The strike direction corresponds with the general course of the belt, being N. 63° E., while the dip is as much as 80° to 85° N. The bedding is quite plain, the layers having a small thickness. The rocky material very largely predominates. A sample from across the whole thickness of 30 feet in sight, including rock and ore seams, yielded only 37.94 per cent. of iron. The ore seams are irregular, from one-eighth to half an inch thick, and contain, mingled with the magnetic oxide, a large quantity of the specular variety, specimens always giving a red streak. A sample from one seam yielded 68.89 per cent. of metallic iron. Associated with the ore seams, in thin laminæ, is much of the black oxide of manganese. White quartz seams, carrying flakes of brilliant hematite, traverse the layers.

On the east side of Potato river, immediately above the slate (III) a number of small exposures of the magnetitic schists are in sight, the largest being near the base of the bed. These show a quartz-schist lean in iron oxides. Higher up in the formation, and about twenty rods north of the river, three small exposures were examined. near the top of the ridge. The structure here is highly slaty, the rock and ore seams alternating as usual. The latter show always the red streak. A sample from the entire 25 feet of thickness in sight yielded: iron sesquioxide, 46.06; iron protoxide, 5.02; silica, 40.50; alumina, 5.10; lime, 0.79; magnesia, 0.54; manganese oxide, 1.41; phosphoric acid, none; sulphur, 0.12; water, 0.55=100.08; specular oxide, 34.91; magnetic oxide, 16.17; metallic iron, 36.14. A ten-inch bunch of slaty ore layers near the base of the exposure was sampled independently of the surrounding rock. The sample contained 38.43 metallic iron. Some of the ore seams, having a bright specular look, yielded: metallic iron, 26.55; specular oxide, 35.55; magnetic oxide, 4.75. Two hundred feet further north, and now on the north slope of the ridge, a thickness of 22 inches of the same slaty rock as before was sampled; the sample yielded: metallic iron, 34.75; magnetic oxide, 24.01; specular oxide, 30.04.

Eastward from the Potato river, IV continues on the same N. 60° to 70° E. course, through sections 20, 17, 16, 15, 10, 11, 12 and 1 of T. 45, R. 1 E. Further east, the course is in general the same through Sec. 6, T. 45, R. 2 E., and sections 31, 32, 33, 34, 27, 26, 23 and 24, T. 46, R. 2 E., to the Montreal river, but there are several curves. On one of these, in Sec. 33, T. 46, R. 2 E., the course is but little north of east for nearly a mile. In all of this distance, the only exposures of any size are those on the Gogogashugun river, Sec. 27, T. 46, R. 2 E., outcrops of any kind being very rare. The only ones noticed west of the Gogogashugun are small ones of a blackish magnetitic slate near the top of the formation, in Sec. 6, T. 45, R. 2 E., and Sec. 32, T. 46, R. 2 E. (Nos. 11, 12, 13, Atlas Plate XXVI.)

At the passage of the Gogogashugun river, the exposures are large and interesting. A map of this place has already been given. The following description of the exposures of IV, as seen here, is taken from the notes of Professor Chamberlin, by whom the examination was made:

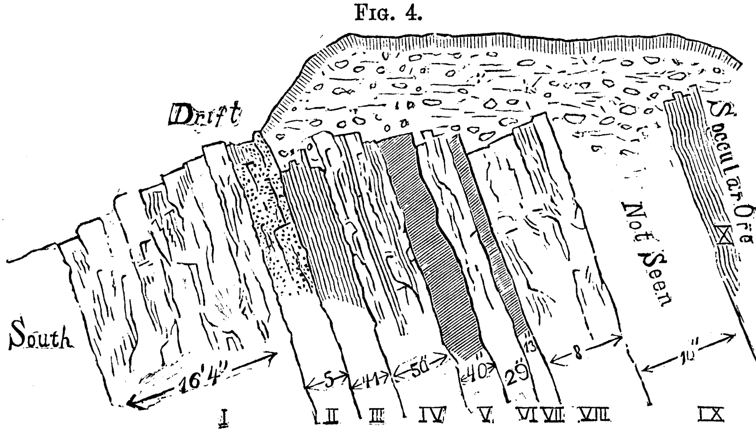
"The lower portion of this belt consists of beds of red and white quartzite of medium massiveness and somewhat irregular texture, and containing a small proportion of ferruginous and other impurities, irregularly distributed. As we rise through the layers the ferruginous material becomes more abundant, and forms thin layers interbedded with the quartzite beds, which are in this portion usually thinner. The iron takes the form of red hematite, or, to a less extent, of limonite, and shows abundant evidence of molecular rearrangement since its original deposition. This is seen in the crystalline form which a portion of it exhibits, and in the fact that in some portions it is mainly aggregated in pockets and fissures in the quartzite. In some portions, the quartzite has evidently been much fractured, and the cracks subsequently filled with the iron ore. There is also present a considerable relative proportion of manganese oxide, often in crystalline aggregations. The interbedded seams of iron ore are usually disintegrated and removed at the surface, when the strata are exposed, leaving the associated beds of quartzite separated by corresponding spaces. The surface width of the quartzite, before it becomes notably ferruginous, is about 200 feet. Beyond this point it is feebly exposed at intervals, on the right bank of the river."

The specimens of iron ore brought from here by Professor Chamberlin show an excellent quality of highly manganiferous soft hematite. It will be seen from this description that in the Gogogashugun section there is no sign of either the magnetic or specular iron oxides that characterize the more western portions of IV. On reference to the map of Atlas Plate XXVI, it will be observed that the magnetic attraction has almost entirely disappeared.

On the Montreal river, the only exposure of IV is a small one of red and gray jaspery quartzite near the base of the formation.

West of Bad river. This portion of the magnetic belt has been examined in detail by Mr. Wright, and will be found described in his report in this volume. A number of points having been noted during the preliminary reconoissance of this part of the belt in 1873, I repeat

FIG. 4.



SECTION IN EXPLORING TRENCH, NORTHEAST QUARTER SEC. 15, T. 41, R. 3 W.

here what was given in my report for that year, with some condensation. Westward from Penokee Gap, there are exposures of the magnetic schists on nearly every quarter section, often of large size. These exposures are nearly always at the summit of the Penokee Range, or near the top of its southern slope, and form not unfrequently almost precipitous south-facing cliffs. This is especially true of the more quartzose layers.

Across Sec. 15, T. 44, R. 3 W., to the eastern line of which section we have already carried our descriptions, the magnetic belt trends but very slightly north of west, its northern border lying just north of the north line of the section. On the northeast quarter of Sec. 15, about 50 paces north and 500 west of the northeast corner, a number of fresh exploring trenches were examined in 1873. In one of these, the section shown in Fig. 4 was obtained.

The following are the details of this section, beginning on the south:

	Ft.	*In.*
1. Heavily bedded, gray, non-magnetic quartzite, the uppermost layers of which show a transition into the next higher layers; a sample from the whole width yielding only 2.03 per cent of iron; thickness	16	4
2. Dark colored, highly magnetic quartzite, containing 11.23 per cent. of iron; thickness	5	..
3. Thinly laminated, brilliant steely-lustred, red-streaking specular iron ore, interlaminated with quartz seams; strongly magnetic, specimens showing strong polarity; a sample from all across the bed yielded: iron sesquioxide, 49.44; iron protoxide, 8.46; silica, 33.89; alumina, 1.15; lime, 3.16; magnesia, 2.40; manganese oxide, 0.34: phosphoric acid, none; sulphur, none; water, 1.5 = 100.34; magnetic oxide of iron, 27.26; specular oxide, 30.64; metallic iron, 41.19; — this analysis showing the same ingredients as in the schists at Penokee Gap, viz.: quartz, specular hematite, magnetite, tremolite and pyrolusite, though in different order of relative importance. On the lower side this layer is sharply defined, but above, a graduation into the next layer is observable; thickness.................	3	5
4. Specular quartz-schist, thinly laminated, feebly magnetic; containing 30.8 per cent. of iron; thickness........	4	2
5. Quartzose magnetite-schist; thinly laminated to slaty; dark colored, without appearance of specular iron; very highly magnetic. The sample from the whole thickness yielded: iron, 30.13: iron sesquioxide, 27.8; iron protoxide, 13.34; a proportion which proves the absence of specular hematite. Thickness......	3	4
6. Quartz-rock, free from ferruginous admixture; thickness	2	5
7. Quartzose magnetite, like No. 5; containing: iron, 38.4; iron sesquioxide, 37.20: iron protoxide, 12.90; magnetic oxide, 51.22; specular oxide, 1.88; thickness	1	1
8. Quartzite, light colored, non-ferruginous; thickness	8	..
9. Not seen; thickness	10	..
10. Specular ore, like No. 3. The analysis of a carefully averaged sample yielded: metallic iron, 45.07; iron-sesquioxide, 59.15; iron protoxide, 4.72; magnetic oxide, 15.20; specular oxide, 48.66; thickness seen............	3	..
Total	56	9

The section thus described serves well to show the alternations of ferruginous and non-ferruginous layers, and the peculiar association of specular hematite and magnetite that is so characteristic of the Penokee Range throughout its whole length. The layers represented in this section belong well down in the formation, and correspond either to the "slaty schists," IV B, (2), or the "lower banded schists," IV B, (1) of the Penokee Gap section. In the immediate vicinity of this trench, at a point 65 paces south and 600 west of the northeast corner of Sec. 15, the shaft of the Penokee mine has since been sunk, and several hundred tons of rock taken out. This pile was carefully sampled in 1875, and the sample analyzed by Mr. E. T. Sweet, the result showing 44.44 per cent. of metallic iron. The pile and the vicinity of the mine were also carefully examined by the writer in 1877. A large portion of the pile is composed of the "banded" variety of magnetic schist, dark-colored magnetite bands alternating with bands of greyish quartz. A few pieces of rich granular magnetite are mingled with the rest, and also others of a fine-granular, friable, brownish kind, which is highly magnetic, and very rich, not only in iron but also in manganese. South from the shaft house 100 paces the siliceous slate III is in place. The mouth of the shaft is just 1,000 feet above above Lake Superior, and about 300 above the railroad track at Penokee Gap.

In Sec. 16 the magnetic belt continues nearly across the section, more and more of it passing to the north of the section line as it is traced westward. A number of exposures of magnetite-schists were noted, one of which, on the northwest quarter of Sec. 16, is a bold mural one, on the south face of the ridge. Here a slaty magnetite-schist is overlaid by a banded kind, all dipping at a high angle to the northward. The thickness of the slaty variety seen was 15 feet, a sample from the whole of which yielded 49.7 per cent. of iron.

About two-thirds across Sec. 16 the magnetic belt begins to curve to the west and south of west, finally taking a southwest course, which is maintained through Sec. 17, the belt crossing the west line of that section about a quarter of a mile north of the southwest corner. In Sec. 17 bold exposures continue to show on the south face of the Penokee range, much of Formation IV being here made up of nearly nonferruginous quartzite. One of these great ledges of quartzite was found forming a steep slope or cliff 50 to 75 feet in height on the northeast quarter of the section. At the top of the exposure 25 feet of slaty magnetite-schist is in sight, the whole dipping only 50° to the northward. A similar exposure, extending several hundred feet along the strike, was noticed near the center of the section. Here both slaty and banded magnetite-schists are in sight above the quartzite, and much of Formation III is in sight below. The dip here is as low as 35°. The quartzite of these ledges occupies in part the position of the similar rock IV A., at Penokee Gap. It is so important a feature of this part of the range, partly because of increased thickness, but also because of the low dip, which gives it a greater surface extent, and at the same time conduces to the formation of such precipices as I have described. A sample taken from the slaty magnetite-schists of the last named exposure, and representing a thickness of 40 feet, yielded: iron sesquioxide, 36.41; iron protoxide, 15.77; silica, 39.53; alumina, 0.11; lime, 1.52; magnesia, 2.52; manganese oxide, 3.12; sulplur, 0.42; phosphoric acid, trace; water, 0.54=99, 94; metallic iron, 37.75; magnetic oxide, 50.8; specular oxide, 1.38 — a composition indicating the same mineral ingredients mentioned so many times before, viz: magnetite, quartz, tremolite or actinolite, pyrolusite, hematite and pyrite.

In Sec. 18, T. 44, R. 3 W., the magnetic belt continues on its southwest course, entering the northwest corner of Sec. 19. A number of exposures occur in Sec. 18, showing generally quite a low dip. One ledge, a few feet wide, near the center of the section, was sampled, the analysis of the sample yielding 38.75 metallic iron.

In the northeastern corner of Sec. 24, T. 44, R. 4 W., the Penokee range ends very abruptly. A number of exposures occur beyond the end of the range, however, in Secs. 13 and 24, and, as first shown by Mr. Wright, the magnetic belt here takes an abrupt turn at right angles, the course now being northwest. On the west line of Sec. 13 another abrupt turn takes place, now to the southwest, after which the belt becomes concealed by drift. Its course has been traced out by Mr. Wright, by the aid of the magnetic needle, and, from his observations entirely, as given in the annual report for 1876, the course of the belt, through R. 4 W., has been marked on my map of the eastern Lake Superior district, Atlas Plate, XXII.

In T. 44, R. 5 W., the magnetic belt rises again through the drift, forming in sections 23, 14, 16 and 17, high ridges. In the southern part of Sec. 14 and northern part of Sec. 23 is a bold ridge made up of magnetite-schists which rises 200 feet above the surrounding country and trends northwest and southeast. Towards the northwest this ridge is cut through by the valley of a small branch which enters the Maringouin river at the foot of the bold falls described on a previous page, northwest quarter of Sec. 23. The principal exposures of magnetite-schist are on the south face of the ridge, and again on the side hill facing towards the valley alluded to. The latter are the most extensive. Beginning a short distance west of the south quarter-post of Sec. 14, they extend as much as 500 feet in a southwesterly direction. The strike of the schist being N. 45° W., these ledges show a thickness of several hundred feet. The rock is quite slaty and uniform throughout, and contains, according to the analysis of an average sample, upwards of 35 per cent. of metallic iron. Passing across the valley in the direction of the strike another bold ridge is found upon which were observed a number of diorite exposures. Some of these appear to lie directly in the course of the magnetic belt, to which their true relation was not made out. In Mr. Wright's detailed account of this region this difficulty will probably be found explained.

In the southern part of Sec. 16, T. 44, R. 5 W., is another bold ridge of magnetite-schist, some 250 feet in height. This ridge stretches from the west side of the Maringouin river, all across the section, curving to the southwestward in the southwest quarter. The magnetic schists here are distinctly interstratified with broad diorite bands, a phenomenon nowhere else observed in the entire length of the magnetic belt.

From the southwest quarter of Sec. 16, the magnetic belt was traced in 1873, by aid of the dip compass, to the northeast shore of Atkins' lake, northwest quarter of Sec. 20, T. 44, R. 5 W. Mr. Wright has since traced it beyond to Numakagon lake, in R. 6 W.

Formation V. Black Feldspathic Slate.

This layer has been seen well exposed only at Penokee Gap. One or two poor exposures have been found of a similar rock, in the proper stratigraphical position, in the eastern extension of the Penokee Range. As seen at Penokee Gap, this member has a width of 200 feet, and a thickness of about 180 feet.

The exposures at the Gap lie altogether on the west side of the fault. They are on the side hill just east of the railroad track, near station 150, Atlas Plate XXIII. As seen here, the rock (29, 1,428) is quite perfectly slaty, in layers one-eighth inch to three inches thick, dull black in color, soft, powdering greyish, and nearly aphanitic, a few minute shining facets being distinguishable with the loupe. According to Professor Daniells' analysis, it contains 9.26 per cent. of iron, and 1.42 per cent. of carbon, the latter having been determined by direct weight. In Mr. Julien's report, Appendix B, it will be seen that he describes the rock as composed of orthoclase grains imbedded in a paste of biotite and opacite, the latter including pyrite and limonite. From the results of Professor Daniells' analysis it is evident that the opacite is in part carbon. In Fig. 4, Plate XV A, I have given a drawing of a part of the slice examined and reported on by Mr. Julien.

East of Penokee Gap, as mentioned on p. 127, V is seen feebly exposed on the east side of Sec. 9, T. 44, R. 2 W., where there is a graduation into the underlying magnetite-slates. Exposures of black slate belonging to this horizon are also to be seen on the southeast quarter of the northeast quarter of Sec. 1, T. 45, R. 1 E. The slate here is distinctly magnetitic, and appears, as indicated by other neighboring exposures in Sec. 6, T. 45, R. 2 E., to graduate downwards, by an increase of magnetite, into the upper portions of IV, themselves here unusually soft and slaty.

Formation VI.

At Penokee Gap, and thence both east and west along the whole course of the Penokee Range, we find immediately north of the magnetic belt, or of Formation V, an interval without exposures. At Penokee Gap this belt has a width of 970 feet, which, with the prevailing dip of 65°, corresponds to a thickness of 880 feet. This barren interval may include several distinct layers, or be all included in one, or contain more or less of an extension of Formation V. In the more southern part of this belt for some miles west of Penokee Gap, Mr. Wright has observed magnetic attractions which he thinks indicate the position of an ore belt. I have not found any such indication in the eastern extension of the Iron Range.

In T. 44, R. 5, W., sections 16, 17, 19 and 20, are large ledges of a peculiar hornblende-rock, evidently overlying the magnetic belt or Formation IV, and occupying a portion of the barren interval here numbered VI. I have hesitated, however, to give the name of this rock to a distinct member of the Huronian series, because it is found only in this one vicinity, where, moreover, several other deviations from the typical stratigraphical arrangement of the lower members are to be observed.

The main exposures of this hornblende-rock are on the southwest quarter of Sec. 16, the southwest quarter of Sec. 17, and northeast quarter of Sec. 19, T. 44, R. 5 W. Those on Sec. 19 lie at the foot of a bold isolated ridge, in part made up of this rock, which is over 300 feet in height, and on the north shore of a small lake. As seen here the rock (101, 105) is a dark-colored one, for the most part medium-grained to aphanitic. In the coarser varieties, quartz and a blackish mineral are distinguishable with the loupe. Large black shining surfaces up to one-fourth inch in length are also occasionally observable. The only section examined under the microscope showed quartz predominating, but mingled with much milky orthoclase; hornblende in large, greenish, partly decomposed, and much shattered crystals; biotite in occasional leaves; rare plagioclase; and apatite as a very abundant inclusion in both quartz and feldspar. From the macroscopic appearance of other specimens, it is supposed that the orthoclase is more abundant in this slice than usual. Greyish and pinkish coarse-grained granite veins were observed penetrating this rock.

Formation VII. Mica-Slate.

This formation, known only in the vicinity of Bad river, is made up of a light to dark gray, aphanitic schist, or slate, the principal mineral constituents of which, as shown by the microscope, are quartz, orthoclase and biotite, the texture being wholly crystalline.

The exposures of this rock in the vicinity of Penokee Gap are all on the side of a low ridge, which rises abruptly fifty feet from the south bank of Bad river, between stations 189 and 190 of Atlas Plate XXIII, and has an east and west extent of about twenty paces. In structure, the rock (1,479, 1,480) seen here varies from schistose to slaty, the laminæ striking east and west, and dipping 60° to 65° north. Examined with the loupe, minute scales of mica are occasionally perceptible, also fine pyrite. The pulverized rock yields a little magnetite. In the thin section, the white background is seen to consist of very fine quartz and orthoclase grains. Thickly interspersed in this are scales of brownish biotite, mostly lying in the schist plane. Small black particles, belonging to pyrite, and finer, dusty magnetite, are contained in small quantity. Fig. 5, Plate XV A, is a representation of this rock. This layer has not been observed exposed at any other point.

Formation VIII.

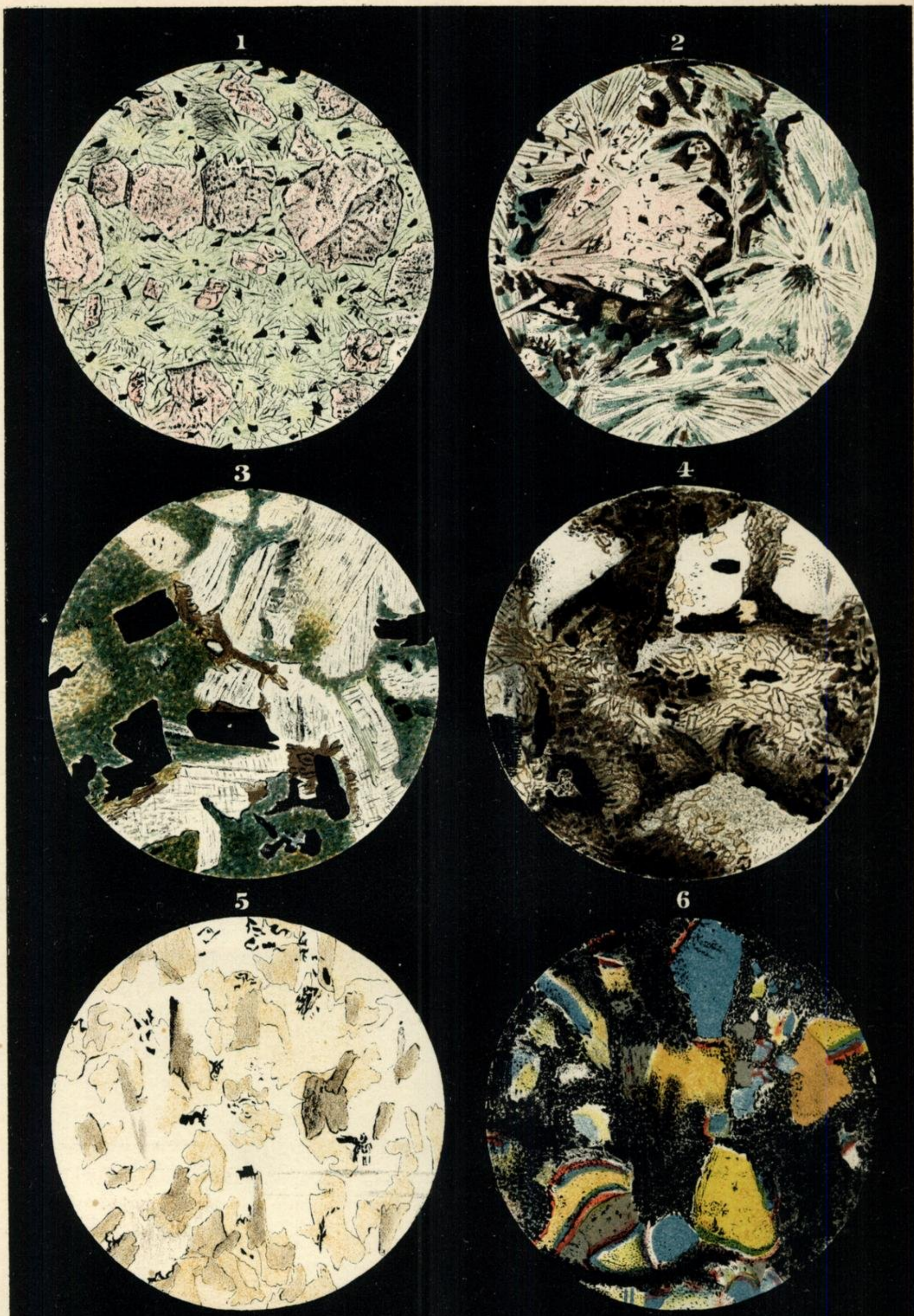
Immediately succeeding the last described layer on Bad river, is a blank 320 feet in width, corresponding to a thickness of 290 feet. There can be little doubt that this blank space is, in part at least, occupied by a continuation of the mica-slate of VII.

Formation IX. Chloritic Diorite.

This layer is known only from its exposures on Bad river, on which it forms a series of rapids. The horizontal width is 170 feet, and thickness 150 feet. The exposures are wholly on the west side of, and very close to the fault line. Their interesting relation to the large exposures of black slate in the immediate vicinity, and on the other side of the fault line, is noted in another place.

The exposures on Bad river are just west of the line between stations 214 and 215, Atlas Plate XXIII, extending across the river. The rock is very dark-colored and massive, being without any appearance of bedding structure. At the foot of the falls, the texture (1,435) is very close, being almost aphanitic, and numerous narrow seams of white quartz are seen. Further up, the rock (1,435 to 1,439) becomes somewhat coarser in grain, and the texture is seen to be highly crystalline, a striated feldspar and dark-colored mineral being occasionally dis-

HURONIAN ROCKS.



R. D. Irving, 1878. The Milwaukee Litho. & Engr. Co.

Fig. 1. Garnetiferous Actinolite-Schist, or Eclogite-Schist (1444), Formation IV C; near N. W. cor. Sec. 14, T. 44, R. 3 W; × 45.
Fig. 2. Same as 1, (1502), coarser; from east side of fault, Penokee Gap; × 45.
Fig. 3. Chloritic Diorite (1439), Formation IX; Penokee Gap; × 45.
Fig. 4. Black Slate (29), Formation V; Penokee Gap; × 135.
Fig. 5. Black Mica Slate (1480), Formation VII; Penokee Gap; × 135.
Fig. 6. Quartzite (1496), Formation XV; N. W. ¼ Sec. 11, T. 44, R. 3 W; × 45.

tinguishable with the loupe. Pyrite is also at times visible, its presence being frequently indicated by the brown iron-stain on some surfaces. The complete microscopic description by Mr. Julien, in Appendix B, renders unnecessary anything farther on my part. It may merely be said that the main ingredients are much altered amphibole and plagioclase, pyrite presenting itself as a constant accessory. I have myself examined a number of other thin sections ground from specimens secured from all parts of the exposure, and, with the exception of variation in coarseness of grain, they correspond in all respects with the one examined by Mr. Julien. I give a representation of the latter in Fig. 3, Plate XV A.

Formation X. Mica-Slate.

This layer is also known only in the vicinity of Penokee Gap, where it is seen exposed on the side of a steep bank near station 48 of Atlas Plate XXIII, and again in the bed of a small stream about a hundred paces further east. It has not been observed on the east side of the fault line. The total width indicated by the exposures is not greater than 25 feet.

This rock (1,440, 1,441, 1,476) is a gray, fine-grained, minutely crystalline, soft slate, closely resembling the rock of Formation VII, from which it is also indistinguishable under the microscope.

Formation XI.

Succeeding the last-mentioned rock, in the vicinity of Penokee Gap, is a space within which no exposures have been observed, having a width of 310 feet. These figures correspond to a thickness of strata of 280 feet. From the evidence of loose fragments, and from the similarity of the rocks on both sides, it is surmised that a large portion, at least, of this blank is filled with mica-slates. No exposures have been as yet observed elsewhere in the Huronian belt that could be referred to this interval.

Formation XII. Black Magnetitic Mica-Slate.

This rock is known only on the east side of the fault line near Penokee Gap, where, however, the exposures are large, and of much interest. The rock is quite closely allied to that of Formation VI, from which it differs in its blacker color, the blackening material including magnetite, pyrite, and probably also carbon. The horizontal width of this formation in sight near Penokee is 250 feet, corresponding to a thickness of 225 feet. The exposures near Penokee Gap are all close to Bad river, the largest being included in the square of stations 214, 223, 198, 189 of Atlas Plate XXIII. Here we find a low hill, some thirty feet in height, lying in the bend of Bad river. In addition to the natural exposures, the railroad excavations have bared the rock in a number of places, besides which there is a cutting 10 to 15 feet in depth, and some 400 feet in length. The rock on all these exposures is quite uniform. It is a jet-black slate or slaty schist nearly aphanitic in texture, soft and argillaceous. Numerous little, elliptical, amygdaloid-like spots of a duller black than the rest of the rock, and one-twentieth to one-thirtieth inch in diameter, dot thickly the surfaces of the lamination planes (1,429 to 1,433). The weathered surface and the surfaces of joint-cracks show often a bright yellow iron-stain. In Appendix B is given a detailed description by Mr. Julien of the microscopic characters of a thin section of this rock. Several other sections which I have myself since examined present exactly the same appearance. The rock is wholly crystalline, having a ground-mass chiefly of quartz, through which are scattered minute scales of mica and black particles of magnetite and pyrite, and probably also carbon. To the oxidation of the pyrite are evidently to be attributed the iron-stained surfaces. The thin section does not show any difference between the black spots seen macroscopically on the schist planes and the rest of the rock, other than the thicker crowding of the black ingredients. It is surmised from the characters of a similar slate occurring somewhat higher in the series, that these spots may be the remnants of crystals of chiastolite.

The slaty laminæ are not always very thin, running sometimes to two inches in thickness. In the cutting at the southern end, the layers strike north 69° west, dipping 69° to the north. Twenty-three paces further on, a band two feet in width of highly contorted slate strikes across the cutting in a north 62° west direction. Further north still, the strike-planes turn yet more towards the north, trending at the northern end of the cutting north 52° west. On the large bared surfaces to the west of the cutting the rock is seen to be much faulted, the presence of whitish bands coinciding with the bedding making the amount of throw in each case quite evident. The unusual amount of northing and the peculiar variations in the strike directions at this place, together with the much disturbed and faulted condition of the rock to the west of the cutting, have an interesting relation to the Penokee fault, as shown on a subsequent page.

Formation XIII. Chloritic Diorite.

This layer is known only in the vicinity of Penokee Gap, where it is found on the east side of the fault with a horizontal width of 40 feet and thickness of 35 feet. The rock is allied to that of Formation XII, although there are well-marked differences, as noted below.

The only exposure known is a poor one on the sides of the railway cutting already described as passing through formation XII, where there is a total width, measured along the sides of the cutting and including exposures and unexposed intervals, of 60 feet, which, taking the strike direction into account, corresponds to a true width of about 40 feet. Macroscopically, the rock seen here (1,434) is very finely crystalline, compact, dark gray to black, and pyritiferous, differing from the rock of Formation IX, which is exposed in the river bed near by, chiefly in its greater fineness of grain, but also in a minute and barely perceptible stringy arrangement of the constituents. Under the microscope, a thin section shows a predominating amount of greenish and much shattered and altered hornblende, which is in certain places only strongly dichroitic. Throughout the whole section, the hornblende fibers retain one general direction, to which also the black magnetite conforms in long strings, indicating apparently a sort of schistose structure. The plagioclases are in quite small, much rounded grains. From the rock of IX that of XIII differs then, (1) in the fibrous character of the hornblende; (2) in the stringy arrangement of the whole section; and (3) in the greater amount of hornblende and subordinate amount of plagioclase.

Formation XIV. Black Mica-Slate.

The principal exposures of this formation are in the neighborhood of Bad river, and in the sections immediately to the west, besides which there are a few small scattering ones in the eastern extension of the Huronian belt, which appear to belong to the same horizon. The rock is a dark gray to jet-black, aphanitic slate, closely similar to that of Formation XII. In certain layers numerous blades of chiastolite are thickly distributed. The blackening material appears to include, as in the rock of Formation XII, magnetite, pyrite and carbon. The total apparent width of this layer on Bad river is 415 feet, corresponding to a thickness of 375 feet. Over 200 feet of the middle portion of this width, however, is without exposure, the continuation of the same rock through the blank space being an inference from drift evidence, and from the close similarity of the rocks on both sides of the gap.

The exposures of this formation in the vicinity of Bad river, Sec. 11, T. 44, R. 3 W., are found on both sides of the fault line. The lowermost layers are to be seen imperfectly exposed in the northern end of the railway cutting already described as showing XII and XIII. The upper layers are seen on the west side of Bad river, between stations 23 and 59, where they form, with the next higher members of the series, a bold cliff some 30 to 50 feet in height, and rising directly from the water's edge. The width exposed is about 140 feet, corresponding to a thickness of 126 feet. The rock (1,495, 1,497, 1,498) is black, aphanitic, and highly slaty, and is almost exactly like that of XII. In some layers numerous blades of chiastolite, one-fourth to one-half inch in length, are thickly crowded, lying chiefly in the schist-plane. The microscopic characters of the rock are described in detail by Mr. Julien, in Appendix B. I have examined several other sections and they coincide entirely with his descriptions. The ground-mass of the rock is made up of biotite, tremolite, magnetite and carbon.

Formations XV to XVIII. Alternations of Black Mica-Slate and Dark Gray Quartzite or Quartz-Schist.

The several layers here included together are known on Bad river, T. 44, R. 3 W.; on Tyler's Fork, in T. 45, R. 1 W., and again on the Potato river, in T. 45, R. 1 E. Several small, scattering ledges, noted in the eastern portions of the Huronian belt, and away from streams, seem also to belong here. The black slate of these alternations is always aphanitic and in general closely like that of Formations XIII and XIV, which it resembles also, at times, in carrying both macroscopic and microscopic chiastolite crystals. In the eastern portions of the Huronian belt, the slate often approaches the argillites, becoming excessively fine-grained, so as to require a power of several hundred diameters for resolution. In these cases it is often not so deeply black in color. The blackening material appears to be only in part carbon.

The quartzites and quartz-schists are massive to thin-schistose, dark gray to light yellowish-grey in color, and of a very fine-granular texture, often appearing under the microscope like a fragmental rock.

On Bad river. The best exposures of these layers on Bad river are to be seen on the cliff-side already mentioned as rising from the west bank of the river near station 266. From this station northward, the cliff continues to within forty paces of station 255, trending thence northwest, with a diminished height, to station 258. XV, the lowest of these alternations, is a quartzite bed having a width of 40 feet, or a thickness of 35 feet. Its junction with the black slate below is seen on the sides and top of the cliff just at station 266, and is an exceedingly irregular line. The quartzite (1,496, 1,494½) here is dark gray, very fine-grained, and compact. Under the microscope it is seen to be made up of angular quartz-grains from 0.2 to 0.5 mm. in diameter, and filled with minute cavities and other inclusions. For the most part these grains are very sharply defined and separate, though at times they merge into the surrounding matrix. Next to the quartz in abundance, and often equal to it in size, are milky grains of orthoclase. The matrix appears quite confused, and seems in part to be made up of very fine quartz and orthoclase granules, together with a considerable quantity of a blackish substance in very irregularly shaped particles. At times this black material seems to form nearly the whole of the matrix, at others it is but sparsely scattered. That it is not magnetite is shown by the action of the magnet on the powdered rock; and but little, if any, can be of a carbonaceous nature, judging from the negative results obtained in a combustion made by Mr. C. R. Vanhise, in the University laboratory.

Beyond this quartzite, on the same cliff-side, XVI is seen in place. It is a chiastolitic, black slate (1,494), in every way like that of Formation XIV. The total thickness of the layer is 18 feet.

Further north again, the cliff is made up entirely of the quartzite XVII (1,493), which has essentially the same character as the rock of XV, though occasionally of a much finer grain. It forms the rest of the cliff all the way to station 258.

XVIII, on Bad river, is a blank 460 feet in width.

East of Bad river. On Tyler's Fork, in the southwest quarter of the northeast quarter of Sec. 28, T. 45, R. 1 W., the alternating quartzites and black slates are finely exposed in the bed of the stream, with a total width of 435 feet, or thickness of 390 feet. The distance of these exposures from the magnetic belt of the Penokee Range, measured across the strike, seems to indicate that they include a portion, at least, of the blank numbered XVIII in the Bad river section. At the head of the falls, which is 684 paces due west from the quarter-post on the east line of Sec. 28, layers of a dark gray, soft, aphanitic, thin-laminated slate (2,106), alternate with others of a more thickly bedded, dark-colored, very close-grained, but distinctly granular rock (2,107), and others, again, of a light gray, harder kind, also with a distinctly, though very finely granular texture (2,108). A thin section of the last-named rock shows that it is largely made up of angular quartz grains, with a smaller number of orthoclase grains, imbedded in a cloudy and ochre-stained matrix, which is apparently composed of the same materials. Sixty paces further down the stream the appearances are similar, except that the lighter colored kind is wanting. Forty paces further, at the main falls, a light gray, distinctly quartzose and thin-laminated slate (2,103) alternates with layers six inches to one foot in thickness, of a dark gray, granular-textured rock (2,104), the thin section of which, under the microscope, presents an appearance similar to that of 2,108, except that the matrix is now thickly dotted with a blackish material that is not magnetite. At the extreme northern end of the exposures a similar alternation is noted. The thin-laminated and more highly slaty layers are here jet-black and aphanitic, while the granular rock of the heavier layers is coarser than any yet noted. Under the microscope, the latter presents almost exactly the same appearance as the quartz-schists (1,496) of XV of the Bad river section. The individual quartz grains run from 0.18 mm. to 0.54 mm. in length. With them are also some equally large, cloudy orthoclase grains, and a few of plagioclase, the clastic nature of the rock being very pronounced.

Formation XIX. Greenstone-Schist.

This important layer is known only in the vicinity of Bad river, where it has an apparent width of 290 feet. The rock is exceedingly close-grained, aphanitic, dark gray to nearly black, and massive to thin-schistose. The thin sections, beneath the microscope, appear to be chiefly made up of chlorite altered from hornblende, and an alteration product of plagioclase, with pyrite and magnetite as accessories, the former being frequently visible macroscopically.

The exposures of this layer in the vicinity of Bad river are very large, presenting themselves in the shape of a narrow ridge 150 to 170 feet in height and several hundred paces in width, rising precipitously from the low ground around. The eastern end of this bluff lies a few paces west of the west line of Sec. 11, T. 44, R. 3 W., between stations 55 and 251 of Atlas Plate XXIII. The rock seen here (1,442, 1,443, 1,483 to 1,487) is essentially uniform, the variations being only slight ones, in the fineness of grain and in the thickness of the schist layers, which run from massive ones, many feet in thickness, to those that are quite thinly slaty. The mineral composition of the rock is given in detail in Appendix B, the main ingredients having already been mentioned. Much of the iron sulphide is strongly attracted by the magnet, and is therefore pyrrhotite, instead of pyrite.

Formation XX.

Immediately north of XIX, in the vicinity of Bad river, we find a wide blank. Part of this blank is filled by exposures of mica-schist (XXI) in the vicinity of English lake, but there remains an unfilled gap of about 525 paces, to which the number XX is given. It is not improbable, however, that we have here merely a continuation downwards of the mica-schist of XXI.

Map of part of
T. 44 R. 3 W.
designed to show the relations of the
LAURENTIAN HURONIAN and KEWEENAW SYSTEMS
R. D. Irving 1873-1877

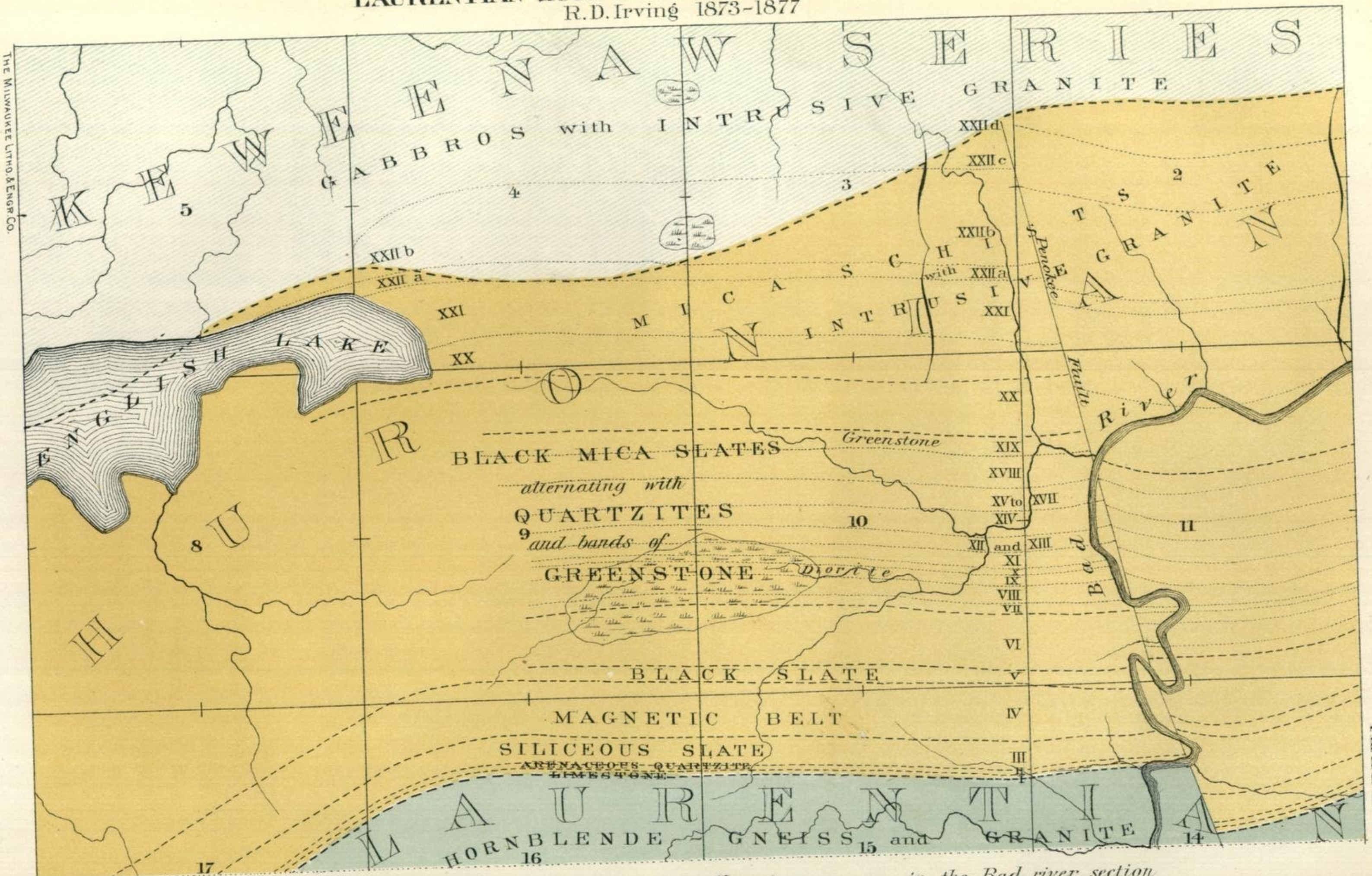


PLATE XV B.

Roman numerals refer to subdivisions of the Huronian as seen in the Bad river section

... the Huronian Mica Schist, and the Keweenawan Gabbro, in Sec. 4, is based on locations

Formation XXI. Mica-Schist, with Intrusive Granite.

This formation is best known from the numerous and often large exposures in the northern sections of T. 44, R. 3 W., from English lake to Bad river. West of English lake its stratigraphical position is found to be occupied by the coarse gabbro which forms the base of the overlying Keweenaw series. East of Bad river, however, this member is evidently continuous for the greater part of the length of the Huronian belt, but as yet is known here only from somewhat scattered, and, with a few exceptions, small exposures.

On Bad river. The exposures of these layers are not large in the immediate vicinity of Bad river. The ledges seen, however, are of interest as occurring in the immediate vicinity of others of the coarse gabbro of the overlying Keweenaw series. These exposures are on the west side of the railroad, in the northwest quarter of the northeast quarter of Sec. 6, T. 44, R. 2 W. (Nos. 18, 19, 20, Atlas Plate XXIV). The rock seen here (2,039), with a width of some 50 feet, is very fine-grained, grayish and quartzose, with very fine mica flakes macroscopically visible, some reaching as much as one-fourth of an inch in length. Under the microscope, the ground-mass is seen to consist of very fine quartz, through which are scattered numerous minute, greenish, chlorite-like flakes and large blades of biotite, 18 mm. to 9 mm. in length. Nearly all of these are vertical sections, showing the cleavage very beautifully. The appearance under the microscope of a thin section of this rock is shown in Fig. 3, Plate XV C, magnified 53 diameters, the lower nicol only attached to the microscope. One biotite blade is figured in the section in three positions, showing the dichroism.

West of Bad river. In the sections immediately west of Bad river, as far as English lake, ledges of mica-schist are frequent, occurring for the most part on the south slope of the ridge next north of the Penokee Range. Taken altogether, these exposures acquaint us with nearly the whole thickness existing here of this portion of the series. The lowest layers seen are those exposed on the south shore of English lake, on the northwest quarter of Sec. 9, T. 44, R. 3 W., less than 100 paces from the section line, where is a ledge 50 feet long and 15 feet high. The rock seen here (73) is fine-grained to aphanitic and dark grayish-black, with rather distinct lamination, and sp. gr. 2.53. Under the microscope, the thin section shows a white ground-mass composed almost wholly of quartz, through which are scattered numerous minute flakes of biotite. The pulverized rock yields no magnetite. On the north shore of the lake the same rock (74) is seen on the southwest quarter of Sec. 4, 100 feet east of the section line, and again further west along the lake shore (77, 78, 79), a few rods east of the outlet of the lake. Other exposures are seen for some 500 paces north of the lake, on the west line of Sec. 4. All of these places show essentially the same rock (75; sp. gr., 2.96). The ledge mentioned as near the outlet of the lake is some 200 feet in length, showing about 40 feet in thickness of very distinct layers, running from one-eighth of an inch to twenty-three inches in width. The strike is N. 65° E., and the dip 74° N. Under the microscope, a thin section of this rock shows that it is the same as that from the south shore of the lake, but much coarser; the mica-flakes and blades often much shattered, running from 0.04 mm. to 0.14 mm. in length. These mica particles present two general colors, a very light yellowish-gray characterizing those in which the basal cleavage is apparent, while those lying in the plane of the section are from a yellowish-brown to a reddish-brown, the latter color being the result of an ochreous decomposition. Scattered through the quartz ground-mass are also black particles, both of magnetite and hematite, the latter often 0.3 mm. in diameter and of hexagonal shape. The appearance of the thin section of this rock magnified 53 diameters is shown on Fig. 1 of Plate XV C.

From their position, it is evident that the exposures in the vicinity of English lake stretch over a large portion of the blank above XIX in the Bad river section. This will be best understood from an inspection of Plate XV B.

Other large and continuous exposures of these mica-schists are seen on and near the west line of Sec. 2, T. 44, R. 3 W. Beginning 30 paces north and 50 east of the southwest corner of Sec. 2, we find, in the bed and on the sides of a small and rapid stream flowing southward, exposures extending northward for over 400 paces. The southernmost of these shows a very plainly-bedded, in places slaty rock (2,001), striking N. 65° to 70° E., which both macroscopically and microscopically is nearly identical with that seen on the south shore of English lake. A full description of a thin section of this rock will be found in Mr. Julien's report. One hundred paces further north there is a change to a lighter colored kind (2,002; sp. gr., 2.69), the lighter color being due, as shown under the microscope, to the presence of numerous grains of quartz which are much larger in size than those of the matrix, reaching 0.28 mm. in diameter. At 150 paces the rock (2,003; sp. gr., 2.68) is darker again, and at 200 paces, quite light-colored and highly quartzose. Further north to 430 paces, the exposures are poor.

At 500 paces north from the southwest corner of Sec. 2, after passing an interval without exposures, we meet a light gray, highly micaceous

ROCKS OF THE HURONIAN AND KEWEENAW SYSTEMS.

The Milwaukee Litho. & Engr. Co.

R. D. Irving, 1878.

Fig. 1. Mica Schist (78) Formation XXI; north shore of English Lake. S.E. ¼, Sec. 5, T. 44, R. 3 W.; × 53.

Fig. 2. Biotite Granite (2009) cutting Formation XXII; east line. S.W. ¼, Sec. 3, T. 44, R. 3 W.; × 15.

Fig. 3. Mica Schist (2039 Formation XXII; N.E. ¼, Sec. 6, T. 44, R. 2 W.; showing dichroism of biotite × 53.

Fig. 4. Showing relation of augite and hornblende in Hornblende Gabbro (2020); west line N.W. ¼, Sec. 2, T. 44, R. 3 W.; × 53.

Fig. 5. Another part of same section; × 53.

rock (2,005; sp. gr., 2.62), which differs from the foregoing kinds in containing an abundance of macroscopically visible black and silvery mica, the latter much the coarser. Twenty-five paces further north we find a change to a very light-gray, highly quartzose. fine-grained kind (2,006; sp. gr., 2.65), in which are visible very close lamination-lines, marked by thickly crowded, fine, black mica scales, which are also disseminated throughout. The thin section of this rock, under the microscope, shows quartz greatly predominating, in grains from 0.09 to 0.18 mm. in diameter; orthoclase, cloudy and as large as the quartz, though less abundant; and biotite, in scales like those in the rock from English lake, but much more sparsely scattered, the blades having a general length of 0.22 mm. This rock extends for 22 paces, when it gives place to a coarser kind (2,007), similar to that which preceded it (2,005). Only a few paces beyond this gives way again to a light-colored variety (2,008), as before. In contact with this, and penetrating it, we find a coarse, pink-white-and-black-mottled granite (2,009), containing pink orthoclase up to four-tenths of an inch in diameter; gray translucent quartz up to two-tenths inches; black lustrous biotite, abundant in fine flakes; and much rarer whitish plagioclase, up to one-tenth inch. The appearance of a thin section of this rock, magnified 15 diameters, is given in Fig. 2, Plate XV C. On the north side of this ledge, at 555 paces north of the section corner, a fine-grained, dark gray mica-schist is seen, in which the fine, glistening, black biotite scales predominate over the other ingredients. The thin section shows that we have here essentially the same rock as seen on the shore of English lake (78), and figured at Fig. 1, Plate XV C, the only difference being the much larger quantity of mica scales. Just beyond this rock is seen more of the light-gray highly quartzose kind described several times before.

Following the section line northward, we pass a blank of 35 paces to a point 595 paces north of the corner. Here we find fine-grained, black mica-schist (2,015) glistening with the minute mica scales, and penetrated by a large quantity of very coarse, porphyritic, pink granite (2,014). At 625 paces the fine-grained, black mica-schist (2,017, 2,018) is again seen.

Further north on this line there are no ledges as far as 285 paces north of the west quarter-post of Sec. 2, where is an exposure of hornblende-gabbro of the Keweenawan series.

Within Sec. 2 are a number of other outcrops of these members of the series, showing the essential continuity of the rock. Only a few of these were located with sufficient accuracy to be placed on the map.

About 100 paces north and 500 east of the southwest corner of Sec. 2, are exposures of blackish mica-schist (1,488). Another large exposure 350 paces north and 550 east of the same point shows a coarser kind (1,490, 1,491, 1,492), which has evidently been shifted southward by the fault. The rock seen here is plainly laminated and even gneiss-like. Fine glistening black mica, weathering brown, is very abundant, and readily seen macroscopically. The lighter bands contain quartz and feldspar. In one place a narrow band of diorite was noted, possibly a dike.

East of Bad river. A number of exposures of the layers of this formation have been observed extending all the way to the Michigan line. These outcrops are for the most part, however, distant from each other.

On the north line of Sec. 5, T. 44, R. 2 W., about 500 paces west of the northeast corner, is a steep bluff facing north and west towards the valley of a small branch of Bad river. The top of this bluff, for several hundred paces, shows nearly continuous rock exposures, in some cases with a height of as much as 25 feet. South of the section line the face of the hill curves more and more to the west, and finally to a southeasterly direction (Atlas Plate XXIV). On the section line, and for about 50 paces southwest along the face of the hill, the rock in sight is a rather fine-grained, dark-gray gabbro, as described on a subsequent page. Beyond this point southward it is a dark-colored to nearly black, very fine-grained mica-schist (3,172) sparkling with minute mica facets, and resembling closely much of the rock seen on the west line of Sec. 2, T. 44, R. 3 W. Under the microscope we have the usual background of quartz and orthoclase, sparsely scattered through which are elongated, highly dichroitic mica blades, reaching 0.18 mm. in length. Further south along the cliff gabbro again appears to come in, thus apparently penetrating the mica-schist in branches.

Further east, in the southeastern part of T. 45, R. 2 W., the mica-schist belt widens considerably, and we meet here higher layers than those seen in the vicinity of Bad river. These upper layers, which are recognizable from here all the way to the Montreal river, are much less micaceous than the lower parts of the formation, often grading into a light gray quartz-schist, the thin section of which under the microscope shows an aggregation of angular quartz grains with less abundant ones of orthoclase, and displays often a great similarity to the thin section of the quartz-schists of Formations XV to XVIII.

In T. 45, R. 2 W. these light gray rocks are exposed in the stream near the south quarter-post of Sec. 27, and again, feebly, in the stream on the south line of the southwest quarter of Sec. 26. In the former place there is a fall of the creek over this schist, which has here a width of some 20 paces, strikes N. 72° E., and dips at a high angle to the northward. As seen here the rock (3,164, 3,165) is very fine-grained, light gray, porous-textured, and very distinctly and evenly bedded, often showing on close inspection even a fine lamination. Under the microscope the thin section appears made almost wholly of minute angular quartz and orthoclase grains, and rare particles of chlorite and mica. The rock exposed in the stream on the south line of Sec. 26 is precisely similar in its characters.

The lower layers of XXI are again in sight in the bed of Tyler's Fork, on the south line of Sec. 21, T. 45, R. 1 W. The exposures are not large, but indicate in all a width of not less than 150 paces. The northernmost observed are 50 paces north of the section line. The rock (2,097, 2,098, 2,099) is a black, aphanitic, conchoidal-fracturing slate.

Other exposures of XXI are known in the northeast quarter of Sec. 13, T. 45, R. 1 W., where the rock is a dark gray to black aphanitic slate belonging to the middle or the lower portion of the formation; in the bed of Potato river, on the east line of the southeast quarter of Sec. 12 of the same township, where the rock is a fine-grained, very dark gray quartz-schist, the thin section of which bears a close resemblance to that of the quartz-schist of XV on Bad river; near the southeast corner of Sec. 6, T. 45, R. 1 E., where are large exposures of an aphanitic, dark to light gray, slaty, quartzose mica-schist, belonging very near the top of the formation; in the northern part of Sec. 3, T. 45, R. 1 E., and southern part of Sec. 34, T. 46, R. 1 E., where the rock is very much the same, and at the same horizon as the last point named; in the west part of Sec. 36, T. 46, R. 1 E., where black slates and light gray quartz-schists are associated together; in about the southeast quarter of Sec. 25, T. 46, R. 1 E., where the rock is dark gray, aphanitic, slaty, and highly pyritiferous, and, as shown under the microscope, largely composed of angular quartz and orthoclase grains from .045 mm. to .13 mm. in diameter; in the southwest quarter of Sec. 30, T. 46, R. 2 E., where the same rock is seen; and in the vicinity of the Lac Flambeau trail, northwest quarter of Sec. 29, T. 46, R. 2 E., where the rock is exactly the same quartzose kind; all of the four last named exposures being in the upper part of the formation. A fine-grained, red, feldspathic quartzite exposed in the immediate vicinity of large ledges of diabase-amygdaloid of the Keweenaw series near the Montreal river, and in the extreme northeast corner of Sec. 14, T. 46, R. 2 E., belongs also to the uppermost beds of this formation.

THE PENOKEE FAULT.

This interesting break has been alluded to in the foregoing pages a number of times, but no particular account of it has yet been given. The main facts which determine its existence and exact position are therefore briefly stated here, further details being supplied by the large-scale map of the vicinity of Penokee Gap, Atlas Plate XXIII. For a clear understanding of what follows, this map must constantly be consulted. It may be said here that the dislocation, though so absolutely determined by the facts in hand, is by no means readily perceived on the ground, the heavy forests that everywhere clothe the surface of the country making it impossible to form any correct idea of the relative positions of ledges, except by actual measurement. The recent clearing and excavation along the line of the Wisconsin Central have now somewhat lessened these difficulties.

Referring to Atlas Plate XXIII, we note the principal facts that determine the fault, beginning at the southern side of the Huronian.

Following the north-85°-east strike-lines of the large surfaces of slate (III) seen on the flanks of the hill near stations 143, 144, etc., eastward, we come, after crossing a blank space less than 200 paces in width, upon cliffs of banded magnetitic quartz-schist rising from the east bank of Bad river. The northern end of these does not reach as far north as the northern border of the slate, while to the southward the exposures of magnetitic rock extend, not only entirely beyond the slate in that direction, but also across the courses of the limestone (I) and quartzite (II), and of the Laurentian gneiss, as seen on the river and in the railway cutting near station 122. That these magnetitic schists are the same as those found north of the siliceous slate (III), on the west side of Bad river, is proven by (1) the existence of the same subdivisions in both; (2) the occurrence of exposures of siliceous slate south of the eastern magnetitic schists; (3) the direct continuity of the magnetitic schists on both sides of the fault with the single magnetic belt of the Penokee Range, beneath which is always found the same siliceous slate; and (4) by magnetic observations. By noting the arrows on the map and sections of Plate XXIII, and on the other detail-maps of the Huronian, it will be observed that the greatest deviations of the needle from the normal direction occur always just on the northern edge of the magnetic belt, the whole body of the attracting mass exerting its influence in one direction. The arrows of the east and west row that follow the northern edge of the magnetic belt, *west* of the fault line, suddenly recover from their abnormal directions *east* of that line. Moreover, in order to find a row of south-pointing arrows *east* of the fault line, we must move southward 300 paces, or to the northern edge of the magnetitic schists east of Bad river.

Continuing our references to Plate XXIII, we note, east of the fault line, on the bank immediately above station 150, and close to the railroad track, large ledges of black slate (V). These extend south to contact with the underlying magnetic belt, a thin layer of aphanitic garnetiferous actinolite-schist marking the junction. Following the north-of-west strike-lines of the slate westward, we encounter, in a distance of only 100 paces, faces of the banded magnetitic rock of IV, rising from the west bank of Bad river, while 300 paces further west, other larger ledges of IV extend entirely across the apparent position of the black slate. Searching now for the black slate west of the fault in its true position north of the magnetic belt, we fail to find it exposed, but the peculiar garnetiferous rock that marks its base is seen in a continuous ledge for several hundred paces eastward from station 32. The occurrence of such a narrow and peculiar layer serves to fix very exactly the amount of dislocation.

While the facts thus far given serve to demonstrate the existence of a fault, and to determine the amount of displacement, they do not fix the position of the fault line, the width of the open space between the ledges on either side of the break leaving it possible for this line to trend in any direction from due north to 25° west of north. As far as the lower layers of the series are concerned, this is a matter of no importance; but farther north, unless the course of the break is quite closely known, it becomes doubtful as to the side of the fault on which several important exposures belong, and an uncertainty as to the true succession of layers is thus introduced. Fortunately, however, the exposures in the vicinity of the falls of Bad river, in the southwest quarter of Sec. 11, serve to fix the exact position of a part of the northern extension of the line, and so to determine its whole course closely enough. The ledges referred to are seen near stations 214, 215, etc., of Plate XXIII, in the bed of Bad river, on the sides of the railway cutting just east, and in the excavations between. The rocks seen here have already been described in detail on pages 139 to 140. That in the river is a massive diorite, while the cutting and excavations east of it show a black aphanitic mica slate. The fault line beyond doubt passes between the two, since the diorite lies directly across the course of the slate. To determine more exactly the relative positions of these exposures, a series of transit and chain measurements was made by Mr. Thomas Barden, of Ashland, under my instructions. These served to confirm entirely the rougher measurements I had made with hand compass and pacing. The abnormal northwest direction of the slate layers in the cutting, and the remarkable display of dislocation just west, are evidently connected with the proximity of the fault line.

The southern part of the break, as placed on the map, is made to pass up the ravine near station 135, because the high rounded hill to the west appears to be made up of the Laurentian gneiss and granite.

To the northward, the fault evidently extends quite across the Huronian series, but, on account of the great thickness of the upper mica-schist members, and the great distance between exposures, it would be impossible to determine here the amount of dislocation.

An inspection of the map of Plate XXIII will bring out the interesting fact that, near to the line of displacement, the strike directions of the several layers are abnormal, there being a curve northward towards the line on both sides, but much more marked on the east. This may be explained, on the supposition that the fault is a vertical one, by the warped condition of the several strata, before faulting. Regarding the displacement as a horizontal one, the pressure coming from the south, the bending of the strike lines may be looked upon as due to the rubbing of the sides of the fault.

It is quite impossible to determine whether the displacement is vertical or horizontal. The former kind is the common one, the horizontal displacement in such cases being apparent only, and resulting from the inclined position of the strata. Looking at it in this light, the "down-throw" is on the east side, and the total amount of vertical descent over 1,700 feet, as figured from the apparent horizontal dislocation and dip angle. It is evident that this is a point of practical importance, since if this explanation is the correct one, the exposures of magnetic rock on the east of the fault line tell us what we would find on the west side of the break, after sinking about 1,900 feet in the direction of the dip. The cause for a horizontal displacement could readily be found in the tangential pressure inward of the sides of the Lake Superior trough, but how a limited horizontal shove could take place against an unyielding mass of rock it is difficult to perceive.

ECONOMIC GEOLOGY OF THE HURONIAN SERIES.[1]

The only materials occurring in this series of probable economic importance are the iron ores. All experience in the regions bordering the southern side of Lake Superior has shown that the iron ores, which here often reach a quite extraordinary development in richness and purity,

[1] In Vol. I of this series of reports, the writer gives a general practical discussion of the principles of which a knowledge is essential to the iron explorer, more especially with reference to the Huronian formation of the Lake Superior country. These points are therefore not here treated of.

are entirely restricted to the Huronian, none at all occurring in the Laurentian or Keweenawan systems, or in the horizontal Lower Silurian sandstones. This fact being recognized, it will at once be seen that the accurate tracing of the boundaries of the Huronian area becomes a matter of great practical importance. This has been done with care, and the results given on the accompanying maps, so that the possible iron-bearing ground is definitely known. Moreover, the stratigraphy of the series having been largely worked out, the ground that is possibly iron-bearing is restricted within still narrower limits. In the famous Marquette region of Michigan it has thus far been the experience that all workable deposits of ores of iron have been found in connection with one particular member of the series, while below there are several beds holding leaner ores, or magnetitic and specular schists. It is shown on a subsequent page that there is at least a remarkable similarity between the succession of layers in the Penokee series and that of the Marquette; and, moreover, that the equivalents of the several lower layers of lean ore as known in Michigan are to be found in the "magnetic belt," IV of the Penokee system. It is also shown that the approximate equivalent of the rich ore belt of the Marquette series is to be found in VI of the Penokee series, which has a width of over 900 feet, and is for the most part a drift-covered blank, without exposures, no ore as yet being known to exist within its limits. The subject resolves itself at once then into two divisions, (1) the value of the iron ores of the magnetic belt, and (2) the question of the probable existence of ores in a higher portion of the series.

The Magnetic Belt. The existence of the magnetic belt of the Huronian of north Wisconsin was first noted in 1848 by Dr. Randall, one of the corps of geologists under Dr. D. D. Owen, whilst following the Fourth Principal Meridian northward. The next season Col. Charles Whittlesey, also one of Dr. Owen's assistants, traced the magnetic belt from the point found by Dr. Randall, westward to the vicinity of English lake.[1] In Dr. Owen's final report are given the results of Col. Whittlesey's explorations, covering several pages. No analyses were made, except one or two of picked specimens, which, of course, showed a high percentage of iron, though even one of these yielded over 20 per cent. of silica. Col. Whittlesey's opinion appears to be summed up in the statement that bruising and stamping is "a process which all must undergo in order to be profitably worked in the forges."[2] Soon after the publication of Dr. Owen's report, quite an excitement was raised with regard to iron in the Lake Superior country, and nearly every quarter-section along

[1] Owen's "Geological Survey of Wisconsin, Iowa and Minnesota," p. 444.

[2] Ibid., p. 447.

the Penokee Range had erected on it a preëmptor's cabin.[1] No actual mining, however, was attempted, and the locations were soon abandoned. In 1860, Col. Whittlesey made a second survey of the region, on part of the state of Wisconsin, but his report was never published. Some of the results of his later surveys are, however, briefly given in several reports to mining companies, and other pamphlets. He appears to have thought well of the qualities of the ores, although recognizing their siliceous character, and to have recommended to several companies the opening of mines, and the erection of iron works.[2] No analyses are referred to in these later reports, other than those of Dr. Owen — made, as already said, on picked specimens.

In 1858 Dr. I. A. Lapham examined the magnetic belt of the Penokee Range from Tyler's Fork to the end of the ridge in Sec. 24, T. 44, R. 4 W., on behalf of a Milwaukee iron company, to whom he made a report which was afterwards published. The opinion he formed of the ore belt is given in the following words:[3] "It will be seen that we have already discovered good ore in such quantities as to be practically inexhaustible, situated at points accessible to water-power and having bold fronts, rendering it comparatively easy to be quarried. For many years to come only the richest and most accessible ores can be brought into use, rejecting, at least for the present, all such as have too large a proportion of silica, and as are not in a condition to be easily and cheaply removed from the natural bed." Dr. Lapham does not refer to any new analyses.

In order to form as nearly correct an opinion as possible from the facts in hand, it is necessary to remember, first of all, that, to be workable, these hard or siliceous ores, the only kind likely to be found in connection with the magnetic belt, except, perhaps, at its eastern end, must occur in a deposit a number of feet in thickness, containing as a whole not less than 50 per cent. of metallic iron; while for a first class ore, the iron content must be over 60 per cent. These figures are determined partly by the nature of the ore — a quartzose mixture always raising the percentage at which an iron ore may be profitably treated — but also largely by the great abundance of the richer ores in the neighboring portions of Michigan. The large amount of these richer ores occurring in the Marquette and Menomonee districts renders unmerchantable the much greater quantities of the leaner ores existing in the same regions.

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[1] The Penokee Iron Range, by Charles Whittlesey. Proc. Boston Soc. Nat. Hist., Vol. IV, July 1863.

[2] Report to the Magnetic Iron Company, Cleveland, Ohio, 1872.

[3] The Penokee Iron Range, Milwaukee, 1859.

In order conclusively to prove the percentage of iron in the outcropping ores of the Penokee Range, during the field work of 1873, a very carefully selected series of samples for analysis was obtained from every outcrop visited. This was, indeed, quite unnecessary to one experienced in the recognition of iron ores, but was resorted to in obedience to instructions, and also that the conclusions reached might be based on something more than expert opinion. The samples for these analyses were never single specimens, but were obtained by breaking small fragments from all across the faces of exposures. From these, after breaking and thoroughly mixing on the ground, smaller samples of about a pound or so in weight were selected. These were still farther pulverized and mixed in the laboratory, before analyzing. As a rule, those outcrops, in which the rock admixture was more than usually great, were not sampled, so that the analyses may be taken as representing the very best of the outcropping ores. Some of these analyses have already been given in connection with the detailed description of the magnetic belt, but all are grouped together here for convenience of reference. With each analysis is mentioned the exact location of the ledge from which the sample was taken, and the number of feet in thickness represented, the thickness being of course measured at right angles to the bedding. In the pages describing the magnetic belt, each of the ledges represented by the analyses, as also a number of others, will be found described in detail.

TABLE I—AT PENOKEE GAP.

	1.	2.	3.	4.	5.	6.	7.	8.
Metallic iron	44.941	17.103	49.40	36.693	44.03	45.871	41.465	19.203
Phosphorus	none.	......	none.	trace.	trace.	0.009	......	......
Sesquioxide of iron	42.897	15.535	......	34.770	......	43.885	49.157	......
Protoxide of iron	19.173	7.851	......	15.819	......	19.479	9.070	......
Silica	31.838	......	27.03	42.896	34.06	30.734	......	......
Alumina	0.384	......	......	none.	......	none.	......	......
Lime	1.373	......	......	1.330	......	1.910	......	......
Magnesia	1.293	......	......	2.623	......	1.632	......	......
Manganese oxide	1.126	......	......	1.726	......	0.873	......	......
Phosphoric acid	none.	......	none.	trace.	trace.	0.021	......	......
Sulphur	none.	......	......	trace.	......	none.	......	......
Water	0.378	......	......	0.471	......	0.545	......	......
Totals	98.462	......	......	99.735	......	99.079	......	......
Magnetic oxide	50.668	23.386	......	50.389	......	62.754	29.225	......
Specular oxide	11.402	none.	......	none.	......	0.610	29.002	......
Totals	62.070	23.386	......	50.389	......	63.365	58.227	......

NOTES.—All of the above taken from the "west bluff" at Penokee Gap, northwest quarter Sec. 14, T. 44, R. 3 W. See description elsewhere. 1 represents thickness of 19 feet; 2, 7 feet, 6 inches; 3, 18 feet; 4, 10 feet; 5, 36 feet; 6, same, a little higher up; 7, 4½ feet in 5; 8, one foot.

TABLE II.—AT PENOKEE GAP.

	9.	10.	11.	12.	13.	14.
Metallic iron	43.292	62.21	57.520	13.801	51.373	68.042
Protoxide of iron	16.598	....	24.602	....	....	....
Sesquioxide of iron	43.402	....	54.825	....	....	....
Silica	....	....	17.276	....	....	....
Insoluble siliceous matter	40.693	....	....	....	....	....
Alumina	....	....	none.	....	....	....
Lime	....	....	2.043	....	....	....
Magnesia	....	....	0.660	....	....	....
Manganese oxide	....	....	0.625	....	....	....
Phosphoric acid	....	....	trace.	....	....	....
Sulphur	....	....	trace.	....	....	....
Water	....	....	0.282	....	....	....
Totals	100.693	....	100.323	....	....	....
Magnetic oxide	53.482	....	79.273	....	....	....
Specular oxide	6.518	....	0.154	....	....	....
Totals	60.000	....	79.427	....	....	....

NOTES.—9, "Banded Ore," 7 feet; 10, layer of magnetite in 9, 2 inches; 12, rock between seams of magnetite in 9; 11, granular magnetite, 10 inch seam, richest portion; 13, same, average of whole 10 inches; 14, seam of magnetite in banded ore.

TABLE III. — WEST OF PENOKEE GAP.

Northeast Quarter of Sec. 15, T. 44, R. 3 W.

	15	16	17	18	19	20	21	22[1]	22[2]	23
Metallic iron....	2.037	11.23	41.192	30.806	30.132	38.409	45.074	56.98	56.89	44.44
Sesquioxide of iron	......	......	49.435	29.18	27.800	37.207	59.147	......	......	.....
Protoxide of iron	......	......	8.460	13.345	13.341	15.896	4.719	......	......	.....
Silica.........	......	......	33.894	......	......	......	......	......	......	.....
Alumina	......	......	1.151	......	......	......	......	......	......	.....
Lime	......	......	3.156	......	......	......	......	......	......	.....
Magnesia	......	......	2.403	......	......	......	......	......	......	.....
Manganese oxide	......	......	0.337	......	......	......	......	......	......	.....
Phosphoric acid.	......	......	none.	......	......	......	......	......	......	.....
Sulphur........	......	......	none.	......	......	......	......	......	......	.....
Water	......	......	1.500	......	......	......	......	......	2.29	.....
Totals	......	......	100.336	......	......	......	......	......	......	.....
Magnetic oxide.	......	......	27.260	42.525	......	51.220	15.205	.....	......	.....
Specular oxide..	......	......	30.635	none.	......	1.883	48.661	......	......	.....
Totals	......	......	57.895	42.525	......	53.103	63.866	......	......	.....

[1] Hard portion. [2] Soft portion.

NOTE. — Nos. 15 to 21 from exploring trench, northeast quarter Sec. 15, T. 44, R. 3 W., 15, represents 16 feet 4 inches; 16, 5 feet; 17, 41 inches; 18, 56 inches; 19, 40 inches; 20, 13 inches; 21, 3 feet. Nos. 22 and 23 from Penokee Mine, northeast quarter, Sec. 15; 22, selected samples of 200 pounds, the soft portion very highly manganiferous; 23, sampled by E. T. Sweet in 1875 from whole stock pile.

TABLE IV. — WEST OF PENOKEE GAP.

On the Penokee Iron Range.

	24.	25.	26.	27.
Metallic iron...........................	49.730	37.751	48.120	38.752
Sesquioxide of iron......................	....	36.414	....	....
Protoxide of iron........................	....	15.767	....	....
Silica	....	39.532	....	....
Alumina..................................	....	0.110	....	....
Lime.....................................	....	1.516	....	....
Magnesia.................................	....	2.516	....	....
Manganese oxide	....	3.120	....	....
Phosphoric acid..........................	....	trace.	....	....
Sulphur..................................	....	0.421	....	....
Water....................................	....	0.543	....	....
Total....................................	....	99.939	....	....
Magnetic oxide...........................	....	50.804	....	....
Specular oxide...........................	....	1.377	....	....
Total....................................	....	52.181	....	....

NOTES. — 24, northwest quarter of Sec. 16, T. 44. R. 3 W., "slaty ore," 15 feet 25, southwest quarter of Sec. 17, T. 44, R. 3 W., "slaty ore," 40 feet. 26, same place, "banded ore," 75 feet. 27, Sec. 18, T. 44, R. 3 W., near center of section, 3 feet.

TABLE V.—WEST OF PENOKEE GAP.

Town 44, Range 5 W.

	28.	29.	30.
Metallic iron	41.994	45.00	26.642
Sesquioxide of iron	40.062	....	....
Protoxide of iron	17.930	....	....
Total	57.992	....	....
Magnetic oxide	57.992	....	....
Specular oxide	none.	....	....
Total	57.992	....	....

NOTES.—28, small exposure in Sec. 14, T. 44, R. 5. W., 3 feet. 29, northwest quarter Sec. 23, T. 44, R. 5 W., "slaty ore," 150 feet. 30, "slaty ore," northwest quarter Sec. 21, T. 44, R. 5 W. 75 feet.

TABLE VI.—EAST OF PENOKEE GAP.

Between Penokee Gap and Mt. Whittlesey.

	31.	32.	33.	34.	35.	36.
Metallic iron	53.465	44.43	45.256	51.389	37.001	47.228
Phosphorus	0.055	....	....	....	....	....
Sesquioxide of iron	67.064	....	....	....	....	....
Protoxide of iron	8.382	....	....	2.239	....	....
Silica	18.472	....	....	....	....	....
Insoluble siliceous matter	....	....	34.774	27.020	47.500	30.653
Alumina	0.305	....	....	....	....	....
Lime	2.483	....	....	....	....	....
Magnesia	2.280	....	....	....	....	....
Maganes oxide	1.050	....	....	....	....	....
Phosphorc acid	0.127	....	....	....	....	....
Sulphur	none.	....	....	....	....	....
Water	0.450	....	....	....	....	....
Total	100.613	....	....	....	....	....
Magnetic oxide	27.008	....	....	....	....	....
Specular oxide	48.438	....	....	....	....	....
Total	75.446	....	....	....	....	....

NOTES.—31, northeast quarter Sec. 14, T. 44, R. 3 W., specular magnetite, 50 feet; 32, same exposure 40 rods west, 5 feet; 33, northeast quarter Sec. 13, T. 44, R. 3 W., represents 40 inches in thickness; 34, same place, 50 feet higher in the bed, represents 5 feet in thickness; 35, northeast quarter Sec. 18, T. 44, R. 2 W., long exposure in windfall, represents 10 feet in thickness of best ore; 36, northwest quarter Sec. 17, T. 44, R. 2 W., represents 4 feet in thickness.

TABLE VII.—EAST OF PENOKEE GAP.

	37.	38.	39.	40.	41.	42.	43.
Metallic iron	41.934	47.245	12.99	47.245	47.29	37.885	25.64
Sesquioxide of iron	41.241	......	......	......	......	40.420	......
Protoxide of iron	16.797	......	......	......	......	12.331	......
Silica	36.508	......	......	......	......	39.171	......
Insoluble siliceous matter	......	28.464	......	......	......	......	......
Alumina	1.025	......	......	......	......	1.139	......
Lime	1.383	......	......	......	......	1.373	......
Magnesia	2.156	......	......	......	......	1.890	......
Manganese exide	0.193	......	......	......	......	0.553	......
Phosphoric acid	trace.	......	......	......	......	trace.	......
Sulphur	0.160	......	......	......	......	none.	......
Water	1.078	......	......	......	......	2.559	......
Totals	100.541	......	......	......	......	99.036	......
Magnetic oxide	......	......	......	......	......	39.733	......
Specular oxide	......	......	......	......	......	13.018	......
Totals	......	......	......	......	......	52.751	......

NOTES.—37, Southwest quarter Sec. 10, T. 44, R. 2 W., Gutzenberger's trench, 58 feet; 38, northwest quarter Sec. 11, T. 44, R. 2 W., 8 rods south of section line, in the bed of Carrie's creek—shows a thickness of 3 feet; 39, southwest quarter Sec. 1, T. 44, R. 2 W., represents thickness of 15 feet; 42, slaty and banded ore, 25 feet below 39—20 feet; 41, more ferruginous seams in 42; 40, one of the purest seams in 42; 43, southwest quarter Sec. 6, T. 44, R. 1 W., represents 4 feet in thickness.

TABLE VIII.—EAST OF PENOKEE GAP.

	44.	45.	46.	47.	48.	49.	50.	51.
Metallic iron	37.22	25.816	67.665	35.449	41.29	35.14	40.01	32.85
Sesquioxide of iron	......	......	65.913	49.254	......	......	......	......
Protoxide of iron	......	......	27.488	5.112	......	......	......	......
Silica	......	......	4.684	......	......	......	......	52.00
Insoluble siliceous matter	46.75	54.630	......	......	......	41.24	......	......
Alumina	......	......	none.	2.059	......	......	......	2.00
Lime	......	......	1.786	1.687	......	......	......	0.80
Magnesia	......	......	none.	1.586	......	......	......	0.76
Manganese oxide	......	......	0.563	0.193	......	......	......	......
Phosphoric acid	......	......	none.	none.	......	......	......	......
Sulphur	......	......	trace.	0.199	......	......	......	......
Water	......	......	......	trace.	......	......	......	1.30
Totals	......	......	100.434	100.183	......	......	......	......
Magnetic oxide	......	......	88.572	......	......	......	......	......
Specular oxide	......	......	4.829	......	......	......	......	......
Totals	......	......	93.401	......	......	......	......	......

NOTE.—44, 500 feet west of gorge of Tyler's Fork; represents 3 feet, rock and ore seams. 45, southeast quarter of Sec. 32, T. 45, R 1 W.; represents 15 feet in thickness, including rock and ore seams. 46, same place, ore seams. 47, 300 feet east of 45, siliceous hematite, 15 inches. 48, siliceous hematite, gorge of Tyler's Fork, 20 inches. 50, gorge of Tyler's Fork, 20 inches, slaty ore. 49, same place, north end, 6 feet. 51, analysis by J. L. Cassells of sample of slaty ore from gorge of Tyler's Fork.

TABLE IX.—EAST OF PENOKEE GAP.

Between the Gorge of Tyler's Fork and the Potato River.

	52.	53.	54.
Metallic iron	40.861	37.939	68.890
Insoluble residue	....	44.661	1.399

NOTES.—52, southeast quarter Sec. 24, T. 45, R. 1 W., slaty ore, 3 feet; 54, one of the richest seams in 53; 53, exposures on the 4th Principal Meridian, Sec. 19, T. 45, R. 1 E., represents a thickness of 20 feet.

TABLE X.—EAST OF PENOKEE GAP

At the passage of the Potato River.

	55.	56.	57.	58.	59.
Metallic iron	36.141	38.434	26.551	43.587	34.740
Sesquioxide of iron	40.056	....	35.824	....	46.602
Protoxide of iron	5.051	....	1.474	....	7.445
Silica	40.495	....	....	....	....
Alumina	5.100	....	....	....	....
Lime	0.786	....	....	....	....
Magnesia	0.540	....	....	....	....
Manganese oxide	1.405	....	....	....	....
Phosphoric acid	none...	....	....	....	....
Sulphur	0.129	....	....	....	....
Water	0.554	....	....	....	....
Total	100.081	....	....	....	....
Magnetic oxide	....	....	44.749	....	24.009
Specular oxide	....	....	32.549	....	30.038
Totals	....	....	37.298	....	54.047

NOTES.—55, represents 25 feet in thickness; 56, slaty ore layers, 6 feet; 57, represents siliceous hematite a few inches; 58, magnetic layers same exposures as 55; 59, 22 inches.

For the purpose of comparison is given the following, taken from the report on the iron-bearing rocks of the northern peninsula of Michigan, by T. B. Brooks:

Approximate General Summary of the Results of Numerous Analyses, Exhibiting the Average Composition of the Four Classes of Ore produced in the Marquette Region.

	I.	*II.*	*III.*	*IV.*
Protoxide of iron	....	19.639	....	....
Sesquioxide of iron	90.520	67.761	75.750	70.980
Oxide of manganese	trace.	0.130	0.800	trace.
Alumina	1.390	2.150	1.536	2.010
Lime	0.700	0.680	0.360	0.450
Magnesia	0.420	0.690	0.294	0.200
Sulphur	0.050	0.132	0.110	0.030
Phosphoric acid	0.238	0.199	0.185	0.130
Silicic acid	5.892	7.328	14.035	25.120
Water, combined	....	....	3.940	....
Water, uncombined	....	....	1.180	....
Water, total	0.77	0.811	....	1.080
Volatile matter	....	....	1.810	....
Totals	100.000	100.000	100.000	100.000
Metallic iron	62.915	62.930	52.649	49.332
Phosphorus	0.111	0.085	0.078	0.073
Sulphur	0.050	0.132	0.110	0.030
Metallic manganese	trace.	0.091	0.560	trace
Specific gravity	4.740	4.59	3.880	4.090

NOTES. — Produced by the following mines:
I. *Red specular ore.* Barnum, Cleveland, Jackson, Lake Superior New York, Republic and Kloman mines.
II. *Black, Magnetic and Slate ores.* Champion, Edwards, Michigan, Spurr and Washington mines.
III. *Soft Hematites.* Foster, Lake Superior, Lake Angeline, Tayler, Macomber, New England, Shenaugo, S. C. Smith and Winthrop mines.

From these tables of analyses, and the detailed descriptions of the magnetic belt given in previous pages, a few conclusions of importance may be drawn with regard to the outcropping ores of the Penokee Range.

(1) The amount of ferruginous schist carrying over 30 per cent. of metallic iron is enormous, there being in fact a band of rock as rich as this extending the entire length of the Penokee ridge, over 40 miles, with a horizontal width of from 100 to 800 feet and an indefinite extension in depth, the only mineralogical constituents of these lean ores being quartz, magnetite, and specular hematite, with small quantities of tremolite or actinolite, and pyrolusite, while both phosphous and sulphur are on the whole conspicuous by their absence.

(2) As a general rule, the "slaty ores," which are the same as the "flag-ores" of the Michigan reports, are no richer in iron than the "banded" varieties, which are allied to the Michigan "mixed ores."

(3) A large amount of both slaty or flag, and banded, or mixed ore can be obtained, containing upwards of 40 per cent. of iron, while in

a few places small thicknesses have been noticed verging in their iron content upon 50 per cent., the lowest limit at which ores of this class are at the present time merchantable. These richer kinds are nearly always those in which the specular oxide predominates over the magnetic.

(4) The streaks of ore, both magnetic and specular, or mixtures of the two, which, with a width of from an inch to one or two feet, seam the banded varieties, contain nearly always from 60 to 70 per cent. of iron; and, if mechanical separation could be made sufficiently cheap, and avoid breaking to too small a size, a large quantity of excellent ore could be obtained.

(5) Manganese oxide is always a prominent constituent, being often perceptible in dull black seams.

Such ores as these have never yet been put to any use in Michigan, where they occur in great abundance. Whether they will have a value in the future remains to be seen.

These conclusions are, however, based upon the outcrops of hard ores, whose very existence as outcropping ledges in a ridge chiefly made up of them is sufficient proof as to their siliceous character. May there not be richer portions within the magnetic belt, a large part of which is without exposures? Very possibly; and for this very reason the exact course of the magnetic belt has been traced with care, by means of the deviation of the compass needle, and of the many outcrops, and mapped upon the accompanying Atlas Plates. It is quite within the possibilities that the ore-streaks of the banded kinds run together in places, producing workable deposits, or that the slaty varieties at times contain more iron than usual. Only direct exploration by trenches sunk across the bedding will ever throw any further light on this question. It may merely be added that no change in depth should ever be anticipated, the outcrop of a bed indicating sufficiently to us its nature in depth. Not only is this the result of all experience with such ores, but it is directly proven by the deep ravines in which the several branches of Bad river pass the Penokee Range, these being equivalent to shafts of the same depth, besides which, as already shown, the fault at Penokee Gap probably gives us a sight of the condition of the beds of the west cliff at that place, at a depth of 1,700 feet.

Between the Potato and Gogogashugun rivers the magnetic attractions along the course of the iron belt grow fainter, ceasing altogether as the Montreal river is neared. At the passage of the Gogogashugun, the lower 200 feet of IV is a quartzite without magnetic or specular iron, but holding thin, irregular seams of rich, very highly manganiferous soft hematite. Whether this soft ore exists in sufficient abundance in this portion of the Huronian, is also to be determined only by direct trench exploration. Such ores never outcrop.

Occurrence of iron ores above the magnetic belt. It is shown on a subsequent page that enough of a similarity exists between the stratigraphical arrangements of the Marquette and Penokee Huronian systems to render it exceedingly probable that the blank space VI of the latter series corresponds to that member of the former in which all of the rich ores have thus far been found. This probability is certainly enough to prompt land-owners on this belt, whose position is accurately indicated on the accompanying maps, to make explorations. Mr. Wright has found some magnetic attraction in the western portions of the blank VI, but my own observations on the more eastern portions have failed to develop any unusual attraction not to be attributed to the proximity of the main magnetic schists, IV. Still, this indicates only the absence of the magnetic ores. The specular ores, which are quite as likely to occur here, do not attract, and, when rich, on account of their inferior durability, rarely, if ever, outcrop.

EQUIVALENCY OF THE PENOKEE AND MARQUETTE HURONIAN SYSTEMS.

There seems to be little doubt that the Huronian basin of Marquette was originally directly continuous with that in which the rocks of the Penokee region were deposited; indeed, there are no facts yet on record to prove that the rock systems are not at the present time directly connected, though at the surface the connection is obscured by the overlying horizontal Silurian sandstone. Pumpelly and Brooks [1] have carried the Penokee belt uninterruptedly eastward as far as Lake Gogebic, where a deeply cut and ancient erosion, occupied now by the horizontal Silurian sandstone, terminates the range abruptly. From here to the westernmost known position of the Marquette Huronian is a distance of less than forty miles, occupied, as far as known, by the horizontal sandstone. There is thus every reason to believe in the actual continuity of the two systems.

In the Marquette Huronian, Major T. B. Brooks has made out, with great care and skill, a succession of beds which he numbers from I to XIX. In XIII of his scheme are found all the rich ores of that famous district. The correlation of the several subdivisions of the Huronian now made out in the two regions becomes thus a matter of both practical and scientific interest. Of course the only guide is to be found in the lithological characters of the several layers. In synchronous formations

[1] Geological Survey of Michigan, Vol. I, p. 183.

occupying wholly distinct basins, any attempt to make out a scheme of equivalency based on lithological characters would be only wasted time. In the present case, however, there is every reason to believe in the continuity of the two districts, while in each certain grand stratigraphical and lithological features are found to be quite constant throughout. It is nevertheless undoubtedly true that it is very easy to make many mistakes in such a scheme, owing to the dying out of layers, and the variations, along the strike, in the same member of the series, which, if not originally present, may have been produced by the partial or complete process of metamorphism to which the whole Huronian series has been subjected. No scheme of equivalency can be regarded as having any value, except that which seizes on those few grand features of the stratigraphy that have been shown to be quite constant. The few prominent facts in this connection that have impressed themselves upon me while studying over my field results, together with the reports and typical collection of the Michigan survey, are here given, all fuller treatment of the subject being left to more competent hands.[1]

In Wisconsin we find, forming the base of the series, a great bed (III) of light-colored quartzose schists and slates over 400 feet in thickness, so marked in its characters as to be everywhere unmistakable, and beyond question absolutely continuous for over fifty miles. The slates of this bed vary from schistose vitreous quartzites, to thin-laminated argillitic mica-schists, while subordinate to it are two other members, a white arenaceous quartzite (II) and a magnesian limestone (I). Now in much of the Marquette region, a great quartzite bed (V), including argillitic schists and limestone, quite undistinguishable in hand specimens from the Wisconsin rock, forms the base of the Huronian series. From the descriptions of this layer by Mr. Brooks, in the Michigan report, it is evidently no less prominent and persistent than the siliceous slate of the Wisconsin series. It appears evident enough that the two are directly equivalent.

Above the siliceous slate in the Penokee system we find a great thickness of magnetitic quartz-schists and slates, which are, beyond doubt, continuous from Numakagon lake, in T. 44, R. 6 W., nearly to Lake Gogebic, in Michigan, a distance of over eighty miles. In Michigan, a succession of strictly similar rocks overlie the great "Lower Quartzite" (V), but are here intercalated generally with heavy diorite

[1] This subject is one which Messrs. Brooks and Wright will have occasion to treat of in other portions of this report. Their extended experience in all of the Lake Superior Huronian districts will undoubtedly enable them to carry the scheme into much greater detail. Major Brooks has already published on this topic, and has in preparation a still more extended presentation of the subject.

bands. Such bands are unknown in the Wisconsin series, except at the west, in T. 44, R. 5 W., where they appear in great force. The peculiar garnetiferous rock of the Penokee series appears also in the Michigan magnetite-schist beds. The Penokee magnetic belt, then, I should regard as equivalent to Nos. VI to XI of the Michigan system.

Immediately above the magnetic belt in the Penokee series, or separated from it by a comparatively narrow band of black slate, seen only at one or two places, we find always a blank (VI) without exposure, nearly 900 feet in width. If our previous suppositions are correct, in this gap should be the equivalent of XIII of the Michigan series, the bed in which occurs all the rich ore. Most of this covered space does not show any unusual magnetic attractions, though Mr. C. E. Wright has found some in the western portions of the Penokee belt. It should always be remembered, however, that only the magnetic ores attract, while the pure specular ores do not. The specular ores are quite as likely to occur as the magnetic, and are, moreover, never found outcropping when rich, being far too fragile to withstand atmospheric action.

Above the blank space numbered VI in the Penokee series, the prevailing rock, for a thickness of over 2,000 feet, is an aphanitic, black mica-slate, often chiastolitic, which includes, however, one or two bands, aggregating some 200 feet in thickness, of quartzite, and two narrower bands of diorite, besides which there are blank spaces, the nature of whose underlying rock is an inference only. The black slates and quartz-schists appear to be very persistent, but the diorites are as yet known only in the vicinity of Bad river. The equivalents of these members in the Marquette series appear to lie from XIV to XVII, where we have quartzite and clay slate, besides some doubtful members. The slate is often brown to black, containing carbon, and frequently distinctly micaceous, when the specimens show some similarity to the black slates of the Penokee series. Nothing has been found in the latter, as yet, that resembles the true clay slate (XV) of the Marquette series.

Forming the uppermost members of the Penokee system we find a great development of mica-schists, including, in the lower portions, a considerable proportion of a dark gray, generally aphanitic rock, quite different, however, from the black mica-slates lower in the series, while higher up are beds of a coarser and more distinctly micaceous texture, often contorted and banded like gneiss, with others in which the mica almost wholly disappears, and we have a light gray, fine-granular quartz-schist. These mica-schist layers reach a total thickness of over 5,000 feet. In the Marquette region the youngest member of the series, XIX, is described as one of the thickest beds in the whole Huronian series, and "sometimes so siliceous as to be rather a micaceous quartzite." The Michigan rock appears, from the descriptions, and from the specimens in the typical collection, to be more like the coarser of the Wisconsin varieties, while the staurolite and andalusite have not yet been noticed in the Wisconsin rock.

It seems abundantly evident, then, that a striking similarity exists between the general stratigraphical successions of these two regions, which may be regarded as indicating a true equivalence between the corresponding members of the two systems.

CHAPTER IV.

THE KEWEENAWAN OR COPPER-BEARING SYSTEM.

The rocks of this system occupy the larger part of our district north of the Huronian belt, the horizontal Lake Superior or Potsdam sandstone being confined to the Apostle Islands and, on the mainland, to the immediate vicinity of the lake.

LITHOLOGY AND STRATIGRAPHY.

As explained at some length on a previous page,[1] the Keweenawan System includes a lower division, consisting chiefly of great flows of gabbro, diabase and melaphyr, and an upper division, composed chiefly of reddish feldspathic sandstone, subordinate to which are heavy beds of bowlder-conglomerate, indurated gray and brown quartzless sandstone, and black shale. The great synclinal depression formed by this system in northern Wisconsin has also been sufficiently explained. No further general considerations need then be introduced in this place, and we may pass on to the description of the nature, distribution and local details of the several kinds of rock that make up the series. Since these lie for the most part in distinct belts, conforming in a general way to the trend of the more southern Huronian belt, we shall be at the same time examining the stratigraphy of the system. The following classification of the kinds of rocks involved will aid to make plain the arrangement of the subject adopted:

I. ERUPTIVE ROCKS —

Basic Rocks
1. Gabbro.
2. Diabase and diabase-amygdaloid.
3. Melaphyr.

Acid Rocks
4. Granite.
5. Porphyries (possibly clastic).

II. CLASTIC OR FRAGMENTAL ROCKS —

6. Bowlder-conglomerate.
7. Black and gray shales.
8. Gray and brown quartzless sandstone.
9. Red sandstone and shale.

[1] See Part I of this Vol., Geological Structure of Northern Wisconsin.

So far as practicable, these rocks are considered in the order of the belts which they severally form, beginning with the southernmost. The granite has a restricted distribution, and is found cutting the gabbro near the base of the system, as also the immediately adjoining upper mica-schists of the Huronian. The eruptive nature of the porphyries, which form belts of large size, is, as explained on a previous page, a matter of some doubt.

Gabbro.

This rock, which in the Keweenaw Point region has but a very meagre development, forms in the Bad river country of Wisconsin a continuous belt from one and one-half miles to five and one-half miles in width, and forty miles in length, besides occurring in minor quantity associated with the common diabase or melaphyr.

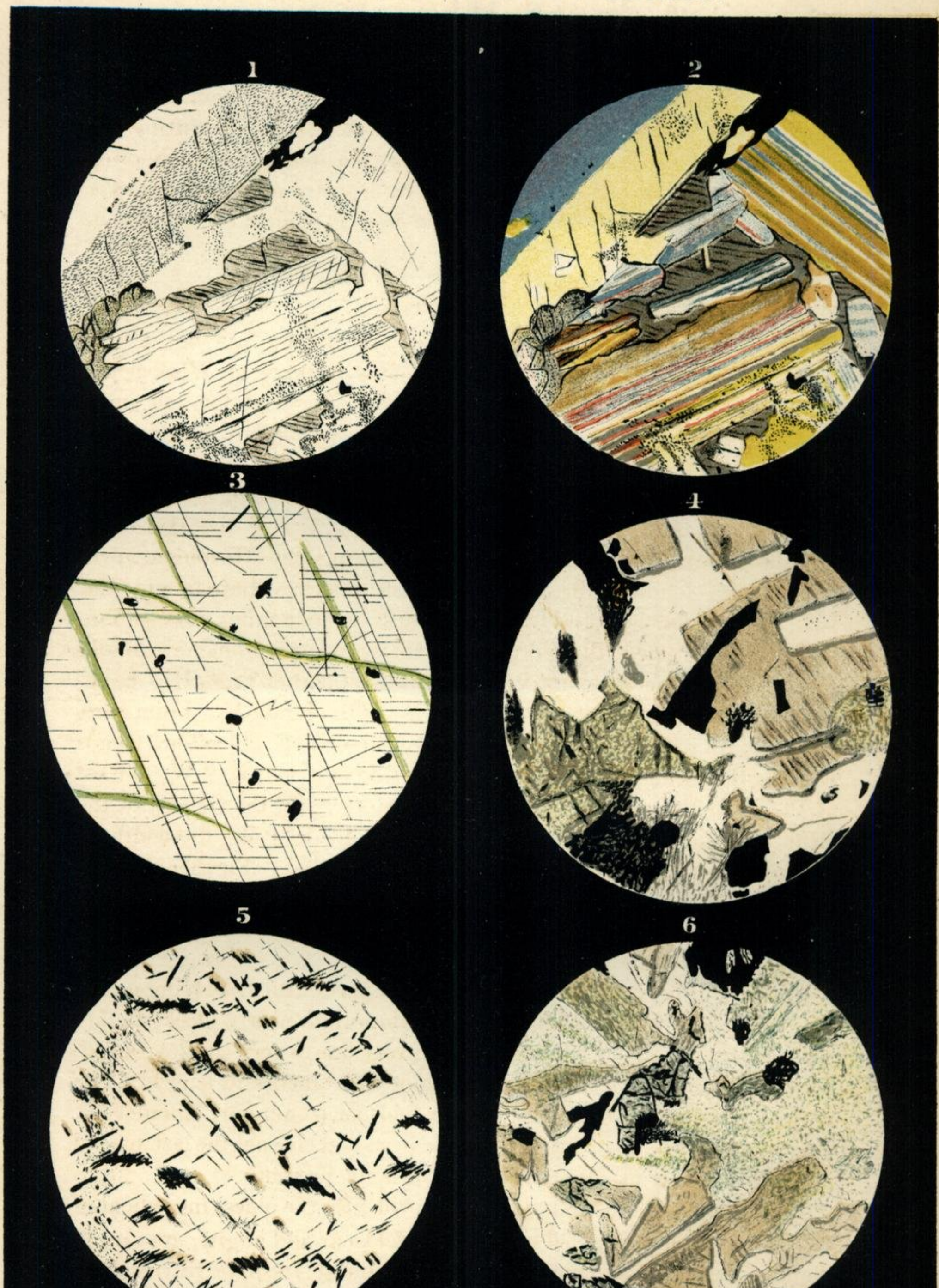
The Bad river gabbro belt forms the base of the system, and is found lying immediately north of the upper mica-schists of the Huronian. On the Montreal river the gabbro is wanting, the Huronian mica-schists being followed directly by greenish chloritic diabase and diabase-amygdaloid. On the Lac Flambeau trail, four miles west, gabbro appears to alternate with the ordinary diabase, and west from here rapidly displaces the latter rock, until, in the southwest part of T. 46, R. 1 E., we have apparently as much as two miles in width of gabbro. From here, with a width of from one and one-half to three miles, the gabbro trends west-southwest to Bad river on the west side of T. 45, R. 2 W. West of Bad river the course is more nearly westerly. In the vicinity of the Brunschweiler river, T. 44, R. 4 W., and T. 45, R. 4 W., the width of gabbro from north to south is as much as five miles. Further west the belt narrows rapidly, disappearing in T. 44, R. 6 W.

In this belt the gabbro occurs of two well marked kinds, of each of which there are subordinate varieties.

The first of these, which forms the greater part of the belt, lying nearly always south of the other kind, is a bluish-gray to nearly black, highly crystalline rock, varying in texture from very fine to very coarse-grained, when the individual crystals reach two or three inches in length. The normal constituents are a plagioclase feldspar (commonly labradorite), augite or diallage, magnetite or titanic iron, and olivine, the last named ingredient being usually, but not invariably present.

The olivine, which, when present, is evidently the oldest ingredient of this variety, being included within both feldspar and augite, appears in the thin section to be not unfrequently almost fresh, or traversed by brownish ochreous stripes, between which more or less of the original mineral still remains. A change to a greenish serpentine-like sub

GABBROS; KEWEENAW SERIES.



R. D. Irving, 1878.

The Milwaukee Litho. & Engr. Co.

Fig. 1. Gabbro (84); Brunschweiler river, near north line Sec. 11, T. 44, R. 4 W.; × 12.

Fig. 2. The same between crossed nicols.

Fig. 3. Inclusions in labradorite of gabbro (70); N.W. ¼, Sec. 6, T. 44, R. 3 W. × 53.

Fig. 4. Gabbro (36 W.); N.E. ¼, Sec. 13, T. 45, R. 1 W.; × 35.

Fig. 5. Inclusions in augite of gabbro (12); N.E. ¼, Sec. 31, T. 45, R. 2 W.; × 53.

Fig. 6. Gabbro or diabase (3177); N.E. ¼, Sec. 5, T. 44, R. 3 W.; × 40.

stance, the common mode of alteration of olivine, has only rarely been observed in the Wisconsin rock. A very interesting mode of alteration of olivine, peculiar, so far as known, to this region, is that first discovered by Mr. A. A. Julien, and described by him in an appendix to this report. This is a change to biotite, viridite and talc, the latter mineral forming a shell of silvery scales around the original grain, while within are scales of biotite (which in some cases have, in crystallizing, broken through the talc shell), patches of viridite, particles of magnetite, and more or less of the original mineral. I have myself observed a number of cases where the nearly unaltered mineral, traversed by a few minute brownish seams, is completely surrounded by the talc shell. This mode of alteration, which is characteristic of the coarser-grained varieties, has been observed in specimens from all portions of the gabbro belt. In specimens brought from ledges in the southern parts of T. 45, R. 2 W., and also from more eastern points, the nearly fresh olivine holds a black opaque mineral in little strips and patches, which is evidently an alteration-product. The olivine, which is rarely very abundant, is commonly microscopic, but may at times be readily detected in the hand specimens in glassy green grains, and more often in the thin sections, without the aid of the microscope.

Next in age to the olivine of this phase of the gabbro is the plagioclase, which is most commonly labradorite, and is in nearly all cases the predominating constituent, in some varieties making up almost the whole of the rock. The single crystals are commonly one to three inches in length, and one-fourth to one-half inch in width, while in the coarser varieties surfaces as much as two to three inches wide are met with. This ingredient is nearly always in a quite fresh condition, showing in the thin section between the crossed nicols a far more perfect and brilliant twin-banding than I have yet seen in sections from any other region. The characteristic inclusion of the labradorite of the typical gabbros of Europe—black needles arranged in several definite directions — are here beautifully developed. They characterize especially large areas which polarize monochromatically, and are therefore readily mistaken for orthoclase. Other inclusions occur, such as viridite, biotite, talc and magnetite, but these are not abundant, and generally are directly traceable to the alteration of adjoining augite or olivine. The plagioclase crystals are always sharply cut, being bounded by straight lines in the thin sections, and constitute a net work, with intervening spaces now occupied by the augite.

The augitic ingredient of this variety, in the thin sections, fills the linearly bounded spaces between the plagioclase crystals in such a manner that its more recent formation is placed beyond a doubt. Commonly several neighboring but wholly disconnected areas of augite will present parallel cleavage lines and will show a common color between the crossed nicols, proving their crystalline identity. In some of the very coarse varieties, a plane surface on a hand specimen will show the same interesting relation between the augite and plagioclase. The augite in the thin sections, when unaltered, varies in color from a pale, scarcely perceptible violet, to a deep wine-tint. In the hand specimens it is always black when visible. It presents in the sections every possible variation from ordinary augite, full of irregular cracks, to the most highly foliated diallage, a variation which is also often to be detected macroscopically. It is frequently unaltered, but presents also several kinds of change. One of these is to a greenish viridite, but more commonly the alteration is to a true hornblende or uralite, which, in the sections, has a greenish tint, and is strongly dichroitic. In some of these uralitic varieties originally rich in augite, the change has been so extensive that the rock looks like a typical hornblende rock.[1] But even in these cases the contours of the original augite crystals, as well as cores of augite, remain. This change affects both the ordinary augite and the foliated or diallage varieties. In the latter case the change tends to take place along the foliation planes. An alteration to a true basaltic hornblende, which in the thin sections is of a deep brown tint, and presents the strongly marked characteristic prismatic cleavage, is also to be noticed. This change seems to affect only the non-foliated augite, and is characteristic of a band near the southern limit of the gabbro belt. In some phases of this rock the change has been extensive, and the appearance of the thin sections suggests that most of the hornblende may be primary. These varieties Professor Pumpelly has called augitic diorites, but I should be disposed to regard them as merely instances of a pushing to the extreme of the paramorphic change from augite to hornblende.

Magnetite or titanic iron is present in most of this variety of gabbro, at times in very large particles, which are rarely, if ever, possessed of crystalline outlines, and which bear such relations to both augite and plagioclase as to indicate their later formation. Biotite is a common, but usually not abundant accessory, and, in some sections, apatite needles are seen abundantly crowded in the plagioclase crystals.

The second variety of gabbro is found especially in the more northern portions of the gabbro belt, forming apparently continuous bands, which have in some cases been traced for a number of miles. It is a red-and-black-mottled, or red-black-and-gray-mottled rock, and commonly very coarse-grained, though never reaching the extreme degree

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[1] See Professor Pumpelly's report, p. 39 of this Vol.

of coarseness which the other variety sometimes shows. It is also marked by very abundant and large (so large as to be readily seen with the naked eye) grains of magnetite, or, at times, of titanic iron. The ingredients of this rock are the same as those of the other variety, except that olivine is only rarely present, and then is completely changed to a greenish material. The lack-lustre plagioclase is at times gray or greenish-gray, at others brick-red, both types being generally represented in the same rock. In both these cases the alteration has been great, even the grayish kinds showing only faint traces of the twin bands in the polarized light, but, instead, the characters of an aggregate, while the red crystals are in addition infiltrated with the red oxide of iron. We have then here to deal with a case of an alteration in a saussurite direction. The augitic ingredient of this rock is always highly foliated, and is commonly also more or less altered to a greenish uralite, which in many cases has passed beyond the uralitic condition into a soft, greasy feeling chloritic substance.

From the general descriptions thus given, it is evident that my observations on these north Wisconsin gabbros bear out the conclusions reached by certain European lithologists, as to the subordinate importance of the foliated condition of augite, by which gabbro is ordinarily separated from diabase, of which it would seem to be merely a phase. Nevertheless, the name is here retained, not only because most of our rock is very close to the typical European gabbros, but more especially because it is so sharply contrasted with the typical Keweenawan diabase that a separate name seems necessary.

Throughout the gabbro belt, no reliable indications of bedding have been seen. A close jointing is sometimes perceptible and may be mistaken for bedding, but a careful examination always shows its real nature.

In the townships west from Bad river, and within the gabbro area, low exposures of a very coarse-grained granite are often met with, in characters precisely resembling the granite cutting the upper mica-schists of the Huronian. Commonly the relation of the granite to the gabbro is not to be made out, but in several places on and near Bad river its true intrusive character is rendered evident by the exposures of its contact with the gabbro. This granite is more completely described on another page.

Besides the coarse granite, narrow seams of very fine-grained pinkish granitic material (mixtures of orthoclase and quartz), are met with. Dikes of heavy black aphanitic diorite also occur.

The gabbro of this belt is regarded as belonging to the Keweenawan system rather than the Huronian, for the following reasons: (1) the close similarity it presents in mineral composition to the true Keweenawan diabase; (2) the evident interstratification with the latter near the junction of the two; (3) the manner in which unmistakable Keweenawan diabase fills the eastern extension of the gabbro belt in the vicinity of Montreal river; (4) the massiveness and apparent eruptive nature of the gabbro; (5) the occurrence of gabbros in the typical Keweenawan region of Keweenaw Point, and with typical Keweenawan diabase in Douglas county, Wisconsin; and (6) the apparent non-conformity of the gabbro and the Huronian schists, as indicated by the way in which the junction line between the two cuts diagonally across the strike of the Huronian beds. The only fact looking in the opposite direction is the disappearance of the gabbro belt in its western extension in the same manner, and in the same vicinity as the belt of Huronian schists.

On Bad river, northwest quarter of the northeast quarter of Sec. 6, T. 44, R. 2 W., the gabbros are seen in the immediate vicinity of ledges of the upper mica-schist of the Huronian (Nos. 19 and 20, Atlas Plate XXIV), rising in bold exposures from the west side of the railroad track. The southernmost rock (2,038) seen here is dark-colored and rather fine-grained, and shows large plates of reddish mica, some of which are one-quarter inch by one-half inch in dimensions. Under the microscope this rock is seen to be a uralitic gabbro, the augite, of pale violet tint, occurring both in the ordinary variety, and as highly fibrous diallage. Both of these varieties show a change into dichroitic hornblende, a number of different stages in the alteration process being perceptible. In the diallage, the change to hornblende has taken place along the planes between the lamellæ. The plagioclase is for the most part much altered. Magnetite or titanic iron, and apatite are present as accessories.

Twenty paces further north along the railroad comes in an exceedingly coarse bluish-grey gabbro (2,037), the greyish labradorite crystals of which are often several inches in length and one to two inches in width. The labradorite greatly predominates, but much greenish-black to black, and often highly foliated diallage is visible, evidently filling the interstices between the previously formed labradorite crystals, an appearance which is always very pronounced in the thin sections of the finer grained varieties of these gabbros. But little magnetite is visible. Following this ledge further northward the grain is found becoming somewhat finer, though still very coarse (2,036).

The northern part of Sec. 6, T. 44, R. 2 W., and most of Sec. 31, T. 45, R. 2 W., show numerous large ledges of gabbro, on the steep hillsides facing east and south towards Bad river. From open places in the windfall on the Penokee Range, Secs. 7 and 18, T. 44, R. 2 W., these may be seen standing out very prominently. In the immediate vicinity of the river and railroad, however, the rocks are concealed until we reach the northern part of Sec. 31. Here large exposures, and often bold cliffs rise from the west side of the railroad track (No. 7, Plate XXIV). At the southern end of these exposures the rock is somewhat decomposed, crumbly and brownish-stained (2035, 2034) and of coarse-grain, the individual plagioclase crystals often reaching half an inch in length and forming the bulk of the rock. A thin section of one specimen obtained at this point (13) shows the augite highly fibrous, and mostly altered to a greenish, dichroitic material. Further north the decomposition is less evident, and the peculiar bluish-grey color prevails (2,033). At 100 paces were noticed numerous pinkish seams of an aphanitic material one or two inches in width, which under the microscope is seen to be chiefly fine quartz mingled with orthoclase. Here was also noticed a 3-inch faulted vein of aphanitic dark-colored, heavy rock (2,032), trending N. 55° E., and dipping at a high angle to the southward. The rock of this vein is seen under the microscope to be an exceedingly fine-grained diorite. Further northward again, the rock is very coarse (2,029, 2,030, 2,031) the labradorite greatly predominating. Here was obtained the specimen (12) described in detail by Mr. Julien in Appendix B. His investigations show as essential constituents: predominating labradorite, with inclusions of viridite, biotite, magnetite and talc; orthoclase in much smaller quantity, with needle-like plagioclase inclusions; augite, both ordinary and diallage, including viridite, magnetite and biotite, and often altered to viridite; and chrysolite or olivine, mostly in or near the augite, and nearly always showing a remarkable and hitherto unknown kind of alteration, namely into viridite, biotite and talc. One thin section in my collection, from a specimen (2,028; sp. gr. 2.82) taken near the northern end of this ledge, and about on the north line of Sec. 31, shows an almost entire absence of the augite, while the predominating labradorite is thickly studded with macroscopically visible olivine grains from 0.5 m. m. to 6 m. m. in the greatest diameter. Most of these show the peculiar alteration described by Mr. Julien, being surrounded by a shell of scales of talc. The biotite is seen in many cases however to be entirely wanting, and in a few grains the alteration appears to be the ordinary serpentinous one.

Some 200 paces north of the south line of Sec. 31, begin large ledges, over and through which Bad river plunges in a wild gorge. (Nos. 4, 5, 6, Atlas Plate XXIV). Here the gabbros are penetrated by veins and masses of coarse pink to red granite, which makes up a large part of the exposure. A railroad cutting along the east bank of the river freshly made at the time of my examination in 1873, afforded an excellent chance for observing the relations of the different rocks at this place. The following is a measured section taken in the cutting, beginning at the southern end.

		Feet.
I.	Dark greenish-black, medium to fine-grained, highly crystalline *gabbro*, (2) weathering brownish; sp. gr., 2.93. Numerous macroscopically visible, metalloidal mica flakes are contained. The principal joint-planes strike N., 30° E., and dip 45° N., and often are so close as to give an appearance of bedding. Under the microscope the thin section shows a much altered rock. The augite is chiefly non-foliated, and is for the most part altered to a yellowish-green and deep bluish-green material, the latter showing slight traces of dichroism. Biotite is an abundant accessory, and is evidently connected with the decomposition of the augite. The feldspar is much fissured and penetrated by greenish viridite. The usual black magnetite or titanic iron is seen	40
II.	Bright red, coarse-grained *granite* (3 and 4) weathering brownish-red; composed chiefly of red orthoclase, and grayish glassy quartz in grains one-fortieth to one-twentieth inch across. Fine black lustrous biotite is present in small quantity. This granite is much jointed, many joint surfaces showing a film of a greenish epidote-like mineral	45
III.	*Diorite dike;* very close-grained, minutely crystalline, dark greenish-gray diorite (5), the thin section of which is chiefly made up of pale greenish, strongly dichroitic hornblende, often showing the characteristic prismatic cleavage, and forming one continuous mass in which the sparser plagioclases appear as if included. Rare biotite and magnetite are present	15
IV.	Red-and-black-mottled, coarse, rough-textured and white-weathering *gabbro* (6); unlike the bluish-gray, and other gabbros, further south on Bad river. Macroscopically both pink and gray feldspar are visible, also foliated black augite, and pinkish metallic-lustered titanic iron. The thin section shows plagioclase usually much altered and reddish stained; augite, both unaltered and changed to uralite; original hornblende; biotite; and titanic iron	50
V.	Pinkish, white-weathering *granite*, finer grained than II. Nests holding quartz, calcite, ripidolite, and purple fluorite seen in this rock	40
VI.	Red-and-black-mottled *gabbro*, like IV	80
VII.	Red *granite*	5
	Total	275

Northward from these falls no exposures of the gabbro belt were noted in the vicinity of Bad river.

East of Bad river. East of Bad river the exposures on the gabbro belt are not so large or numerous as to the west of the river. There are, however, many of them, and quite enough to prove the continuity of the belt and to fix its limits. A few only of the more important outcrops are here referred to.

On the south line of the southeast quarter of Sec. 32, T. 45, R. 2 W., and running several hundred paces south, are large exposures (No. 27, Atlas Plate XXIV) on the sides and summit of a steep side-hill which faces north and west towards the valley of one of the main branches of Carrie's creek. The northern portions of these ledges, near the section line, are of a dark gray, rather fine-grained, but highly crystalline, often much jointed olivine-gabbro, or diabase, in which the black augite and gray plagioclase can at times be just seen macroscopically (3,168 to 3,170). Going southward from the section line along the west-facing slope, we find at 50 paces south of the line a cliff some 20 feet in height, of very close-grained, dark gray mica-schist, belonging to the Huronian series, and described on a previous page. Following the slope still farther southward, we find it curving eastward, and at about 120 paces, measured along the curve of the hill, exposures of the same olivine-gabbro as before noted are met with (3,177 to 3,179), proving the great irregularity of the junction of the mica-schist and gabbro, or, more probably, the actual penetration of the schist by the gabbro, which is regarded as of an igneous origin. Under the microscope, the gabbro seen at this place shows the augite of the usual wine color, for the most part full of irregular cracks, and only occasionally with a tendency towards diallage, which tendency is, however, very distinctly visible in a few of the crystals. The olivine is very abundant, sometimes showing a greenish, fibrous alteration-product, but for the most part the only alteration is one indicated by frequently penetrating irregular strips and borders of a black mineral (magnetite?). The relative ages of the several ingredients are very plainly olivine, plagioclase, augite, magnetite. The magnetite occurs also quite plentifully independently of the olivine. A representation of a section of this rock (3,177) is given on Fig. 6, Plate XV D, magnified 40 diameters.

Exposures showing the same rock exactly, and also the same peculiar relations between the mica-schists and gabbros, are to be seen in and near the stream which crosses the south line of Sec. 27, T. 45, R. 2 W., near the quarter-post. Just north of the line, and extending some fifty paces up the stream (northward), are exposures of a very distinctly and evenly bedded, light gray, quartzose mica-schist (3,164, 3,165). Down the stream (southward) from the section line, are quite large, entirely structureless, though often much jointed ledges of a gabbro (3,166) very close to that on the south line of Sec. 32 (3,177). Under the microscope the rounded olivine grains, often as much as 0.3 m. m. in greatest diameter, are very beautifully marked and often almost entirely undecomposed.

On the east line of the same township, fifty paces south of the northeast corner of Sec. 25, a closely similar rock is again seen (3,160). The wine-colored augite here often tends towards diallage. The olivine is in large pronounced grains, reaching 0.5 mm. in length. It is to be noticed that the rock of no one of the three localities last described shows any sign of the talcose alteration of olivine which is characteristic of the otherwise closely similar rock on Bad river.

In T. 45, R. 1 W., the ledges are more numerous, often presenting cliffs ten to twenty feet high, hundreds of feet in length, and facing in every direction. At the southeast corner of Sec. 6, the rock is dark brown, much weathered, rather coarse-grained, and very rough-textured, the black augite standing out very prominently. Under the microscope the general appearance of the thin section allies this rock more nearly to the gabbros seen interstratified with the typical Keweenawan diabase. According to Pumpelly, it is near to the rocks of bed 107 of the Eagle river section, Keweenaw Point; the plagioclase being anorthite, and the augite tending to diallage.

In the southeast quarter of Sec. 5 of the same township, Tyler's Fork makes rapids over a peculiar green-and-red-blotched, much altered gabbro. The greenish, soft, often unctuous base appears to be an alteration-product of the augite. No thin section has been examined, but the general appearance of the rock, especially the very coarse, reddish stained plagioclase, would refer it to the red and black gabbro seen in a number of places in the more northern portions of the gabbro belt.

Several large exposures of gabbro occur in the vicinity of the now nearly obliterated Ironton trail. One of the largest and most interesting of these is near the corner of sections 9, 10, 15 and 16, of T. 45, R. 1 W. It is about 100 feet long and 10 to 12 feet high, showing light gray, often nearly white, and coarse-grained gabbro (166; sp. gr., 2.80), a peculiar phase not elsewhere noted. The striations of the plagioclase are very plain macroscopically. Under the microscope the large plagioclases, often beautifully clear, though occasionally spotted with decay, make up nearly the whole section. Between the crossed nicols the colored banding of these is the handsomest I have ever seen. The augite is nearly all diallage, the close parallel lines of cleavage marking very distinctly the foliation. In some sections large olivines, as much as 1.5 to 2 mm. in length, are seen. Some of these show every phase of the peculiar alteration to talc and biotite described by Mr. Julien in Appendix B, while others are almost wholly unaltered. Fig. 2, Plate XV E, represents a portion of a section of this rock showing the diallage and altered olivine magnified 20 diameters. Only a few hundred paces to the west of the ledge last described is another equally large one, of a fine-grained, very dark gray to nearly black variety of the gabbro (167). This rock has not been examined under the microscope.

The exposure near the south line of the northwest quarter of Sec. 2, T. 45, R. 1 W., shows a dark gray, finely crystalline variety, in which both the plagioclase and augite are macroscopically recognizable and which contains pyrite. This rock has a specific gravity of 3.02, and contains oligoclase, original hornblende, augite and uralite (Pumpelly). Both hornblende and uralite are very plentiful. The general appearance of the section would place the rock with the gabbros, to which it belongs by position. It is, however, a strongly marked and peculiar variety.

On the northeast quarter of Sec. 13, T. 45, R. 1 W., west of the Potato river, are exposures of a dark gray, medium-grained gabbro, in which much greenish olivine is readily observable with the naked eye. This rock closely resembles that of the ledges in the southern and southeastern part of T. 45, R. 2 W. (3,161, 3,166). Under the microscope, the similarity holds, the section showing, however, an extraordinary amount of olivine, much of which is quite unaltered, while the rest presents frequently a change to biotite, ochre, and magnetite, but not to talc. The augite is wine-colored and tending to diallage. The olivine is both in the augite and in the plagioclase.

In T. 46, R. 1 W., the gabbro belt crosses the southeast corner of the township. Here, on and in the vicinity of the old Ironton trail, a number of ledges have been noted. In the northeast quarter of the southeast quarter of Sec. 34, the northernmost rock seen is a coarse gabbro of the red and black variety, showing grayish, dull plagioclase, in faces up to two-tenths inch in width; dark greenish-black, foliated augite as large as the plagioclase; bright metallic-lustered magnetite in particles one-tenth to two-tenths inch across, very abundant; and minute greenish olivine grains. The silica content is 53.03; the specific gravity 2.89 (Pumpelly). The thin section presents the usual appearance of this variety of the gabbros. An inspection of the map will show that this exposure lies directly in the general line of trend with the entirely similar rocks in the bed of Tyler's Fork, southeast quarter Sec. 5, T. 45, R. 1 W., and in the southeast quarter of Sec. 6. It is an interesting fact that in this ledge was observed a narrow vein of greenish epidote and quartz, holding native copper in minute flakes. About 75 paces further along the trail southward, the rock is light grayish, coarse-grained gabbro, very close indeed to that observed near the southwest corner of Sec. 10, T. 45, R. 1 W. (166). Three hundred paces further are ledges of a fine-grained, very dark colored rock, the thin section of which, under the microscope, resembles somewhat the typical Keweenawan diabase, but it evidently belongs with the other gabbros. Three hundred and fifty paces further the ordinary coarse grayish gabbro is seen, and beyond, near the south line of the section, are exposures of the brick-red granitic porphyry elsewhere spoken of.

In T. 45, R. 1 E., the gabbro belt crosses the northeast corner of the town. Fine-grained, dark gray gabbro is seen near the northwest corner of Sec. 6, about a mile, measured across the general trend, from the nearest Huronian exposure. A similar rock shows near the southeast corner of the same section.

In the southwest part of T. 46, R. 1 E., are other similar rocks, but, following the trend of the gabbro belt eastward through this township, we soon begin to meet ledges of the Keweenawan diabase and diabase-amygdaloid, which rock finally, in T. 46, R. 2 E., after passing the Gogogashugun river, appears to usurp entirely the position of the gabbro, no sign of which is to be seen on the Montreal.

On and near the Lac Flambeau trail, in the eastern part of T. 46, R. 2 E., several exposures of gabbro occur. One of these, in the north part of Sec. 30, near the northern border of a great swamp, appears to be very near the Huronian boundary, while for a mile and a half to the northward the exposures in the vicinity of the trail are all of the typical diabase, and diabase-amygdaloid. The rock exposed here is a very coarse-grained gabbro, in which the greenish-black diallage preponderates, and much coarse magnetite or titanic iron is perceptible with the naked eye. In the southwest quarter of Sec. 7, T. 46, R. 2 E., both in the bed of the creek and again near the southwest corner of the section (3,030), the gabbro exposed is a very coarsely crystalline, dark gray to black rock, similar to that last described, but showing much reddish altered plagioclase. It evidently belongs with the red-and-black-mottled variety. The easternmost gabbro observed was on the Gogogashugun river, near the south line of Sec. 8, T. 46, R. 2 E., where are low exposures running along the right bank of the river, for several hundred feet, of a fine-grained, very dark gray variety (1,549). Above and below on the the river the ordinary diabase and diabase-amygdaloid are seen. The whole country to the east seems also to be occupied by the latter rocks.

West of Bad river, the gabbro belt has a width of from two and a half to five and a half miles, covering the southern portions of T. 45, and the northern of T. 44, ranges 3, 4 and 5 W. The central portion of this belt is a broad but well marked ridge, cut through in only two or three places by the larger northward-flowing streams. The rock exposures are very numerous, often presenting precipitous fronts, which

KEWEENAWAN GABBROS.

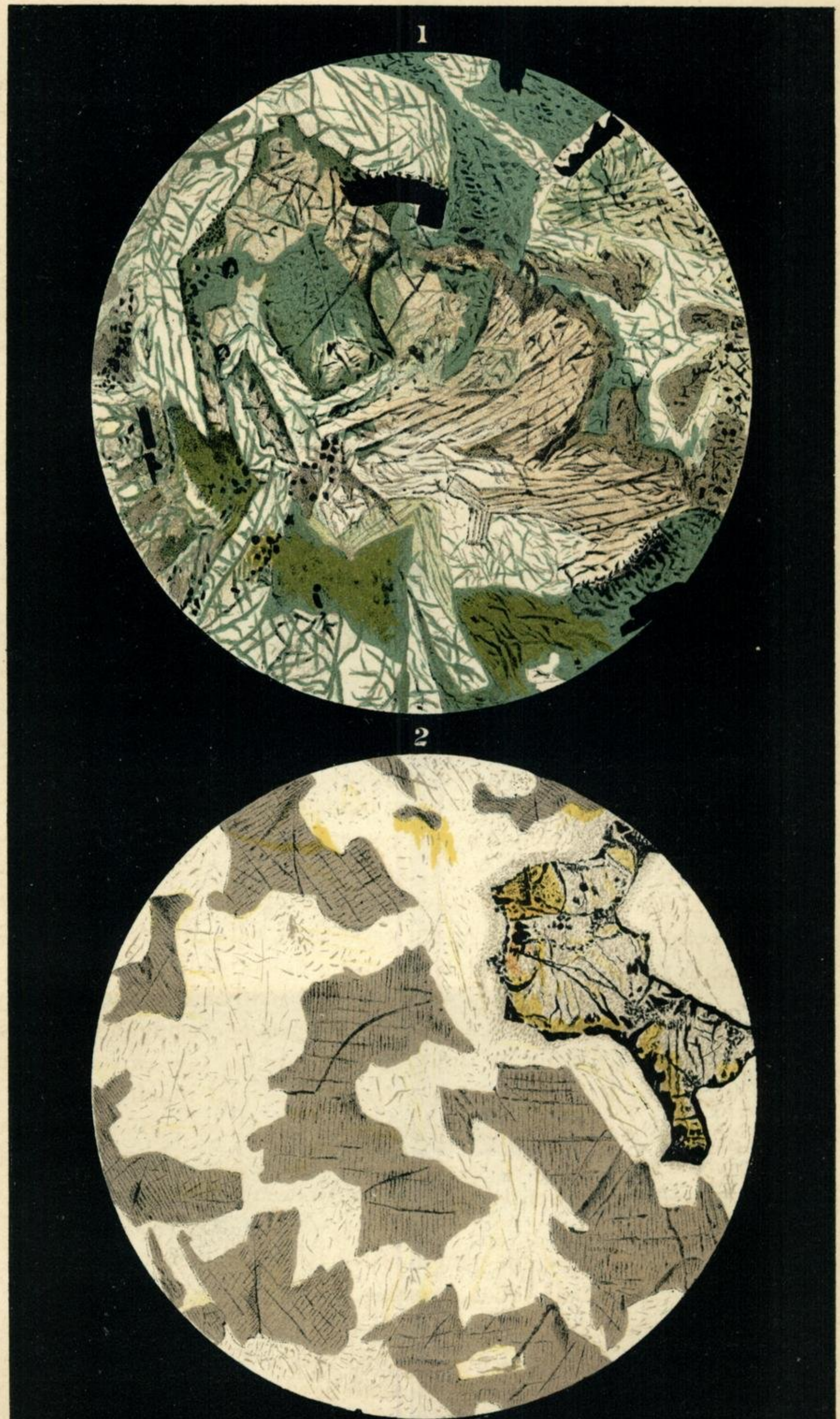

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Fig.1. Uralitic Gabbro (119 W.), S.W.¼, Sec.14, T.44, R.6 W.; × 40.
Fig.2. Olivine Gabbro (166), N.W.¼, Sec.15, T.45, R.1 W.; × 20.

face in all directions, are nearly always without trace of structure, and often show, for an area of several miles, no perceptible variation in the rock. The same coarse granite that cuts the gabbros on Bad river makes in these townships frequent exposures, which are spoken of in another connection.

In sections 1, 2 and 3 of T. 44, R. 3 W., the northern limit of the mica-schists of the Huronian lies only about a quarter of a mile south of the town line. In this narrow space, however, there are a number of exposures of gabbro, and of the intruding granite. Many of the gabbro outcrops show a peculiar hornblende-bearing variety, which has already been noticed as occupying about the same stratigraphical position in the vicinity of Tyler's Fork, T. 45, R. 1 W. On the west line of Sec. 2, T. 44, R. 3 W., 286 paces north of the quarter-post, are small exposures of this hornblende-bearing rock (No. 12, Atlas Plate XXIV). As seen here (2,019; sp. gr., 3.09), it is fine-grained, grayish, rough-textured and highly crystalline, showing under the loupe much of a black lustrous mineral. Under the microscope, the thin section shows plagioclase; augite in rounded granules; brownish, deep-tinted hornblende, often surrounding cores of augite; and magnetite. The relation of the hornblende and augite is probably best explained by regarding the former as secondary, though it does not present the light-tinted scaly appearance of the ordinary uralite.[1] At 750 paces north of the same quarter-post is seen a medium-grained, nearly black rock (2,020) which shows a deep, rough weathering, and closely resembles an ordinary hornblende-rock. The thin section of this is like that last described, showing plagioclase; augite in rounded granules; brown, very highly dichroitic hornblende surrounding cores of augite, from which it appears to present every stage of alteration, and often showing strongly marked the characteristic prismatic cleavage; diallage with narrow strips of hornblende along the cleavage lines; magnetite; and viridite. Figs. 4 and 5, Plate XV C, are representations of thin sections of this rock.

On the north shore of English lake, at the head of the outlet, is a hill 50 feet in height, composed of one of these hornblende-bearing varieties (80). In this case the hornblende is the most abundant ingredient, and would undoubtedly be regarded as primary, but for the occurrence of those kinds just described, of which this appears to be merely an extreme case. Prof. Pumpelly has given to this rock the name of augite-diorite, he naturally regarding the hornblende as primary. Macroscopically, the rock is rather fine-grained and of a dark-

[1] Rosenbusch, "Mikroskopische Physiographie der massigen Gesteine," page 464.

gray, hornblendic aspect, a few particles of mica and of olivine being distinguishable. Under the microscope, the deep brown hornblende makes up most of the section. The augite (which occasionally appears as a core to the hornblende), plagioclase, mica and magnetite are subordinate. Following the outlet of the lake northward, the ordinary bluish-gray, often very coarse gabbro, is seen in large cliffy exposures on each side of the stream.

The same rock is to be seen in large outcrops on the east line of the northeast quarter of Sec. 5; on the west line of the same section, a few paces north of English lake; and very frequently throughout Sec. 6, and in the northern part of Sec. 7. Some of the exposures in Sec. 6 reach several hundred feet in length, and 10 to 15 feet in height, showing no trace whatever of structure. In a specimen (70) brought from the northwest quarter of Sec. 6 the glassy, wholly unaltered labradorite greatly predominates, while an unusual amount of coarse olivine is perceptible to the naked eye. Under the microscope, the individuals of labradorite are often simple, and thickly crowded with the characteristic needle-like inclusions. A representation of these is given in Fig. 3, Plate XV D. The olivine shows the same peculiar alteration-products (talc, etc.) noticed in the gabbro of Bad river.

In T. 45, R. 3 W., the gabbro ledges are again very numerous. On the southwest quarter of Sec. 25 was noticed a fine-grained, dark gray variety, (33), in the thin section of which the augite presents the appearance of aggregated grains, though frequently displaying the strong cleavage of diallage. On the west line of Sec. 35, 58 paces north of the corner, is a long south-facing ledge presenting two varieties of the gabbro. One of these (2,021; sp. gr., 3.00) is fine-grained and very dark gray, approaching the rock of the large ledge on the south line of Sec. 33, T. 45, R. 2 W. The augite is largely altered to a greenish viridite, while some secondary hornblende is present. The other variety (2,022; sp. gr., 2.83) is of a coarser grain, and mottled black and white. In it are perceptible very narrow blades, sometimes one-half inch in length, of striated white feldspar, and a lustrous black mineral. Under the microscope are seen, in addition to the plagioclase, very highly fibrous diallage with interlaminated brown-tinted hornblende, large scales of biotite, and rarer original (?) hornblende and magnetite. Fig. 6, Plate XV C, is a representation of this rock, showing all the ingredients named.

In the vicinity of Bladder lake, T. 44, R. 4 W., the gabbro ledges are especially large and interesting. On both sides of the Brunschweiler river, after its exit from Bladder lake, and as far north as Sec. 15, T. 45, R. 4 W., bold cliffs of gabbro are almost constantly seen, while the same rock, in ledges and large fallen masses, produces frequent rapids in the river. In Sec. 11, immediately below the exit from the lake, is a vertical structureless wall, several hundred feet in length. Both the unaltered bluish-gray and the crumbling brownish varieties are here seen (84, 85). The thin sections show the usual characters. Immediately at the head of the river the rock is uralitic. Every stage of change is seen from the pinkish augite or diallage to the greenish dichroitic uralite, and from this to chlorite, completely altered crystals often preserving their sharp outlines.

Along the west side of Bladder lake, and up to the mouth of the inlet, the gabbro is almost constantly in sight. In the northwest quarter of Sec. 13, it lies within less than half a mile of the magnetic belt of the Huronian. On all of these exposures the rock appeared to be the same very coarse bluish-gray variety. West from Bladder lake the gabbro extends southward more than half way across the township, but, except in the northern row of sections, the exposures are not frequent, the ground being low and swampy. Near the northeast corner of Sec. 3, the ordinary bluish-gray rock is seen. The several ledges on the west lines of sections 6, 7 and 18, show the same rock. The ledge on the west line of the northwest quarter of Sec. 19 shows a coarse, very dark-colored variety, in which the foliated, greenish-black diallage is macroscopically very conspicuous. Not three-fourths of a mile south from here, the Laurentian granite is in sight.

In T. 45, R. 4 W., the gabbro exposures are large and numerous. The bluffs on each side of the Brunschweiler river, southward from the northeast quarter of Sec. 22, frequently show perpendicular faces 15 or 20 feet in height. Away from the river similar lines of cliff, often several hundred feet in length, are very frequent. The accompanying intrusive red granite is also often seen. Most of these ledges show the ordinary, very coarse, bluish-gray variety (71). To the north, however, and immediately south of the diabase belt, the gabbro exposures show usually the peculiar red-and-gray-mottled variety (64) that has already been described as occupying a similar position on and east of Bad river. The most interesting exposures in this township are those in and near the Brunschweiler, on sections 15, 16 and 22. Here are a number of ledges both of gabbro and of the porphyry and fine-grained diabase and diabase-amygdaloid, which make up the more northern belt of the eruptive portion of the Keweenaw series.

The line of junction between these two classes of rocks is quite irregular. The northernmost gabbro, on the east line of Sec. 15, lies about 375 paces south of the quarter-post. This is a coarse-grained, rather unusually dark-colored rock, which, under the microscope, is seen to be uralitic. According to Professor Pumpelly, it has a specific gravity of

2.90, and consists of labradorite in long narrow crystals; another younger feldspar with undefined outlines; uralite, mostly changed to chlorite and associated with quartz; and magnetite. Further south, about 500 paces north of the southeast corner of Sec. 15, the rock is again uralitic, but differs from the last in having an unusually light gray color, owing to the large content of labradorite. At the falls of the river, southwest quarter of Sec. 15, the rocks are porphyry and fine-grained diabase. Just above the falls, at the crossing of the old Penokee road, a fine-grained, very dark-gray gabbro is in sight, which, according to Professor Pumpelly's determination, has a specific gravity of 2.85, and consists of anorthite, diallage, actinolite as an alteration-product of the diallage, magnetite, and a serpentine-like substance, possibly an alteration-product of olivine.

Following the river upward from here, a narrow band of bright red felsitic porphyry is met with, beyond which the gabbro continues changing from a rather fine-grained variety (69) to the ordinary coarse kind, as it is traced southward. The thin sections examined present no peculiar features. Ledges are found up both of the streams that enter the river in the southwest quarter of Sec. 15, and the southeast quarter of Sec. 16. Here the gabbro (64) is coarse, of a dark greenish-gray color, and mottled with dull red and white. The greenish-gray feldspar, in facets up to one quarter inch in breadth and without apparent striation, makes up most of the rock. A soft, greenish mineral, very coarse magnetite, and large black augite crystals are also perceptible. The thin section presents the usual characters of this well marked phase of the gabbro. The plagioclase is often red-stained, and only faintly banded in the polarized light, in which it at times presents the appearance of a crystalline aggregate. The diallage is mostly altered to a greenish uralite and this again to a bluish-green chlorite. Almost exactly the same rock is seen on the west line of the northwest quarter of Sec. 30, and again at the southwest corner of the same section.

In T. 45, R. 5 W., the gabbro occupies the southeastern sections, and in T. 44, R. 5 W., the northern half of the township, where ledges of this rock are often found within a half mile of the magnetic belt of the Huronian. Several ledges on the east line of T. 44, R. 5 W. have already been noted. In Sec. 16 gabbro ledges occur as far south as the center of the section, less than half a mile from the magnetic belt. On the north line of the northwest quarter of Sec. 17, 250 to 300 paces east of the creek, ledges were noted of a variety (106, 107) the thin section of which shows much deep-tinted hornblende and biotite. The rock resembles that (2,022) seen on the west line of Sec. 35, T. 45, R.

3 W. On the west line of Sec. 18 more exposures of the same rock were noted. On the west lines of sections 7 and 6 are large ledges of the red-and gray-mottled kind (112, 113; sp. gr. 2.76). One of these ledges, at the quarter post of Sec. 7, is 25 feet in height, while another, half a mile further north, in the northeast quarter of Sec. 12, T. 44, R. 6 W., presents a face 40 to 50 feet in height and 150 to 200 feet in length. The rock from both of these places is coarse-grained, very tough and compact, and of a dark greenish-grey color mottled with red. The thin section (Pumpelly) shows plagioclase, red-stained and in part altered to chlorite, and diallage mostly altered to greenish uralite and chlorite, though often remaining in cores and indefinite patches.

In T. 44, R. 6 W., the gabbro belt rapidly narrows, and by the time that R. 7 W. is reached, seems to have disappeared altogether. The westernmost gabbro ledge now known, on the southwest quarter of Sec. 14, shows a medium-grained, dark greenish-black kind, looking exactly like an ordinary hornblende rock. Professor Pumpelly has alluded to this interesting rock (119 University collection) in his lithological report, page 35 of this volume. The hornblendic appearance is due to the large content of uralite, whose production by a change in the original augite or diallage is most beautifully shown in the thin section, of which I give a representation in Fig. 1, Plate XV E.

Diabase and Melaphyr.

These rocks, which, with their amygdaloidal and pseudo-amygdaloidal phases, make up the greater part of the Keweenawan System in Michigan, are continued into Wisconsin with essentially the same characters. In our district they make up most of a belt of country lying on the north flank of the uplands, immediately north of the gabbros, and from two to six miles in width. The melaphyr, while known to be very abundant beyond our district to the west, is only known here in a few places, and then without the marked macroscopic characters of the Michigan rock.

For a general description of the lithological characters of these rocks, the reader is referred to Professor Pumpelly's report (pp. 31 to 34 of this volume). The same author has described the processes of change which these rocks have undergone in still greater detail, in a paper on the "Metasomatic Development of the Copper-bearing Rocks of Lake Superior."[1]

The diabase in our district makes up the larger part of the system

[1] Proc. Amer. Acad. Sci., Vol. XIII, p. 268 (1878).

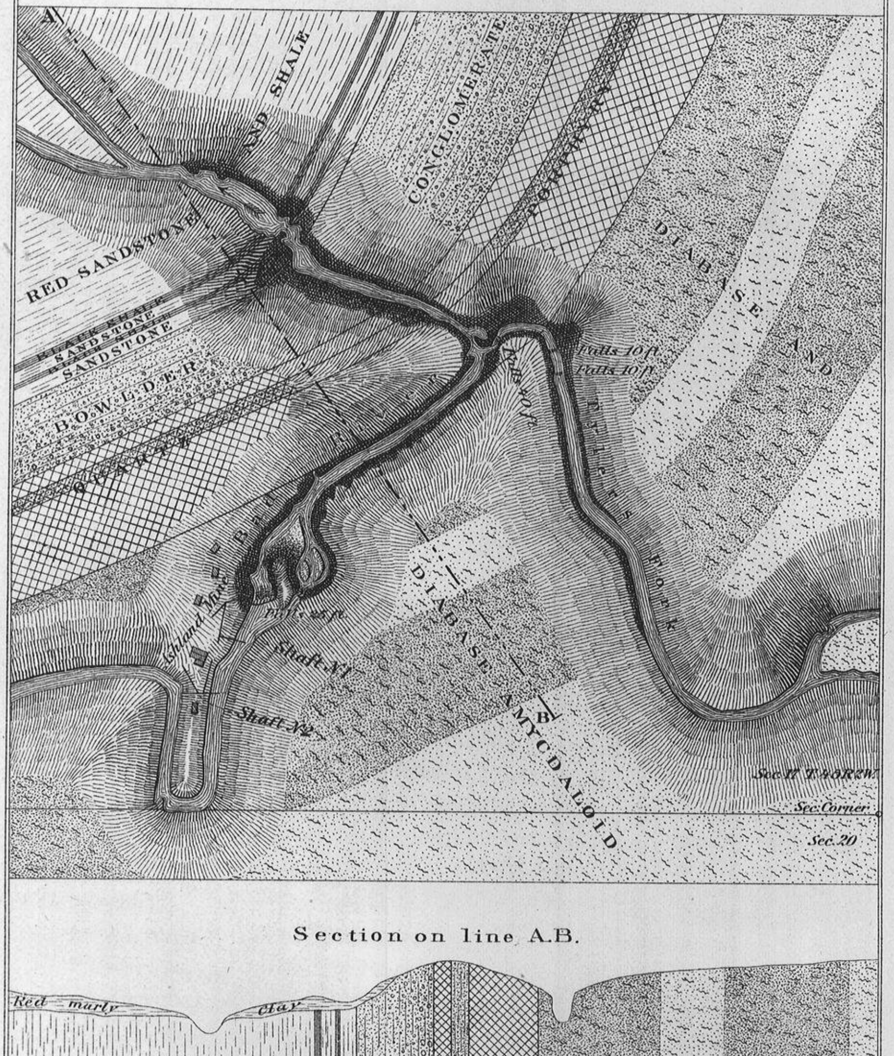
north of the gabbro belt and south of the great conglomerate. It lies in more or less distinct belts, separated by bands of porphyry, and in one portion of the district by intercalated beds of sandstone and shale. The several beds made out are indicated on the map of Atlas Plate XXII, which, with the details given below, will render unnecessary any more definite description here. The broader bands, having been worked out from more or less scattered exposures, may very possibly include narrow bands of porphyry. A few beds distinctly of detrital origin (sandstone and shale) are also included, though at only two or three places has any marked indication of this been noted. The distinct intercalations of sandstone and shale with diabase and diabase-amygdaloid are restricted to a narrow belt at the junction between the eruptive and fragmental portions of the system. This belt, moreover, though probably of great length in Michigan, extends into Wisconsin but a short distance. On the Montreal it is some 1,200 feet in width, but before Bad river is reached it has entirely disappeared. The indications are that in all these diabase belts there is a subdivision into different flows, as described by Professor Pumpelly, but, from the scattered positions and often unfavorable nature of the exposures, it has not been possible to establish this for all portions of the southernmost and broadest of the belts. A pretty distinct succession of flows can be made out, however, on the Gogogashugun river, and somewhat less distinctly on the Upper Montreal. The diabases interstratified with sandstone and shale, as seen on the Montreal and Potato rivers, are very distinctly bedded, nearly every flow being characterized in a pronounced manner by its amygdaloidal, pseudo-amygdaloidal and compact divisions. The same is true, though less markedly, of the two broad diabase bands next south from these alternations, as seen on the Potato river, Tyler's Fork, and on the Bad and Brunschweiler rivers.

In kinds of rock there is some distinction between the several bands. In the belt of alternating diabase and fragmental rocks, and in the two belts next to the southward, the prevailing diabase is the typical rock of Michigan, much more frequently, however, showing a tendency to the laumontite-calcite change of the amygdaloidal portions, than to the epidote-quartz alteration, which, according to Pumpelly, characterizes the amygdaloids of the Keweenaw Point region. In these bands the black, compact rock of the Ash-bed type is quite subordinate, though present. The broad belt, which, east of Bad river, lies to the north of the gabbro belt, is not so well known as the more northern ones, but it includes evidently a very much larger proportion of the Ash-bed type of rock. The diabase of the ordinary kind, included in this belt, is, judging from the exposures seen, much less prone to decay, and more rarely

Map and Section
SHOWING THE FORMATIONS AT THE
JUNCTION OF BAD RIVER AND TYLERS FORK

R. D. Irving

1873



Courses of rivers from instrumental surveys by J. A. Bailey
Scale 600 feet = 1 inch.

M. Swenson Del.

amygdaloidal than in the more northern belts. The laumontitic decay has never yet been noticed here, and the epidotic change in a few instances only. Some of the exposures examined show a comparatively coarse-grained rock, approaching the gabbro that lies further to the south.

Of the diabase marked on the map as taking up the whole width of the eastern extension of the gabbro belt in the vicinity of the Gogogashugun and Montreal rivers, there are two distinct divisions. That on the south, occupying about half the width, is nearly always a greenish, distinctly crystalline rock, of fine grain, and often highly amygdaloidal. The amygdules of quartz, chalcedony, chlorite, orthoclase and epidote are of unusually large size, and often elongated into cylindrical shapes. In the more northern part of this area the black Ash-bed diabase appears to prevail, though interstratified with the ordinary diabase, which has not been noticed in a highly amygdaloidal condition.

The interesting manner in which the several bands of diabase and porphyry thin out as they are followed from the Montreal to Bad river, has been noticed on a previous page.

On Bad river.— All the exposures of diabase known on Bad river are in the immediate vicinity of its junction with the Tyler's Fork branch, Sec. 17, T. 45, R. 2 W., where are also large exposure of porphyry and of the clastic rocks of the Keweenaw series. The topography of the vicinity of the junction of these two streams has already been described in some detail, and is further illustrated by Plate XII, which also indicates the geological structure. The several rock beds have here a vertical position, with a curving strike, as indicated on the plate. The diabase beds have evidently the same divisions into compact, pseudo-amygdaloidal and amygdaloidal zones, as displayed so constantly in the corresponding rocks of Keweenaw Point, but they appear to have here a much greater thickness, and, moreover, to be less distinctly marked from each other than in that region. Bad river, in a large part of its course through the diabase, makes a small angle only with the strike, so that the very large exposures seen both above the falls and in the gorge below, do not give us a knowledge of a very great thickness.

On Tyler's Fork the exposures are not nearly so large, but here the stream passes more directly across the strike, and the thickness seen is very considerable. At the time of my examination of this place (1873) the courses and subdivisions of the several layers were not made out, nor indeed were the relative positions of the several exposures fully understood until after the field notes had been studied. From the large number of specimens collected, however, the existence of at least eight distinct layers within the exposures in Sec. 17, has been since made out. Each of these has its compact, pseudo-amygdaloidal and amygdaloidal portions, and the aggregate thickness in sight is some 1,600 feet. Descending Bad river, the first exposure is met with at about 400 feet north of the quarter-post, on the south line of Sec. 17. From here low ledges are nearly continuous around the horseshoe bend of the river to the falls, and show, as far as a point 300 feet north and 640 east of the quarter-post, or nearly to the workings of the old Ashland mine, a compact, dark purplish-brown to reddish-brown, altered, diabase (3,270 to 3,275). At the Ashland mine the amygdaloidal portion of this bed comes in.

Beyond, to the falls, we are in the lower compact portion of another great bed, of which the amygdaloidal portion (39) comes in at the falls. Below the falls the rock is again compact to the end of the high rocky point which here divides the river. Beyond this again is a pseudo-amygdaloid, and then a true amygdaloid all the way to the junction with the overlying porphyry, which is only about 100 feet above the mouth of Tyler's Fork. The compact portions of these beds are close-granular, dark grayish where freshest, but more commonly some shade of red, from a dark purplish-brown to a bright red, the color depending of course on the degree of alteration the rock has undergone. The most common amygdules are of a pale greenish prehnite, ordinarily one-tenth to one-twentieth inch across, though occasionally reaching one-fourth inch. Dark green chlorite, laumontitic cleavable calcite, and quartz are also frequent amygdules. Often the whole mass of the amygdaloid is calcitic, effervescing briskly with acids. Other places occur in which both matrix and amygdules appear to have given way to a laumontitic change.

Ascending Tyler's Fork we meet first the red porphyry, over which it falls at the junction with Bad river, and then the same layers that are in sight on the main stream. The first massive rock above the falls (139; sp. gr., 3.06), the same as that just below the falls on Bad river, is very dark colored and aphanitic. In the thin section under the microscope are seen labradorite; augite, partly fresh and partly altered to a green non-dichroitic material; and altered chrysolite (Pumpelly). The alteration of chrysolite is to a greenish, feebly dichroitic substance, and to blood-red scales and seams of ferric oxide. Further up, we cross a pseudo-amygdaloid, the same as that below the amygdaloid of the Ashland mine, the matrix being of a dark purplish-brown cast, and the pseudo-amygdules prehnite and calcite. Since Tyler's Fork crosses the strata usually at right angles, we soon reach the horizon of the highest rock seen on the main stream. This is at a point some 700 feet west and 800 north of the southeast section corner. Continuing the ascent above this point, we meet similar alternations of compact (144) and amygdaloidal (143) diabase as far as the east line of the section, and beyond.

East of Bad river, as already shown, the exposures of the diabase are chiefly in the beds and the sides of the larger streams. On Tyler's Fork above the exposures in Sec. 17, already described, the diabase extends only a few hundred steps along the stream, where it gives place to a purplish quartz-porphyry, which appears to be the rock across Sec. 16 to within 500 steps of the east section line. From here Tyler's Fork is without ledges as far as the rapids in the southeast quarter of Sec. 5, T. 45, R. 1 W., where a green-and-red-mottled gabbro is seen, as described on a previous page.

On and near the middle of the east line of Sec. 12, T. 45, R. 2 W., are several low ledges of a much altered dark-colored diabase (3,160). These are very near the northern limit of the gabbros.

On the old Ironton trail, in the northeast quarter of Sec. 34, T. 46, R. 1 W., several diabase ledges were noticed. These are also very near the northern limit of the gabbro, several large exposures of which were seen a short distance southward along the trail. The rock seen here is an aphanitic, greenish to nearly black, highly altered variety, with specific gravity 2.86, and containing, as shown by the thin section, oligoclase, augite in remnants, titanic iron altered to a white substance, chlorite, epidote, and quartz (Pumpelly). Twenty rods to the south, on the trail, a red, felsitic porphyry (164) is in sight.

On Potato river, the exposures of diabase are large, especially of those beds lying immediately below the fragmental members of the series. On the upper portions of the river, sections 23 and 26, T. 46, R. 1 W., numerous low outcrops of a blackish diabase are seen. Near where the river crosses the north line of Sec. 26, the rock is compact, black, microcrystalline and conchoidal-fracturing, belonging to the "Ash-bed type." The thin section shows labradorite, augite in small grains, a green substance in clouds of granular masses, and magnetite (Pumpelly). A specimen (161) brought from 300 paces above the mouth of the creek in Sec. 23, shows a highly crystalline black rock, with numerous small, lustrous surfaces. Under the microscope the plagioclase seems to be the principal ingredient, while the augite is seen both fresh and in largely altered grains. Magnetite and apatite are both abundant.

From a short distance below the north line of Sec. 14, to the mouth of the Little Potato, the only rock in sight is a pinkish quartz-porphyry, while from this latter point downwards for nearly two miles the river is without exposures. In the southeast quarter of Sec. 17, 450 paces north and 600 west of the section corner, begins a series of exposures which continue almost uninterruptedly to near the middle of Sec. 18. In this distance the river makes three falls of 25, 25 and 32 feet respectively, besides several smaller ones, and a number of heavy rapids. The uppermost portions of these exposures, as far as the southwest quarter of Sec. 17, are of diabase, while the remainder are chiefly of conglomerate and sandstone.

The topography and the positions of the several rock beds in this vicinity are indicated on Plate XVII. The exact point at which the diabase ceases in descending the river, is 800 feet east, and 1,340 north of the southwest corner of Sec. 17. This gives a total width of diabase, measured across the general strike, of something over 2,000 feet, and, since the dip is nearly 90°, this figure also expresses the thickness. The rock is seen at times in the river bed only, and at others in low exposures on one or both banks, while in a few places precipitous walls 10 to 40 feet in height rise directly from the water's edge. We have evidently to deal here with a succession of layers nearly each one of which shows the normal divisions into compact, pseudo-amygdaloidal, and amygdaloidal portions. The subdivisions are, however, not readily perceptible except in those few places where the amygdaloidal zone has undergone the characteristic laumontitic decay. There are three prominent zones of this laumontitic rock, which have the general trend of the more northern fragmental beds. The same is true of a single red sandstone layer, intercalated at 350 feet below (stratigraphically) the conglomerate.

The compact portions of these beds are all closely allied to each other, and are all largely altered. The fresh surface is minutely crystalline to aphanitic, with a reddish-brown to dark purplish-brown tint, the color varying according to the amount of ferric oxide. Two of the beds, according to Professor Pumpelly, are of melaphyr, though macroscopically they differ but little from the compact portions of the other layers. The amygdaloids are not nearly so finely developed as on the Montreal, the amygdules being of smaller size, and not so thickly scattered. The minerals noticed in these amygdules are prehnite, laumontite, and calcite. From a series of nearly one hundred specimens collected here, the following succession of layers has been made out, beginning below:

		Feet.
I.	*Melaphyr:* dark reddish-brown, very fine-grained; the lustre-mottlings of greenish spots very small when compared with those of the typical rock of Keweenaw Point. In the thin section are seen fresh plagioclase and augite, and highly altered olivine (Pumpelly); in all	35
II.	*Diabase:* with pseudo-amygdaloid at top	70
III.	*Diabase:* massive, 227 feet; pseudo-amygdaloid, 70 feet; in all.........	297

Map Showing the
SUCCESSION OF LAYERS ALONG
POTATO RIVER
T. 64 R.1 E. Secs. 17 and 18
Surveyed by A.D. Conover. Geology by R.D. Irving. 1878.
Scale 6 inches = 1 mile.

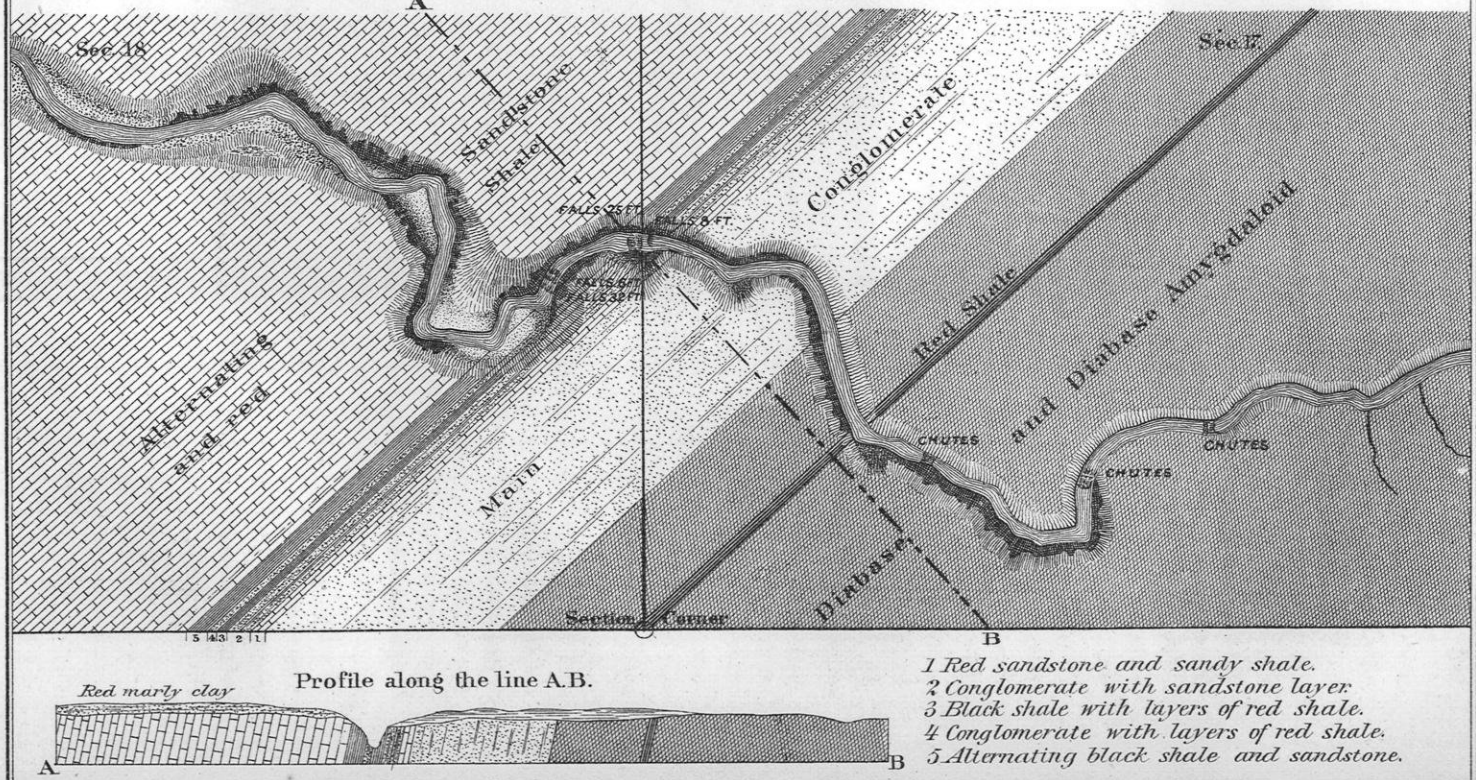


PLATE XVII

		Feet.
IV.	*Diabase:* compact, 35 feet; covered, 87 feet; pseudo-amygdaloid and laumontitic amygdaloid, 52 feet; in all	174
V.	*Diabase:* compact, and pseudo-amygdaloid	160
VI.	*Melaphyr*	50
VII.	*Diabase:* compact, 20 feet; laumontitic amygdaloid, 110 feet; in all	130
VIII.	*Diabase:* mostly laumontitic amygdaloid	140
IX.	*Diabase*, and diabase-amygdaloid; divisions not made out	660
X.	Red *shale*	9
XI.	*Diabase:* compact and pseudo-amygdaloid, 200 feet; laumontitic amygdaloid, 20 feet; in all	220
XII.	*Diabase:* compact and pseudo-amygdaloid	122
	Total	2,067

T. 46, R. 1 E., is mostly drift-covered. There are, however, several large exposures, the principal of which are on the north side of the creek running through the southern part of the town. A specimen brought from about the northwest quarter of Sec. 35 is a distinctly crystalline, dark, brown-and-black-mottled amygdaloid. The grain is coarser than usual, the plagioclase crystals averaging 0.2 mm. in breadth and 1 to 10 mm. in length. The amygdules are large and almost wholly chlorite and calcite.

On the Flambeau trail, in T. 46, R. 2 E., are several diabase exposures. The southernmost of these, a short distance north of a large swamp, and near the southeast corner of Sec. 19, is dark greenish diabase, of pronounced character, and similar to the rock which is so largely exposed further to the eastward on the Gogogashugun and Montreal rivers. A few rods to the east of this is a ledge of coarse gabbro described on a previous page. The diabase is seen along the trail for about a mile and a half, north of which, to near the middle of Sec. 7, a coarse-grained gabbro appears again to be the principal rock.

A mile and a half east of the Flambeau trail, on the Gogogashugun river, and in a number of places east of the river in Sec. 16, the same green diabase is seen. A specimen brought from near the middle of Sec. 16 has a specific gravity of 2.9 and shows under the microscope, oligoclase, largely altered to chlorite (to the presence of which mineral the rock owes its pronounced greenish color); augite, abundant and fresh; magnetite in small irregular forms apparently filling cracks; and pseudo-amygdules of chlorite (Pumpelly). These rocks appear to continue along the Gogogashugun river nearly to the northwest corner of Sec. 16, where comes in a coarse gabbro, similar to that seen along the Flambeau trail. This rock forms here but a narrow belt, the easternmost prolongation of the broad gabbro band so prominent in the townships westward from here. All along the course of the Gogogashugun the exposures are constant, and show the ordinary typical diabase and diabase-amygdaloid, with one interstratified bed of felsitic porphyry, and one or two of the black compact diabase of the Ash-bed type, to the north line of Sec. 8, beyond which, to the mouth of the river, there are no exposures.

East of the Gogogashugun a black aphanitic rock was noticed on the south line of Sec. 9, T. 46, R. 2 E., and further south the green chloritic diabase is to be seen occupying the same position as on the Gogogashugun.

On the Montreal river there is a great display of the green diabase, the exposures running along for more than a mile down stream from the N. W. $\frac{1}{4}$ of the N. W. $\frac{1}{4}$ of Sec. 13, T. 46, R. 2 E., in which distance there are several heavy falls. The southernmost exposures are within a few rods of a reddish quartzite belonging to No. XXI of the Huronian (Atlas Plate XXVI). All of these ledges show a brown-to-pink-weathering rock, which is moderately fine-grained, greenish-gray to green on a fresh fracture, distinctly crystalline, and amygdaloidal. The amygdules are large, often reaching a fourth of an inch in diameter, somewhat plenty, and composed of (1) calcite, often with a shell of chlorite; (2) pink orthoclase; and (3) chalcedony-like quartz. Others occur of a cylindrical shape, as much as an inch in length and an eighth of an inch in diameter, and composed of a center of greenish epidote, around which is a ring of quartz, making up most of the amygdule, and beyond this again a shell of very dark green chlorite. Microscopically, this rock closely resembles the green diabase of the Flambeau trail and the Gogogashugun river, of which it is beyond doubt a continuation. Greenish and orange-colored patches in the thin section of the Montreal river rock seem to indicate altered chrysolite. No definite structure was made out on any of the exposures. Dikes were seen one to two feet wide, of an aphanitic, black, heavy rock, showing a strongly marked cross-columnar structure.

Below the green diabase on the Montreal river, in Sec. 2, T. 46, R. 2 E., were noticed exposures of black aphanitic diabase of the Ash-bed type, apparently part of the same belt as recognized on the Gogogashugun in Sec. 8. From the mouth of the Gogogashugun nearly to the crossing of the Flambeau trail in the N. E. $\frac{1}{4}$ of Sec. 21, T. 47, R. 1 E., there are no exposures on the Montreal. From the trail to the mouth of the latter stream, the rocks are almost constantly in view, often forming the walls of deep gorges, or producing rapids and falls. In all this distance the rocks form a continuous series, the layers standing on end, with a dip lessening from 90° to about 75°–80° at the lake shore. At the base, in the vicinity of the Flambeau trail and the upper fall, diabase and diabase-amygdaloid alternate with red sandstone and shale. Farther

MAP and SECTION showing succession of layers along the MONTREAL RIVER, T. 47 R.I.E.

Scale: 2¼ inches = 1 mile

R. D. Irving 1876.

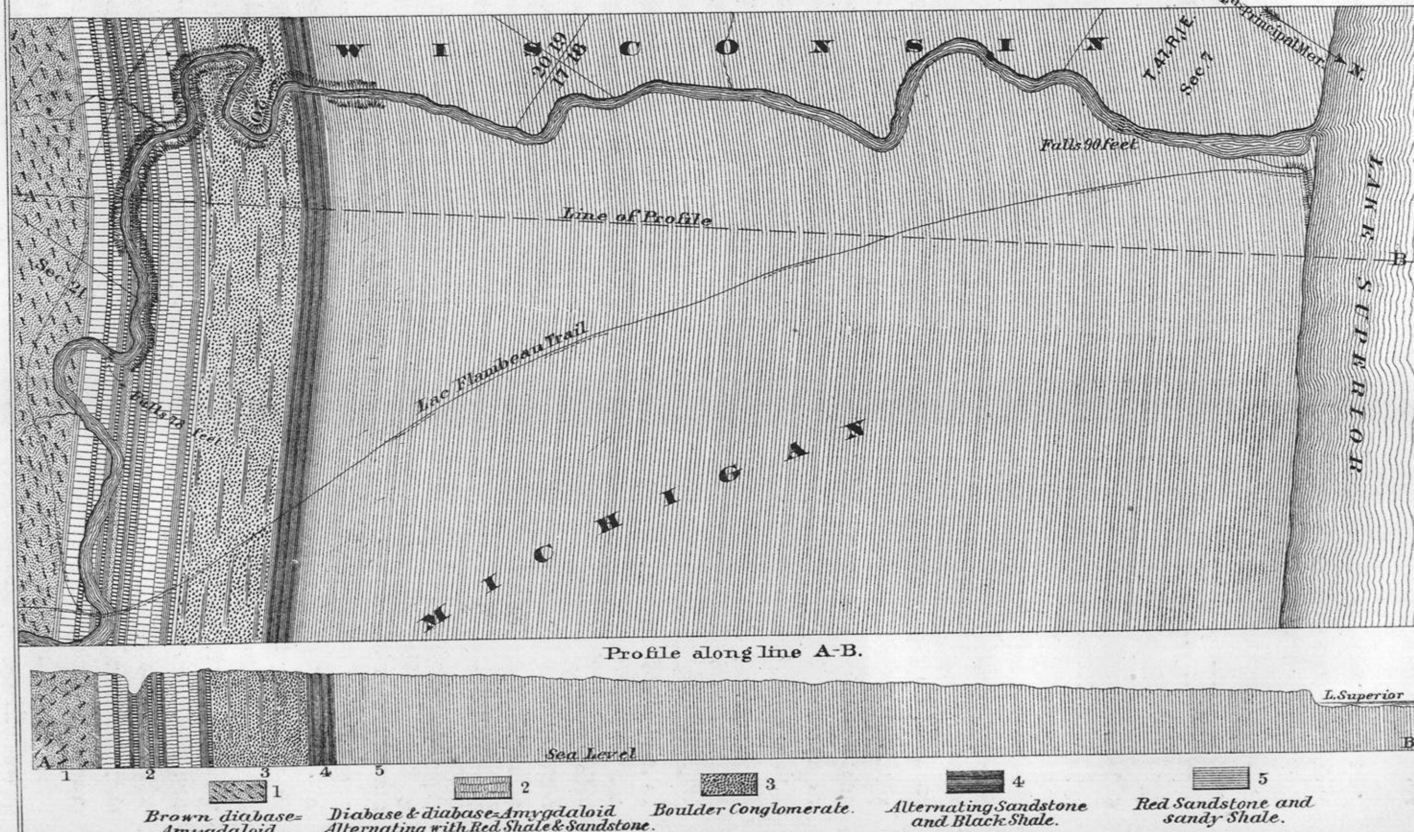


PLATE XVIII.

The Milwaukee Litho. & Engr. Co.

down the stream are boulder-conglomerate, and alternations of sandstone and black shale, followed by an enormous thickness of red sandstone and red sandy shale. This general succession is shown in the map and section of Plate XVIII of this volume, and the details of the alternations of diabase and sandstone, with the main features of the topography, in Plate XIX.

The diabase of the beds shown on the latter plate is the ordinary typical, grayish to brownish, sometimes reddish rock described by Professor Pumpelly. The beds are well defined from one another by the amygdaloidal portions, which are here far more strongly marked than at any other point in Wisconsin. The lower portions of the flows are characterized by a very distinct columnar structure at right angles to the bedding. The finest exhibition of both amygdaloidal belts and columnar structure is to be seen at the head of the upper falls, where at low water there is a very large surface of bare rock. The following is the succession of layers shown on Plate XIX, beginning above, at the base of the conglomerate:

		Thickness in feet.
I.	*Diabase*	20
II.	Red shaly *sandstone*...	10
III.	*Diabase*	4
IV.	*Sandstone* and shale, including the following subdivisions: (1) thin laminated red shale, 4 feet; (2) purplish, lumpy, fine-grained sandstone, 8 feet; (3) like (1), 2½ feet; (4) like (2), 6 feet; (5) like (1), very bright red, 1½ feet; (6) like (2), 5 feet; (7) bright red clay shale, 14 feet; total	41
V.	*Diabase*, including the following subdivisions: (1) amygdaloid with abundant amygdules of prehnite, laumontite, calcite and chlorite, and with seams of laumontite and large patches of calcite in the more thoroughly altered portions, having at base a heavy laumontite and calcite seam carrying copper, and on which some mining has been done, 25 feet; (2) pseudo-amygdaloid, 5 feet; (3) compact portion with distinct columnar structure, the rock having on a fresh fracture a grayish color and distinctly crystalline appearance, though very fine-grained, 70 feet; in all	100
VI.	Covered	185
VII.	*Diabase*, with subdivisions as in V	92
VIII.	Red *sandstone* and shale..	20
IX.	*Diabase* with subdivisions as in V; compact portion dark chocolate brown	50
X.	Reddish conglomeratic *sandstone*	60
XI.	*Diabase*, including: amygdaloid, 10 feet; compact portion, 20 feet; in all,	30
XII.	*Diabase*, including: amygdaloid, 5 feet; compact portion, 20 feet; in all,	25
XIII.	*Diabase*, with usual subdivisions..................................	10
XIV.	*Conglomerate*	33
XV.	Red *sandstone* and shale..	60
XVI.	*Diabase*, with usual subdivisions..................................	60
XVII.	Red *sandstone* and shale..	20
XVIII.	Compact, dark greenish-gray *diabase*, with amygdaloid at top, and showing a tendency to a cross-columnar structure..................	21

		Thickness in feet.
XIX.	*Diabase*, including: (1) amygdaloid, in many places showing a tendency to cross-columnar structure, some bands almost completely made of amygdules, and others with but few, 15 feet; (2) compact portion, highly columnar, 8 feet; in all	23
XX.	*Diabase*, including: (1) amygdaloid in distinct bands as in XIX, some of the bands showing a change to laumontite and calcite — the amygdules, in order of abundance, being prehnite, pink orthoclase, orthoclase and calcite, orthoclase and prehnite, calcite, 11 feet; (2) compact portion, with columnar structure, 10 feet; in all	21
XXI.	*Diabase*, including: (1) amygdaloid, in many places altered into laumontite seams, 2 feet; (2) compact portion, 30 feet; in all	32
XXII.	Red clay *shale*	5
XXIII.	*Diabase*, without amygdaloid	10
XXIV.	*Diabase*, including: amygdaloid, mostly covered, 15 feet; compact portion, 40 feet; in all	55
XXV.	Covered	185
XXVI.	Red *shale*	40
	Total	1,209

Beyond the limits of Plate XIX, and up the river to the trail, there are numerous exposures of Nos. XVI to XXVI. A specimen of the rock at the trail has been examined by Professor Pumpelly, according to whom it is a typical diabase pseudo-amygdaloid, containing anorthite and augite, with chlorite and calcite in the amygdules, which are exceedingly small and not readily recognizable with the naked eye. It is a brownish rock minutely speckled with white and green.

West of Bad river, the only exposures of diabase that have been seen are on Silver creek and the Brunschweiler river.

The exposures on Silver creek are chiefly in sections 15 and 22, T. 45, R. 3 W. Where the Wisconsin Central road crosses, in the south half of Sec. 10, the creek is in a steep-sided ravine 85 feet deep, with banks of red clay. Ascending from here the ravine continues with about the same depth to the south line of Sec. 15, where it shallows and becomes narrower. The exposures are all low, never rising more than five or ten feet above the water. The northernmost rock (130; sp. gr., 2.67) is about 20 rods below the forks, and near the south line of Sec. 15. It is a dark-brown, soft, and highly altered diabase, the matrix changed to reddish laumontite, and the amygdules of laumontite and calcite. From here, up the left hand or western fork, small exposures continue of a similar rock (132, 133), often showing also the epidotic change. About half a mile up the same creek are low ledges of a brick-red compact felsitic porphyry (134), beyond which are again small outcrops of altered diabase-amygdaloid (135). The eastern fork is without exposure.

Map showing the
SUCCESSION OF LAYERS ALONG THE
GORGE OF THE MONTREAL RIVER
T. 47 R. 1 E. Secs. 20 and 21
Roland D. Irving. 1876
Scale 10 inches = 1 mile.

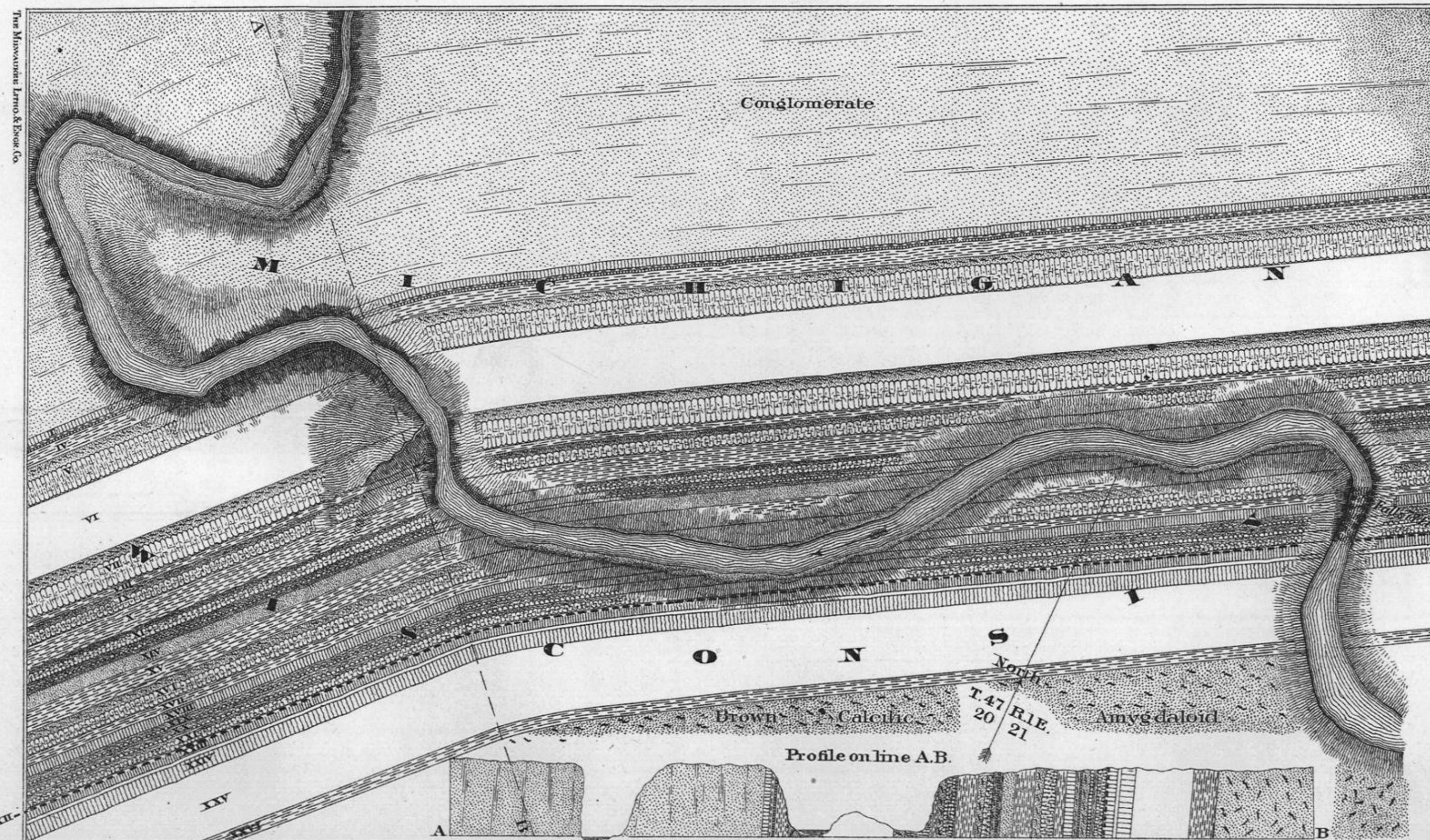


PLATE XIX

On the Brunschweiler river in sections 15 and 22, T. 45, R. 4 W., the exposures are much larger than on Silver creek. There are also ledges in the creeks to the west of the river. On the river itself, the rock immediately succeeding the gabbro is a non-quartziferous porphyry (65), having a brown matrix and long thin plates of reddish feldspar. This is succeeded by a narrow belt of brick-red felsitic porphyry, over which the river falls, near the south line of Sec. 15. The quartzless porphyry is seen again on the east side of Sec. 15, near the quarter-post. Both here and on the river the next rock above is a black, aphanitic, conchoidal-fracturing diabase of the Ash-bed type, with a width of some 60 paces. Below this on the river there are no exposures for 200 to 300 paces, when small ones appear of a reddish porphyry, succeeded by others of the ordinary diabase and diabase-amygdaloid, the latter for the most part largely altered to laumonite. These extend down the river for some 300 paces. Beyond these are no exposures until the southeast corner of Sec. 10 is reached, where are ledges of conglomerate.

In the northwestern part of T. 44, R. 5 W., are a number of low diabase exposures. In T. 44, R. 6 W., and beyond, they become more numerous and larger, as described by Professor Chamberlin in another part of this volume.

Granite.

The same coarse granite that is found cutting the upper mica-schists of the Huronian penetrates also in veins and vein-like masses the gabbro at the base of the Keweenawan System. It is coarse-grained, and in color from pink to red, mottled with white, gray, and black. The constituents, mentioned in order of importance, are pink orthoclase, but little altered, in grains which frequently reach one-fourth to one-half inch in length; gray translucent quartz in grains up to about two-tenths of an inch in diameter; abundant black lustrous biotite, in minute flakes; also rarer and smaller white plagioclase and still rarer magnetite; apatite. The quartz of this granite, as is commonly the case with the coarse-grained intrusive granites, is crowded with liquid inclusions, which in some cases cloud the grains, and not unfrequently contain separate cubes of sodium chloride. The coarseness of grain, the highly crystalline texture, the entire absence of a laminated arrangement of the constituents, and of any indication of a clastic origin, and the comparative richness of the quartz in fluid inclusions, all serve to distinguish this granite from that which is merely a dependency or particular phase of the Laurentian gneisses, and at the same time to ally it to the true intrusive granites. That it really is intrusive is proven by the position it has been found occupying both in the mica-schists of the

Huronian, and in the Keweenawan gabbro. In a number of places, however, the same coarse granite has been seen rising in low mound-like forms, without neighboring outcrops of the including gabbro, and this has given rise to the erroneous idea that the belt I have described as made up of gabbro, is composed largely or entirely of granite.

Messrs. T. B. Brooks[1] and C. E. Wright have found, in the Marquette and Menominee districts of Michigan, a granite formation, regarded by them as indigenous, at the summit of the Huronian system, and Mr. Brooks has assigned the rock now under discussion to the same horizon, having the erroneous impression mentioned above. I am unacquainted with the upper Huronian granite of these gentlemen, but in the Bad river country we have unquestionably to do with a true intrusive (exotic) granite, which is quite subordinate in quantity to the gabbro it penetrates.[2]

Detailed descriptions have been given in preceding pages, of the granite cutting gabbro at the falls of Bad river, Sec. 30, T. 45, R. 2 W., as also that found cutting both mica-schist and gabbro in the north-

[1] Am. J. Science and Arts, March, 1876.

[2] Mr. Wright, who has had occasion to examine the Bad river granite in one or two places, in his report as Commissioner of Mineral Statistics to the state of Michigan, alludes to the Laurentian and upper or Huronian granites at some length, stating that all of the Michigan and Wisconsin varieties of which he has examined thin sections, are metamorphic, *i. e.*, are indigenous or merely sediments altered in place. This conclusion he bases, however, on the wholly erroneous idea that an igneous (intrusive) granite is always characterized by the absence of liquid-filled and presence of glass or stone-filled cavities, in the quartz, these characteristics being inverted for the metamorphic (indigenous) granite. But the true intrusive granites are well known to carry quartzes in which the liquid-filled cavities are in especial number and abundance, many holding the salt cube of which Mr. Wright speaks; while glass and stone-filled cavities have never been observed in true granular granites, their existence even in those varieties which carry crystals of quartz in a base approaching that of the felsites being strongly questioned by such authorities as Zirkel and Rosenbusch. The term igneous, used by Mr. Wright, who seems also to hold to the unwarrantable theory that the original rock of the earth's first-formed crust would be granite, is one not applicable to any granites, since even in the case of the exotic kinds the relation of the constituent minerals disproves a true igneous origin. The quartz of granite is always the last-formed mineral, whereas, from its infusibility, it would certainly be the first to form in cooling from a state of fluidity. All the facts go to show that the true intrusive granites are but sediments softened by what has been termed aquo-igneous fusion to a degree of plasticity sufficient to allow of their penetrating fissures in the adjacent formations. The intrusive or exotic granites, and the metamorphic or indigenous granites, have thus had about the same origin, and there are no lithological characteristics whatever, either microscopic or macroscopic, by which we can distinguish them in specimens. See H. Rosenbusch, in "Microscopische Physiographie der massigen Gesteine," pp. 8, 9; also "Microscopische Physiographie der petrographisch-wichtigen Mineralien," p. 225. F. Zirkel, "Microscopische Beschaffenheit der Mineralien und Gesteine," pp. 105, 317; also, "Geological Survey of the Fortieth Parallel," Vol. VI, pp. 58, 59.

eastern portion of T. 44, R. 3 W., and southeastern of T. 45, R. 3 W. The other granite exposures, which, so far as known, occur wholly in the towns west of Bad river, show exactly the same rock. The positions of a number of these are indicated on Atlas Plate XXII. Fig. 2 of Plate XV C of this volume, shows the appearance of sections of this granite under the microscope.

Granitic Porphyry.

In the vicinity of the Ironton trail, in the southern part of Sec. 34, T. 46, R. 1 W., have been noticed ledges of a bright red rock (165), which macroscopically appears to consist of a compact red base, in which are developed numerous small cleavage surfaces of orthoclase, and minute dark gray quartzes. A few particles of greenish chlorite also appear. The silica content is 72.5, and the specific gravity 2.63. These characters appear to place it with those granite-like rocks which stand between the true granites and the felsitic porphyries. Under the microscope the quartz and orthoclase are the main constituents, with magnetite and chlorite as accessories. The quartz carries very abundant fluid inclusions, often reaching .015 mm. in length. Most of these hold a bubble, which is at times stationary and in other cases moves rapidly from side to side of the cavity. The orthoclase crystals are both clear and red-stained. The latter are most plenty, and are often rendered nearly opaque by the decomposition and red iron oxide which stains them.

Felsitic Porphyries.

Interstratified with the diabase beds of the Keweenawan System, are bands made up of felsitic porphyries, mostly of the quartz-porphyry kind. These rocks have the usual characters of allied rocks in other regions, namely a felsitic base of orthoclase and quartz — and consequently a high silica content — which may contain macroscopic crystals of orthoclase and quartz, or one of these alone, or neither. All of these varieties are found. The prevailing color is some shade of red. One of the most abundant and least altered kinds has a lilac to pink matrix, in which are scattered black quartzes, full of fluid inclusions, and porcellaneous orthoclase. In some of the red varieties the orthoclase crystals and orthoclase base are more or less completely altered, and the softened rock is easy to confound in the field with some of the red-stained and highly altered diabases.

In one or two places these porphyries have been noticed having a distinctly conglomeratic character, and in one or two other places are seen to grade into a fine-grained rock of clastic appearance. Since similar appearances are known with other ancient porphyries,[1] and since in the Michigan region all the porphyry beds yet studied in detail are distinctly clastic, a strong suspicion is aroused as to the possible fragmental nature of all of the apparently compact porphyries of this region. Should we regard them as certainly eruptive, we should be led at once to reject Richthofen's law as to the succession of acid and basic rocks, as far as the more ancient formations are concerned, for here we have distinct alternations of the two kinds. In Douglas county, on the north side of the great synclinal, Mr. Sweet has found similar alternations, the porphyry without indication of clastic origin.

The southernmost of the several porphyry belts recognized is that represented by low exposures in the vicinity of the Ironton trail, in the eastern part of Sec. 34, T. 46, R. 1 W., and again on the Potato river in Sec. 35 of the same township. From its position it seems not improbable that the porphyry in sight on the Gogogashugun river, near the north line of Sec. 8, T. 46, R. 2 E., belongs to the same belt, which appears to have but an inconsiderable width when compared with the more northern ones. It is possible that the red rock on the Brunschweiler river, in the north part of Sec. 22, T. 45, R. 2 W., belongs also to this horizon, but it has distinct gabbro both north and south of it, and is at such a distance from the other exposures named, that this must remain a mere conjecture.

The rock seen on the Brunschweiler is a light pinkish to brick-red and even purplish-red felsite (sp. gr. 2.52), showing only rare and small crystaliine facets to the naked eye. It is exposed both on the river and also at a point some 30 to 40 rods west. The rock near the Ironton trail in Sec. 34, T. 46, R. 1 W., is not well exposed, and is much weathered and brown stained. It appears to approach closely to that seen on the Brunschweiler. The same is true of the rock on the Potato river, in the north part of Sec. 35. The exposures of porphyry on the Gogogashugun form a belt just 100 paces in width, bounded both north and south by diabase. The northernmost exposures lie but a few steps south of the north line of Sec. 8, T. 46, R. 2 E. On the northern border of this porphyry is a narrow belt, two paces wide, of a hard but distinctly laminated shale-like rock. The porphyry itself (3,026 to 3,028) has an exceedingly hard, pinkish to dark purplish-red matrix, the lighter colored kinds carrying small porphyritic quartzes, the darker varieties small brick-red orthoclase facets, and also showing a minute blackish green mottling due apparently to chlorite.

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[1] In Eastern Massachusetts, near Boston, very ancient felsitic porphyries show every possible stage of alteration, from conglomerate to compact porphyry. See T. P. Bouvé: Proceedings Boston Soc. Nat. Hist., 1862, p. 57; 1876, p. 217.

The second porphyry belt, one of the two principal ones, is known from exposures on the Brunschweiler, Silver Creek, Tyler's Fork, and the Potato, it having apparently a much greater width in its eastern, than in its western portions. On the Brunschweiler this belt is not over 100 paces in width. The rock is seen at the foot of the falls, near the south line of Sec. 15, T. 45, R. 4 W., where it is a brick red felsite (sp. gr. 2.62) almost without crystals. On the west fork of Silver creek, northwest quarter Sec. 22, T. 45, R. 3 W., a precisely similar rock (134) is seen in a small and low exposure.

On Tyler's Fork the exposures which appear to belong to this belt are in the southern part of Sec. 16, T. 45, R. 2 W., where the river has an easterly course. Here are a number of low ledges forming rapids in the bed of the stream. The ledge 500 paces down the stream from the east line of Sec. 16 shows, for a width of 100 feet, the characters of the ordinary porphyry conglomerate of the Keweenaw System. On the other exposures the conglomeratic appearance is not evident. Some of the rock is a dark red, exceedingly compact, jointed felsite, but most of it has a pinkish to lilac base (145), thickly studded with white porcellanous crystals of orthoclase, the larger ones one-eighth inch by one-twentieth inch in size, and smaller dark gray glassy quartzes. If there are no beds of the diabase intercalated in the covered spaces, the porphyry has here a width of as much as 800 to 1,000 paces.

On the Potato river, in Sec. 15, T. 46, R. 1 W., from the mouth of the little Potato up the stream for several hundred paces are low outcrop of a rock (162; sp. gr. 2.58) very close to that last described. Under the microscope it presents a wholly crystalline base, in which orthoclase appears to predominate, and which includes numerous minute, yellow and blood-red scales of ferric oxide, to which the color of the rock is probably due, as also minute particles of magnetite and biotite. Quartz and orthoclase occur porphyritically, both showing often in the section sharp linear outlines. The quartz is crowded with liquid inclusions, while the orthoclase is dulled and whitish. Above the Ironton trail to the southeast part of Sec. 15, other porphyry exposures occur. That seen in Sec. 15 is a brick-red felsite. If all these ledges indicate one porphyry belt, which is by no means necessarily the case, its width is as much as a mile. Brick red felsite is to be seen at several points along the course of this belt, in the northwest part of T. 46, R. 1 E., and southeast of T. 47, R. 1 E., but where it would strike the Montreal river there are no exposures.

The third and northernmost porphyry belt is known from exposures near the Brunschweiler in Sec. 15, T. 45, R. 4 W., and on Bad river, at the mouth of Tyler's Fork, Sec. 17, T. 45, R. 2 W. The exposures at the latter place are very large. The gorge of Bad river is cut for some distance through the porphyry, and the fall of 45 feet at the mouth of Tyler's Fork is over the same rock. The position of the exposures and their relations to the adjoining conglomerate and diabase beds, will be best understood from an inspection of Plate XVI of this volume.

We have here several phases of porphyry in the same bed; (1) the lilac porphyry, like that described above as characterizing much of the middle one of the three porphyry belts (150); (2) a much altered quartz-porphyry (37, sp. gr., 2.58; 42, sp. gr., 2.60) having a brick-red, somewhat softened matrix, scattered through which are minute brighter red orthoclases, and dark gray to black quartzes; and (3) an exceedingly compact, dark red to brown, highly jointed rock (138, sp. gr., 2.7), without sign of porphyritic feldspar or quartz. According to Professor Pumpelly, the second one of these varieties shows in the thin section abundant quartzes, into which club-shaped masses of the felsitic base project, and orthoclases almost wholly decayed to a kaolin-like substance. According to the same authority, the last named variety is merely an aggregation of tabular crystals of orthoclase, stained brown with iron oxide. This variety comes from the upper portion of the bed and immediately below the conglomerate, where it is cut up by two systems of joints into small, smooth-faced fragments a few inches on a side. In many places the joint-cracks have since been filled with calcite, which, in the uppermost 25 or 30 feet, makes up a large part of the whole mass.

Conglomerate.

Besides the conglomeratic phase of quartz-porphyry and the fine conglomerates subordinate to sandstone, there are recognized as characterizing the Keweenawan System, throughout its entire extent, great bands of boulder-conglomerate, often many thousand feet thick, and made up of rounded boulders from six inches to two feet in diameter.

One of these great conglomerate beds extends entirely across our district from the Montreal river to the west line of R. 5 W. Further west it appears to be present at a number of points described in the notes left by the late Mr. Strong. It seems to have been thus traced for a total length of 70 miles in Wisconsin. It also certainly extends a long distance eastward into Michigan, being distinctly recognizable as far east as the Porcupine Mountains. Like all of the beds lower down in the system, it lessens in thickness as it is traced westward, being 1,200 feet thick on the Montreal, over 700 on the Potato, and only about 300 on Bad river, west of which it appears to widen again, though this is partly due to a flattening in the dip. The constituent boulders include many of felsitic porphyry; more are of the ordinary diabase and diabase-amygdaloid, and in some places quartzite boulders are plenty. The matrix, which is often almost wholly excluded, is a dark reddish-brown sandstone, composed apparently of the same materials as the boulders in a finer condition. The stratification of the mass is in many places only evident from the occurrence of thin layers of sandstone with few or no boulders. There is often much calcite between the boulders and sand grains, evidently an infiltration product.

The conglomerate exposures on the Montreal, the finest in the district, are in Sec. 20, T. 47, R. 1 E. The river passes here through a narrow tortuous gorge with walls of conglomerate on each side several hundred feet in height. Plates XVIII and XIX will serve to give a correct idea of the topography and geology at this place. Plate XVII shows the occurrence of the conglomerate on the Potato, Sec. 17, T. 46, R. 1 W., and Plate XVI does the same for the conglomerate on Bad river, Sec. 17, T. 45, R. 2 W. The general course of the conglomerate belt is shown on Atlas Plate XXII. On Potato river, besides the main conglomerate, 740 feet wide, there are four narrower bands, separated by shale and sandstone layers, and ranging from seven to forty feet in width. On Bad river there is a distinct graduation into the overlying sandstone.

Sandstone and Shale.

Above the boulder-conglomerate just described, and forming the uppermost part of the Keweenawan System, is an immense thickness of sandstone, including some red sandy shale grading into clay-shale, and, at the base, in the eastern half of the district, layers of blackish shale interstratified with a peculiar hard, gray to brown and brownish-red sandstone, unlike the ordinary red variety. Immediately below the boulder-conglomerate, also only in the eastern part of the district, red sandstone and shale are interstratified with diabase and diabase-amygdaloid; and further down in the series occasional indications of interstratified sandstones are met with.

The alternations of red sandstone and shale with diabase and diabase-amygdaloid immediately below the conglomerate, on the Montreal river, are given on page 191 and on Plate XIX. In a total thickness of about 1,200 feet, there are here 289 feet of sandstone and shale, in nine different beds, ranging from five to sixty feet in width. The rock of these layers grades from a fine conglomerate through coarse sandstone, and thin-laminated, fine-grained, shaly sandstone to clay-shale, the color being always some shade of red. All of these are largely made of a feldspathic constituent, though quartz is generally present to some extent, and bright scales of mica often dot the planes of lamination.

On the Potato river these sandstone layers have nearly disappeared, there being only one narrow one left, as shown on Plate XVII and in the descriptions given on page 188.

The alternations of black shale and sandstone mentioned as coming just above the conglomerate constitute a sharply marked horizon, and have received a separate color on the map and sections of Atlas Plate XXII. Like the conglomerate and other members of the series below them, they narrow rapidly as followed westward, having on the Montreal a total thickness of 350 feet, on the Potato of 250 feet, and on Bad river of 120 feet; beyond which it is not known how far they extend. The relations of these layers to the other formations, as shown in the gorges of the three rivers named, will be best understood from Plates XVI, XVII and XVIII of this volume.

The shale of these alternations is dark purple to black, very soft and clayey, and quite regularly laminated. It is possible that it at times holds carbon, though in the only specimens tried this did not prove to be the case. The shale layers run from ten to fifty feet or more in width, and the shale is subordinate in amount to the associated sandstones, into which there is seen in places a distinct graduation. The low percentage of silica obtained from a specimen brought from Bad river confirms the view that they are merely fine-grained varieties of the associated sandstone. These are dark gray to brown, very close-grained and compact, and often appear macroscopically like a very fine-grained crystalline rock. A close examination shows fine lines of lamination, parallel to which there is a difficult cleavage, affording surfaces thickly dotted with silvery mica flakes. On the Montreal the rock rises in massive exposures, often much cross-jointed, and forms in several places islands in the middle of the stream thirty or more feet in height.

Under the microscope the thin section of this rock (1,516) shows at once its clastic nature, and at the same time the reason for its resemblance to some of the compact diabases of the eruptive portions of the system. It proves to be made up chiefly of rounded particles of the diabase, and of the constituent minerals of that rock, some of the particles showing only one mineral, others, derived from finer-grained varieties, showing the several minerals associated together. A smaller number of similarly rounded particles present the appearance of the felsitic matrix of a porphyry, and other angular fragments, the orthoclase crystals of the latter rock. Only a rare quartz grain is to be seen. All of these are embedded in a cement of calcite, in which the rhombohedral cleavage and twinning in the polarized light are very pronounced. Most of the clastic fragments show more or less decomposition, the augite being usually changed to chlorite, and the plagioclase partly dulled, though still often recognizable by its twin lamellation. Other less easily followed changes have evidently been set up after the formation of the sandstone. The grains run from 0.135 mm. to 0.45 mm. in greatest length, most of them averaging 0.25 to 0.35 mm. Figs. 1 and 2, of plate XIX A, are representations of the thin sections of this rock.

This sandstone, with its accompanying shale, occupies apparently just the horizon of the silver and copper-bearing rocks of Iron river, Michigan, over forty miles east of the Montreal. The succession there seems to be closely the same as that on the Montreal, and the silver-bearing rock is the same as the rock now under description, which is almost wholly without quartzose admixture.[1] Assays made on large samples of the Montreal river sandstone and shale showed distinct traces of silver, but nothing more.

The great mass of red sandstone which makes up the upper part of the Keweenawan System, with an apparent thickness of upwards of 10,000 feet, is exposed on both sides of the synclinal. Within our district the northward-dipping sandstones are to be seen in the gorges of the Montreal, Potato and Bad rivers, while the southward-dipping beds are seen at two points only, on Bad and White rivers, at each of which, however, there is a considerable thickness exposed. Elsewhere they are concealed beneath the glacial drift and Quaternary lacustrine clays, although they undoubtedly underlie all, or nearly all, of the area between the lake shore and the northern edge of the highlands.

In both external characters and composition these sandstones differ much from the brown calcitic rock last described. They are for the most part reddish in color, and of a fine to medium grain, more rarely coarse-grained. Occasionally light-colored layers are seen. The fine-grained kinds become more and more thinly laminated, and more thoroughly clayey, as they become finer, grading into a regular clay-shale, in which, however, some little admixture may be detected. The clayey material is to some extent always perceptible in the coarse kinds, in which quartz can often be made out as the main one of the coarse ingredients, feldspars being then also distinctly recognizable to the naked eye. The one or two thin sections examined corroborate this. In them are to be seen colorless grains 0.225 mm. to 0.5 mm. in length, imbedded in a fine-grained reddish matrix. The larger fragments are most frequently

[1] Called quartzite by C. E. Wright; see report of Commissioner of Mineral Statistics of the State of Michigan for 1878, p. 202. See, also, Geological Survey of Michigan, Vol. III, p. 157, where Dr. Rominger calls the same rock a "sand-rock hardened by abundant calcareous cement."

quartz, but a very considerable proportion are plagioclases, and there are also some orthoclases. The matrix appears to be made up largely of the same ingredients, the feldspars, however, being for the most part altered to a clay-like substance, mingled with which is the oxide of iron by which the red color is produced (Figs. 3 and 4, Plate XIX A). Many samples will yield a large beard of magnetite on treating the powder with a magnet.

On the Montreal river, the northward-dipping sandstones are exposed almost continually from the mouth up to the great conglomerate. The total apparent horizontal width here is 12,000 feet, and the thickness cannot be much less, since the dip is so nearly vertical (Plate XVIII). At the mouth of the river the sandstone rises in bold cliffs, 80 to 90 feet in height, directly from the lake, the cliffs stretching a long way eastward on the Michigan shore, but ending just to the west of the river's mouth. Up the river there are similar bold exposures, a fall of some 90 feet being met with only a few rods from the lake. All about here the sandstone layers bear about N. 42° E. (magnetic), and dip 75° to 80° to the northward. The thin slaty layers alternate with the heavily bedded ones, the former coming out under the hammer in large thin slabs, sometimes two or three feet square. Further up the river the characters are generally the same, with but slight variation, the vertical sandstone layers in many places rising in cliffs 100 feet and upwards in height.

On the Potato river the sandstone exposures are chiefly in the S. E. ¼ of Sec. 18, T. 46, R. 1 W., below the last falls. Here the exposures are not so bold as on the Montreal, the rock being often overlaid by banks of red clay. The vertical dip is still preserved, the strike being N. 45° E. The entire thickness in sight is about 1,800 feet. The characters are the same as on the Montreal (Plate XVII).

On Bad river, Sec. 17, T. 45, R. 2 W., the thickness in sight is only about 300 to 400 feet. The exposures are, however, bold, rising in cliffs 60 to 90 feet in height. The characters are otherwise the same.

Southward-dipping sandstones are in sight on Bad river, in Sec. 25, T. 47, R. 3 W., near Leihy's old mill. They form here a series of rapids between one and two miles long, but the total width seen is only about half a mile, corresponding, with a dip of 38° south, and N. 50° to 60° E. strike, to a thickness of about 2,000 feet. The same alternations of thin and shaly, and heavy-bedded layers, as noted with the northward-dipping sandstone, are here to be seen. Figs. 3 and 4, Plate XIX A, represent a thin section of a specimen obtained from just below the dam at Leihy's.

Precisely similar rocks are again in sight on White river, N. E. ¼ of Sec. 6, T. 46, R. 4 W., at Welton's dam. Here the river cuts through the sandstone and shale for about a quarter of a mile. The whole thickness in sight, however, is not more than 300 to 400 feet. The dip is 25° S. E., and the strike N. 40° E.

The following table of analyses will serve to show the composition of the several kinds of sandstone described in the foregoing pages as belonging to the Keweenawan System:

	1	2	3	4	5	6	7	8
Silica	54.50	49.94	55.91	51.98	75.24	69.78	72.14	68.91
Alumina	......	......	......	......	......	15.43	......	......
Iron sesquioxide	......	......	......	......	......	7.93	......	......
Lime	......	......	......	......	......	.49	......	......
Magnesia	......	......	......	......	......	1.17	......	......
Potash	......	......	......	......	......	2.64	......	......
Soda	......	......	......	......	......	2.42	......	......
Total	......	......	......	......	......	99.86	......	......

Of these analyses, Nos. 1 to 3, inclusive, are of the quartzless brown sandstone belonging just above the great conglomerate. No. 1 is of a specimen (154) from the wall of the gorge of Bad river, Sec. 17, T. 45, R. 2 W., about a hundred feet down stream from the conglomerate (Plate XVI); and No. 2 is from about one hundred feet further down the stream (155). No. 3 is from an island in the Montreal river, northwest quarter of Sec. 20, T. 47, R. 1 E. A thin section of the same specimen (1,516) is represented in Figs. 1 and 2, Plate XIX A. No. 4 is black shale (156) interstratified with 1 and 2 on Bad river. No. 5 is a reddish sandstone (158) from Bad river, in Sec. 17, T. 45, R. 2 W., the last seen in descending the river from the mouth of Tyler's Fork. No. 6 is a reddish feldspathic sandstone (44) from the falls of Bad river, Sec. 25, T. 47, R. 3 W. The thin section of the same rock is shown in Figs. 3 and 4 of Plate XIX A. No. 7 is a somewhat more quartzose rock (45) from the same place. No. 8 is a coarse reddish and greenish sandstone (125) from Welton's dam, Sec. 6, T. 46, R. 4 W.

ECONOMIC CONTENTS OF THE KEWEENAWAN SYSTEM.

The Keweenawan rocks have long been known as the "Copper-Bearing" series, in allusion to the large amount of copper they contain in the typical region of Keweenaw Point. Copper is a constant associate of these rocks throughout their entire extent in Michigan and Wisconsin. Silver generally occurs associated with the copper, though in small quantities. It also occurs in independent deposits, especially on the north shore of Lake Superior, where one vein has proved of extraordinary richness.

The copper of Michigan occurs entirely in the native state, a thing elsewhere observed only in the upper or altered portions of veins containing other copper minerals. In Michigan there are two classes of copper deposits known, the true fissure veins — fissures crossing the bedding of the system, and filled by infiltration from the sides, — and mineralized belts, or beds of rock impregnated with copper. As shown before, the beds making up the copper series are chiefly diabase and diabase-amygdaloid of eruptive origin from 20 to 100 feet in width, interstratified with porphyry conglomerates and reddish sandstones from mere films to many hundred feet in width, in all of which copper occurs. The earlier mines were on the true fissure veins; a few of which are still successfully worked near the eastern end of Keweenaw Point. Much the larger portion of the copper now obtained, however, comes from the porphyry conglomerates and amygdaloids. The latter are often largely epidotic, and, from the contrast they present to the surrounding rocks, have often received the name of lodes. They are, however, merely amygdaloids which have undergone an extreme degree of alteration, brought about by the percolation of water through their minute cracks. One of the last results of this alteration has been the introduction of copper. The amygdaloids can be worked at a much lower percentage than the conglomerate beds, since the latter have such an unusual hardness that drilling in them is exceedingly difficult.

In order to apply to our district the experience obtained in Michigan, we may first give briefly the facts with regard to the former region.

The copper-bearing rocks in the Bayfield peninsula are, so far as now known, everywhere deeply buried beneath the drift, and are unlikely to become the objects of exploration. In Ashland county, however, we have large exposures, chiefly in the beds of the streams. The gabbro belt, at the base of the system, is the best exposed portion. No copper has been seen here, and no signs of veins, bedding of any kind, or interbedded conglomerates. Nearly the same may be said of the southern part of the large area underlaid by diabase in the eastern half of Ashland county. Indistinct bedding is to be made out here, and in one or two places epidotic bands have been observed carrying minute flakes of native copper. There is, however, no such analogy between these rocks and those in which the typical copper amygdaloids of Portage Lake are found as would warrant exploration for copper. Further north, between the Montreal and Potato, is quite a large area where but few exposures have been met with, and the rock may or may not be of a favorable character. Still further north we have exposed on the Montreal, Potato, Tyler's Fork, Bad and Brunschweiler rivers, and on Silver creek, a belt in which the diabase and diabase-amygdaloids are quite distinctly bedded, and in which copper has been seen in greater or smaller quantity at each exposure. Between these rivers the rocks of this belt are everywhere deeply buried beneath the drift and red clay. At the crossing of each river some little exploration has already been done, and on the Montreal and Bad rivers, actual mining operations were at one time begun.

The work on the Montreal was on Sec. 20, T. 47, R. 1 E. The topography and geology of the vicinity of this place have been described on previous pages, and are further indicated on Plate XIX of this volume. Work was begun here as early as 1846, by the Montreal River Mining Company. The property afterwards came into the hands of the Cambrian Mining Company of Detroit, who caused some work to be done, but, beyond proving the presence of copper in considerable quantity, nothing was accomplished. The principal workings were in an altered laumontitic amygdaloid, at the summit of a heavy bed of diabase not far from the conglomerate (No. V of Plate XIX). At present little is to be seen here except the partially filled excavation, although fragments of sandstone carrying fine copper may be picked up. One large fragment, several hundred pounds in weight, was seen in the river bottom below the old workings.

According to a report by[1] Col. Chas. Whittlesey, the bed[2] was found, on sinking, to have an average width of about five feet, with a veinstone of calcite in which bunches of prehnite, quartz, and fine copper are disseminated. Two narrow cross-veins are to be seen in the walls of the gorge in the same bed as that including the altered amygdaloid above named. They carry calcite, prehnite, and much fine copper.

On Bad river, near the mouth of Tyler's Fork, Sec. 17, T. 45, R. 2 W., more extensive workings were carried on by the Ashland Mining Company, beginning in August, 1864. The geological structure at this point is described on page 185, and is further indicated on Plate XVI, upon which are shown also the positions of the mine shafts, and the course of the levels run. These are taken from a map furnished by Mr. J. A. Bailey, the superintendent of the mine. The following facts were furnished by the same gentleman.

The work of the Ashland mine began in August, 1864, and closed in February, 1866. The workings sought for copper, both on a "vein," and in the diabase itself. The vein, lying apparently parallel to the

[1] "The Montreal River Copper Location," Cleveland, Ohio, June 1st, 1865.

[2] Called by him "vein."

general bedding, appears to view on the west wall of the gorge just below the falls. Here it was entered and followed by an inclined shaft — angle 35° — which was carried down to the level of the bottom of a second shaft sunk at a point some 400 feet south, and to the east of the vein. From the bottom of these shafts gangways to connect them were begun, and several hundred feet of other adits driven. The vein has a width of nine feet, and carries throughout a brownish calcareous spar with fine particles and laminæ of native copper. Most of the work was done in the diabase itself. All the workings showed small quantities of copper. Mr. Bailey expresses, however, the opinion that the prospects were "not very flattering," but thinks that on the east side of the river, and especially on Tyler's Fork above the mouth (Plate XVI), where the bedding is more regular and distinct, the prospects are more favorable.

We may say then, briefly, that, with our present knowledge, the only portions of the Keweenawan System within the district likely to bear copper, are those belts of diabase and diabase-amygdaloid immediately below the great conglomerate, and within a mile from it, and the gray sandstones immediately above the conglomerate. The former are well exposed on the Montreal river, sections 20 and 21, T. 47, R. 1 E.; on the Potato, Sec. 17, T. 46, R. 1 W.; on Bad river and Tyler's Fork, Sec. 17, T. 45, R. 2 W.; on Silver creek, sections 15 and 22, T. 45, R. 3 W.; and on the Brunschweiler, Sec. 15, T. 45, R. 4 W. The latter are seen on the Montreal, Sec. 20, T. 47, R. 1 E.; on the Potato, Sec. 18, T. 46, R. 1 W.; and on Bad river, Sec. 17, T. 45, R. 2 W. Should thorough exploration, by which is meant, of course, actual mining, fail to develop anything at these points, it would be useless to attempt to penetrate the drift which everywhere else covers the rocks. Should the working on any one of the rivers seem to promise much, the productive belts may be readily followed beneath the drift. For a more definite understanding of the positions of these two copper horizons, see Atlas Plate XXII.

The upper one of these horizons, the hard gray quartzless sandstone alternating with black shale, is beyond doubt the same as that carrying the silver deposits of Iron river, in Michigan. Samples selected on the Montreal showed distinct traces of silver. The amount is, however, too inadequate, and the results of working in the Iron river region too unpromising to warrant our offering any encouragement that this metal will ever be found in paying quantities.

KEWEENAWAN AND POTSDAM SANDSTONES

R. D. Irving, 1878. | The Milwaukee Litho. & Engr. Co.

Fig. 1. Quartzless, calcitic sandstone, (1516); Keweenawan; gorge of the Montreal River, N.W.¼, Sec. 20, T. 47, R. 1 E.; × 45.

Fig. 2. Another part of the same section; × 45.

Fig. 3. Feldspathic red sandstone, (44); Keweenawan; falls of Bad river, Sec. 25, T. 47, R. 3 W.; × 45.

Fig. 4. The same, between crossed Nicols.

Fig. 5. Red Sandstone, (60); from the Lake Superior or Potsdam Sandstone; southwest corner of Steamboat Isl.; × 30.

Fig. 6. Light buff sandstone, (55); Lake Superior Sandstone; Wilson's Island; × 30.

CHAPTER V.

THE LAKE SUPERIOR OR POTSDAM SANDSTONE.

This formation appears as a horizontal sandstone, underlying the lower ground along the entire lake shore of our district, besides forming the basement rock of all the Apostle Islands. The considerations which have led to the separation of this sandstone from the Keweenawan sandstone, as a newer and unconformable formation, and which warrant our regarding it as the equivalent, or at least as the downward continuation of the Potsdam sandstone series of the Mississippi Valley, have been stated at length in Part I of this volume, and need not be here repeated. For a further idea of the area occupied by this formation, see Atlas Plate XXI.

The exposures of the Lake Superior sandstone are almost entirely restricted to the shores of the lake, on the main land and the Apostle Islands, and have never been seen reaching more than fifty feet above the lake level, so that this figure must be taken as representing the greatest thickness certainly known within our district. Further west, in Douglas county, the horizontal sandstone reaches to 360 feet above the lake, and it is supposed that it may reach nearly or quite as high on the flanks of the high land of the Bayfield peninsula. (See section attached to Atlas Plate XXI.)

The prevailing color of this rock is some shade of red, from bright brick-red to a brownish-red or purplish-red. Pinkish, straw-colored, and even nearly pure white varieties occur, either blotching the ordinary red rock in small patches, or occuring in layers from an inch to two or three feet in thickness. Even in the darker varieties the color is generally lighter than that of the Keweenawan sandstone. The grain is usually quite fine, but is often sufficiently coarse for the detection of the individual grains, at least with a pocket lense. Much of the rock is very friable. Analyses and microscopic examinations show that there is always a large preponderance of quartz-grains, which are from angular to sub-rotund in outline, never showing the extreme degree of roundness that characterizes the constituent grains of the Potsdam sandstone of the Central Wisconsin region. Mingled with the quartz grains are generally more or less — the amount varying — of feldspar grains, both orthoclase and plagioclase. The feldspar grains appear, however, to be represented more commonly by the little soft, white clay specks that can readily be detected with the naked eye in all but the finest kinds, and which do not appear in the thin section. Coating the grains of quartz is the reddish iron-stained matrix, largely clayey. In no specimen has any trace of lime-carbonate been detected, and in the thin sections which I have examined under the microscope, no sign of any deposition of material from solution in the interstitial spaces, which are often seen in the section without even the clayey matrix in them.

In some of the fine-grained varieties there is an approach to a clayey shale, though no distinct clay-shale like that seen with the Keweenawan sandstone has been observed. The following analysis, by Mr. E. T. Sweet, of sandstone from Bass Island, gives a fair idea of the composition of the general run of this rock:

Silica	87.02
Alumina	7.17
Iron peroxide	3.91
Lime	.11
Magnesia	.06
Alkalies	1.65
Water	trace
Total	99.92

Of several other specimens examined, one from Wilson's Island (55), a very light-colored, medium-grained rock, with many whitish kaolinic spots, yielded 91.64 per cent. of silica, being very largely quartzose. A section of this rock is figured on Plate XIX A, Fig. 6. A specimen from Bass Island, of reddish, rather fine-grained rock (54), yielded 89.76 per cent.; and one from Steamboat Island, a pinkish, medium-grained kind, 84.13 per cent.

In structure, the Lake Superior sandstone is heavy-bedded to nearly shaly. The following section, taken at the southwest corner of Steamboat Island, is typical of a great many of the cliffy exposures of the lake shore:

	Ft.	*In.*
Red marly clay (Quaternary)	5	..
Shaly sandstone, in layers from one-fourth to one-half inch thick; light reddish to brown, medium-grained, chiefly made up of subangular quartz grains	4	9
Compact sandstone	2	..
Shaly sandstone	..	3
Compact sandstone; pinkish and moderately coarse-grained, chiefly made of quartz grains, but many white clay spots indicating the decomposed feldspar	2	..
	14	..

The shaly and massive layers are, however, not constant, and either will grade into the other in a short distance, the shaly kinds being often merely a result of weathering. Often the massive layers have a thickness of five feet and upwards, and lie together in considerable thicknesses without intervening thin-laminated seams. In many places round bunches of red clay, from an inch to several feet in diameter, are seen imbedded in the massive sandstone. In other cases the clay lies in limited and very irregular seams, from a fraction of an inch to several inches thick. Some of the round clay patches appear as if formed by the decomposition of granite or gneiss boulders, imbedded in the sandstone at the time of its formation.

There would be no particular advantage in describing all the exposures of this formation examined, since one is like another. In giving the coast features of the district, and in describing the Apostle Islands in a previous chapter, the positions of the various sandstone cliffs have been noted in some detail. It may merely be repeated here that the easternmost exposure is at Clinton Point — a few miles east of the mouth of the Montreal — where there are extensive flat ledges at, and just under the water level; that from here to the head of Chaquamegon Bay there are no exposures; that from Fish creek all around the coast of the Bayfield peninsula to the west line of the district, low sandstone cliffs, from 5 to 20 feet high, and often worn into deep caverns and arches by the waves, are almost continuous, being here and there interrupted by sand beaches and clay banks; and that nearly every one of the Apostle Islands shows similar cliffs on its eastern or southeastern side.

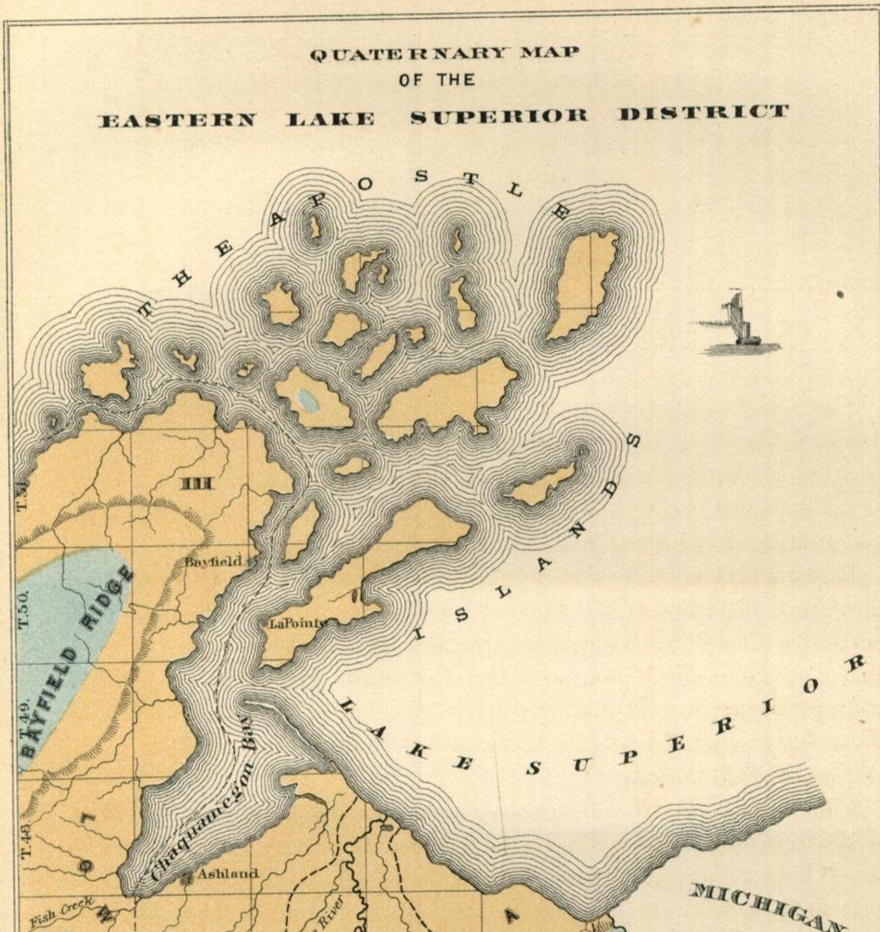
ECONOMIC CONTENTS OF THE LAKE SUPERIOR SANDSTONE.

The only material of economic value in this formation is the rock itself, but this is undoubtedly destined to become one of the most important native products of northern Wisconsin. This statement is warranted by the great abundance of the stone, by its color and ease of working, by the immense size of the blocks obtainable, by the extraordinary facilities that exist for shipment, and by the fact that, with the exception of the rocks quarried from the same formation near Marquette and L'Anse in Michigan, there is not a single brownstone that can compete with it in the western market. Indeed good building sandstones of any kind are rare in the west. The cream-colored Ohio stone, from the Waverly group, is the only one of any great reputation. The Lake Superior brown-stone compares favorably with the brown-stones of the Connecticut valley and of New Jersey so largely used in the eastern cities. The Marquette and L'Anse sandstones are already in considerable demand in Detroit, Chicago and Cleveland, and other lake ports, some 50,000 to 60,000 cubic feet being quarried annually.

Two quarries of some size have also been opened in the Wisconsin sandstone, on Houghton Point, and on Basswood Island, one of the Apostle group. The Bass Island quarry has been most largely worked, and, having examined both it and the Marquette quarries, I have no hesitation in saying that the Wisconsin stone is in all respects fully equal to the Michigan. It is of a somewhat deeper hue, and very uniform in color, while much of the Michigan stone presents a mottling of white and reddish-brown, and has to be sorted to obtain stones of uniform color. The mottled varieties have, however, a pleasing appearance in wall, though not so highly approved of as those of uniform tint.

The Bass Island quarry was opened in 1868, and has been worked somewhat interruptedly since, producing in all a large amount of stone, most of which has gone to Milwaukee and Chicago, the court-house building at the former place being made of it. At the time of my visit in 1873, the quarry had a face twenty-six feet in height, of a peculiarly massive appearance, only three continuous bedding joints running across the whole face. Several strong inclined joint-planes traverse the face, but at such a distance from each other that the only limit to the size of the blocks obtainable is the difficulty of handling. The stone cuts very easily in the quarry, and, as is often the case with sandstones carrying a certain amount of clayey admixture, becomes very hard and firm on exposure.

After a thorough examination of nearly every sandstone exposure on the Apostle Islands and the adjoining mainland, I can have no doubt at all that there are many other points where stone as good as that on Bass Island can be obtained. The nearness to the lake, and the consequent facilities for cheap shipment, ought to make it possible for this stone to find a market in all the ports of the great lakes, while the two railroads that now reach the western part of Lake Superior, should carry it into the interior of Wisconsin and Minnesota, and, via St. Paul, to all points in the Mississippi Valley.


QUATERNARY MAP
OF THE
EASTERN LAKE SUPERIOR DISTRICT
THE APOSTLE ISLANDS
LAKE SUPERIOR
MICHIGAN
BAYFIELD RIDGE
LOWLAND AREA
HIGHLAND AREA
RIDGE AREA
INTERIOR TABLE
Bayfield
LaPointe
Ashland
Chaquamegon Bay
Fish Creek
White River
Bad River
Potatoe River
Maringouin River
Tyler's Fork
Montreal River
Copper Range
Gabbro Range
Penokee Iron Ridge
Corrie's Creek
Bladder Lake
English L.
Herberts Lake
Atkins Lake
County Boundary
Fourth Principal Meridian
Watershed
T.51
T.50.
T.49.
T.48
T.47.
T.46.
T.45
T.44N.
T.43N.
R.5W.
R.4W.
R.3W.
R.2W.
R.1W.
R.1E.
R.2E.
R.3
I
II
III
IV
S. W. Tullock, del.
The Milwaukee Litho. & Engr. Co.
Glacial Drift
Lacustrine clay (Champlain)

CHAPTER VI.

THE QUATERNARY DEPOSITS.

The object of the present chapter is merely to give a very brief summary of the observations made on the Quaternary deposits of our district, which is too small a portion of the whole Lake Superior trough to allow of our basing upon the facts observed within it any important generalizations with regard to the formations in question.

It is evident enough that we have here to deal with the same two prominent divisions of the Quaternary deposits that Professor Chamberlin has described as characterizing the region bordering the western shore of Lake Michigan, viz., the older true glacial drift, and the younger lacustrine clays, deposited by the waters of Lake Superior in the greatly expanded condition reached by them during the Champlain, or Post-Glacial period.

The Glacial Drift. The true glacial drift is buried throughout all of the lower land, and up to an elevation of between 500 and 600 feet above Lake Superior, beneath the later lacustrine clays, and is therefore only to be seen in the divisions of the district that I have designated the "Ridge Belt," and the "Interior Tableland," and on the summit of the "Bayfield Ridge." Even in these portions of the district, the forest covering is so dense, and cuttings into the drift so rare, that the chances for observations are much lessened. It is evident, however, that we have here in a full development all the characteristics of a glaciated region, viz., heaps of boulders, sand and clay, without stratification (except where modified by existing streams), and in certain portions reaching a true morainic development; surface erratics of considerable variety, and often of enormous size; striated surfaces; and true *roches moutonées.*

The general drift covering, with a predominating clayey ground-mass, prevails over the whole ridge area, reaching always its greatest thicknesses on the northern slopes of the ridges. The northern slope of the Penokee Range especially presents everywhere a heavy mantle of drift In none of this division of the district, however, is anything like a morainic development of the drift materials to be observed. To the south of the Penokee Range, and especially on and beyond the watershed, heaped-up drift is frequently to be seen, the underlying gneissic and granitic rocks being nearly everywhere concealed beneath an immense coating of loose materials. The morainic character seems to become more and more pronounced towards the southern limit of the district, and further south Professor Chamberlin has made out a true "Kettle Range" of mingled rounded and irregular depressions, without outlet, and similarly shaped heaps of drift, such as are observed in the moraine belts of eastern and central Wisconsin. The morainic condition of drift would seem to characterize a wide area on the highlands about the head waters of the Wisconsin and Chippewa rivers.

The surface erratics include many kinds of rocks, the more common of which are dark colored basic rocks (largely of varieties belonging to the copper series), red porphyries and granites. Many of these must have come from the Canadian side of Lake Superior. In many places on the summit of the Penokee Range — several of which are noted on the accompanying detail maps of the Huronian — are to be seen numbers of erratics of a very coarse boulder-conglomerate. Many of these are very large, reaching ten feet cube, while several were noted as much as twenty feet on a side. These have been brought from the great conglomerate belt of the Keweenawan series, at points on its course somewhere between the Montreal river and the Porcupine Mountains of Michigan; and have come in a direction of about 50° west of south. This direction coincides with that of the few glacial striæ observed on the summit of the Penokee Range.

The rounded summits of the Penokee Range approach in their general shape to true *roches moutonées*, and these shapes are very distinct on the rounded granite exposures of the region to the south of the Penokee Range. A number of these, with highly polished surfaces, are to be seen along the Wisconsin Central road, and in the great windfall, in the southern part of T. 44, R. 3 W.

In this connection should be mentioned the linear arrangement of the outlines and groups of the Apostle Islands, and of the contours of the adjacent lake bottom as shown in Plate XII. It will be noticed that there are several depressions shown in the lake bottom, without outlet, and over a hundred feet deeper than the surrounding portions. That these depressions and the other linear trends mentioned, should be attributed to glacial action does not seem unreasonable.

The Lacustrine Clays. These underlie all of the lower levels bordering the lake, above which they rise to altitudes of between 500 and 600 feet. This carries them well up the front slope of the Copper Range, and high also on the flanks of the Bayfield highland. Plate XX of this volume serves to show their distribution more definitely.

On the Wisconsin Central, the clays reach to an altitude of 560 feet, and are finally left, on ascending the railroad line from Lake Superior, near where Bad river is first struck, in the southwest quarter of Sec. 19, T. 45, R. 2 W. In this vicinity, the clays are seen overlying an irregular surface of true glacial or boulder drift. Eastward from Silver Creek, Sec. 10, T. 45, R. 3 W., as the railroad ascends the front of the Copper Range, the clay is seen in more and more thoroughly detached patches, with intervening patches of sand and gravel belonging to the true glacial drift, the more recent clays having been washed off in these places.

The topography of the clay area has already been fully indicated in Chapter I. The streams flowing through it, as also their numerous branches, have cut it everywhere into narrow, deep and steep-sided ravines, which are always thickly timbered. The sides of the ravines not unfrequently show large exposures of bare red clay, where landslips have occurred. On the surface of this area the clay is covered by only a very thin coating of vegetable mould, and is nearly always to be reached by a single stroke of the spade. The absence of anything like the gravel of the glacial drift is very noticeable, and boulders are very rare and small. In leaving the clay area along the line of the railroad, the change in this respect is very striking, boulders and gravel becoming quite suddenly abundant.

The clay of these deposits varies largely in amount of sandy admixture. There is commonly some sand included, though at times it seems almost wholly absent, and at others to make up the bulk of the formation. The clayey matter is always of a red color and always contains a considerable proportion of lime carbonate. The following are analyses of samples of clay taken at Ashland. No. 1 is from a well near the western end of the village; Nos. 2, 3 and 4 are from the banks of Bay City creek, at the railroad bridge; and No. 5 is from the lake bluffs near the shore end of the railroad pier:

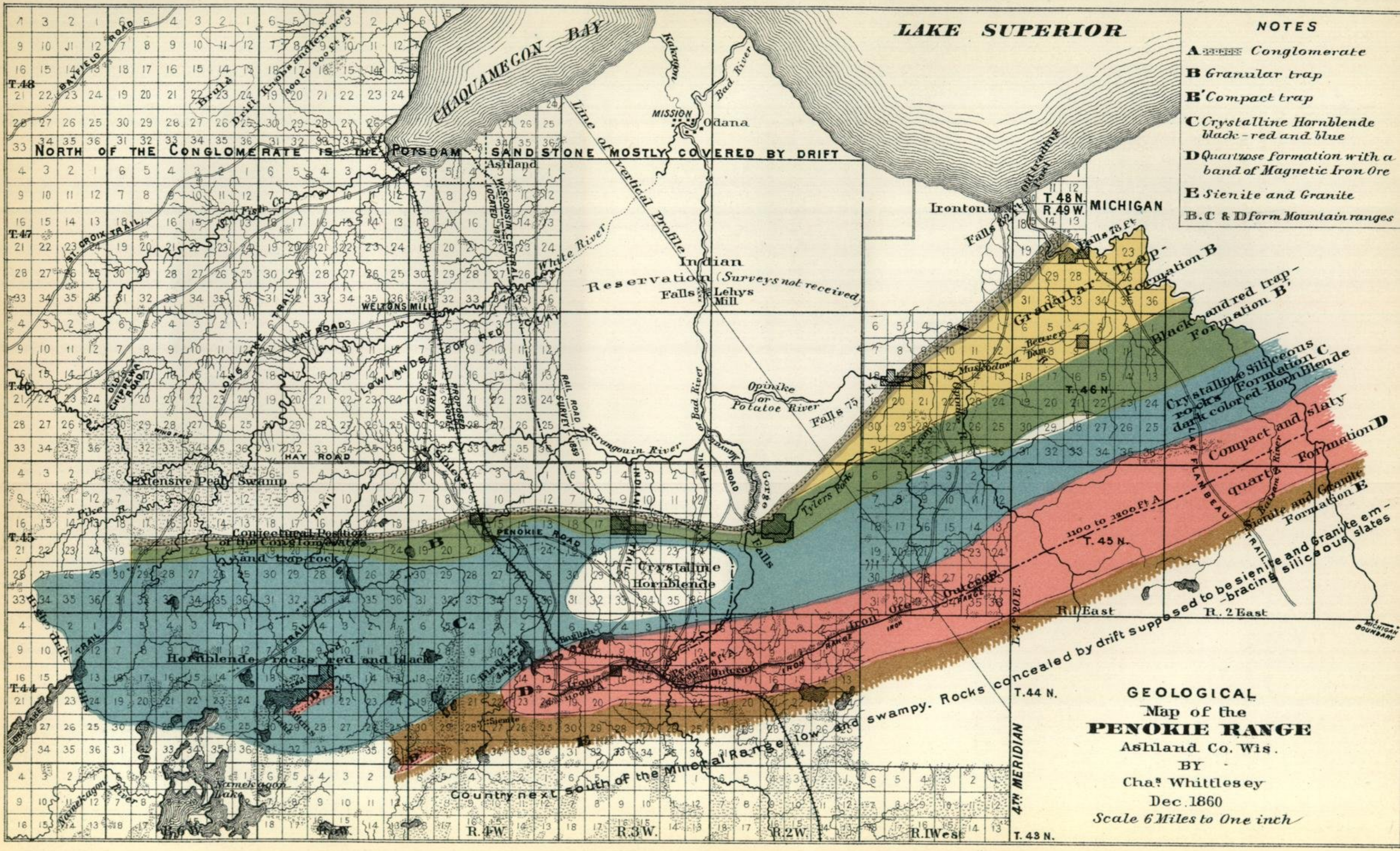
	1.	2.	3.	4.	5.
Insoluble residue	....	....	....	....	76.37
Silica	58.09	64.56	....	....	61.68
Iron sesquioxide	4.44	4.11	....		....
Alumina	25.32	18.86	....	....	....
Calcium carbonate	4.31	6.40	11.93	10.09	7.15
Magnesium carbonate	4.01	3.53	....	....	....
Water	4.09	2.56	....	....	....
Totals	100.26	100.02	....	....	....

The stratification of this formation is not evident on close inspection. Generally a bank will show more and less sandy portions at different levels, but the distinction between the layers is not sharp, and nothing like a fine lamination is to be seen. At a little distance, however, from the bare clay banks, as is often to be noticed on the shore bluffs of the Apostle Islands, the stratification becomes much more evident, from the darker color of the moist sandy layers as compared with the lighter sun-dried clay.

It has already been said that boulders are not common on the surface of the clay area. In many places, however, numerous small boulders, chiefly of some dark greenstone-like rock, are to be seen embedded in the clay, and pebbles of the same and other crystalline rocks are abundant. On the shores of some of the Apostle Islands, and in places along the mainland coast, dark-colored boulders of large size, presumably washed out from the clay, are very abundant.

The entire thickness of these clays cannot be less than from 400 to 600 feet, about 100 feet being the greatest thickness seen in any one section.

The clay of this formation is often too sandy to be of any value for brick making, but there can be no doubt that much of it would make an excellent brick. The calcareous admixture, though commonly supposed to be deleterious, is not so. The famous cream-colored brick of Milwaukee contains a still larger proportion of lime carbonate, which, with the high temperature at which these bricks are made, gives rise to a light-colored lime-iron silicate in the finished brick.



LAKE SUPERIOR
NOTES
A Conglomerate
B Granular trap
B' Compact trap
C Crystalline Hornblende black - red and blue
D Quartzose formation with a band of Magnetic Iron Ore
E Sienite and Granite
B. C & D form Mountain ranges
CHAQUAMEGON BAY
NORTH OF THE CONGLOMERATE IS THE POTSDAM SAND STONE MOSTLY COVERED BY DRIFT
Ashland
Odana
MISSION
Line of vertical Profile
Indian Reservation (Surveys not received)
Falls
Lehys Mill
Ironton
MICHIGAN
T. 48 N.
R. 49 W.
Granular Trap Formation B
Black and red trap Formation B'
Crystalline Siliceous rocks Formation C
dark colored Hornblende
Compact and slaty quartz Formation D
Sienite and Granite Formation E
Opinike or Potatoe River
Falls 75 ft
Marangouin River
WELTONS MILL
LOWLANDS OF RED CLAY
HAY ROAD
Extensive Peat Swamp
Conjectural Position of the Conglomerate and trap rock
PENOKIE ROAD
Crystalline Hornblende
Hornblende rocks red and black
Iron Ore Outcrop
Country next south of the Mineral Range low and swampy. Rocks concealed by drift supposed to be sienite and Granite embracing siliceous slates
T. 45 N.
T. 46 N.
T. 44 N.
T. 43 N.
R. 1 East
R. 2 East
R. 4 W.
R. 3 W.
R. 2 W.
R. 1 West
4TH MERIDIAN
MICHIGAN BOUNDARY
Namekagon Lake
GEOLOGICAL
Map of the
PENOKIE RANGE
Ashland Co. Wis.
BY
Chas. Whittlesey
Dec. 1860
Scale 6 Miles to One inch

APPENDIX A.

I.

List of Publications by Colonel Chas. Whittlesey on the Geology of the Regions Drained by the Bad and Montreal Rivers:

1. *Report of Explorations on the South Shore of Lake Superior, in Wisconsin, 1849.* Owen's Geol. Report, Washington, 1852; pp. 425–447; with a map.
2. *The Penokee Mineral Range.* Proc. Boston Soc. Nat. Hist. July, 1863; pp. 10.
3. *Fresh Water Glacial Drift of the Northwest.* Smithsonian Contributions, Article 197, July, 1864.
4. *Penokee Copper Range.* Pamphlet. 1865.
5. *Marangouin River Iron Property, T. 44, R. 5, W., Bayfield Co.* Pamphlet report to an iron company, 5 pp. Cleveland, Ohio, Jan. 1, 1865.
6. *The Montreal River Copper Location.* Cleveland, Ohio, 1865. Pamphlet, 5 pp.
7. *The Magnetic Iron Company's Property, T. 44, R. 3 W., Ashland county.* Pamphlet, 7 pp. Cleveland, Ohio, April, 1872.
8. *Transient Fluctuations of Level on Lake Superior.* Proc. American Association, Portland Meeting, 1873.

II.

Formations of the Bad River Country, as given by Colonel Whittlesey in Owen's Geological Report, 1852.[1]

1. *Sedimentary.*
   - *a.* Red sandstone.
   - *b.* Black slate.
   - *c.* Conglomerate.
2. *Trappous Rocks, or those of Volcanic Origin.*
   - *a.* Black and red amygdaloid trap, and greenstone.
   - *b.* Augitic, hornblendic, and feldspathic rocks, embracing sienites and granites of the same age.
3. *Metamorphosed Rocks.*
   - *a.* Hornblendic slates.
   - *b.* Iron slates.
   - *c.* Black slates in large, thin, rectangular sheets.
   - *d.* Talcose slates with quartz.
   - *e.* Slaty quartz.
4. *Granitic Rocks.*
   - *a.* Sienite, and
   - *b.* Granite, occupying the country south of the mountain range or uplift; the oldest rocks seen.

[1] Of this classification, 1 evidently covers the horizontal sandstones, and the fragmental Keweenawan rocks; 2, the Keweenawan eruptive rocks; 2 *a*, the gabbros with intrusive granite, approximately; 3, the Huronian, nearly, and 4, the Laurentian. — R. D. I.

III.

Extract from an Article on the "Penokee Mineral Range," by Colonel Whittlesey, in the Proceedings of the Boston Society of Natural History, July, 1863.

[Note. — This paper is given here entire, except the last page or two, which treat of the Menominee river rocks, because it is a summary of Colonel Whittlesey's results in the Eastern Lake Superior District, and embodies all the information obtainable with regard to this region, beyond what is given on Colonel Whittlesey's map (here reproduced), at the time of the beginning of my own work. — R. D. I.]

The copper-bearing strata of Pt. Keweenaw (Lake Superior) extend southwesterly across the boundary of the state of Michigan into Wisconsin. These strata constitute a long, narrow and bold mountain range from Copper Harbor to Long Lake, a distance of one hundred and sixty miles. There are no stratigraphical breaks along this line, the order of the rock being everywhere the same. The dip of the beds is always northerly or northwest, and the strike to the northeast or east, the general line of outcrop being northeast-by-east. On Point Keweenaw, and as far southwest as the Akogebe Lake, on the west fork of the Ontonagon river, the copper veins have been found valuable.

Beyond the waters of the Ontonagon, in the same direction, veins have been discovered, but after limited workings have been abandoned. The Montreal river forms the boundary between *Michigan and Wisconsin;* and as early as the year 1845 mining locations were made on its waters where they pass the range. Locations were also made upon the waters of the Bad or Manvaise river, a stream with numerous branches, draining the country from the Montreal to the headwaters of the Chippewa and St. Croix rivers.

Historically considered, the exploration of this region commenced in the year 1840, when Dr. Houghton, as a commissioner of the state of Michigan, accompanied Capt. Cram of the United States Topographical Engineers, who was then surveying the Menominee and Montreal rivers.

In 1840 and 1841, Dr. Houghton examined the rocks on both these streams, and the country between their sources. I am in possession of a transcript of his field notes during these explorations. In 1845-6 I made examinations along the range across the Montreal to the westward, as far as the main branch of Bad river.

Up to this time the public lands in this part of Wisconsin had not been surveyed. The fourth principal meridian was extended northward through Wisconsin to Lake Superior in 1848. Dr. A. Randall, one of the assistants of Dr. Owen upon the survey of the Chippeway Land District, in reference to mines and minerals, accompanied the linear surveyors along this line. In Town 44 north, Dr. R. discovered an outcrop of magnetic iron ore, and brought in a specimen. The next season, as a member of Dr. Owen's corps, I made an exploration on the western branches of Bad river, crossing southerly to the headwaters of the Chippeway. Near Lac des Anglais, and thence easterly across the middle or main fork of the Bad river, I found cliffs and bluffs of silicious magnetite. The results of this examination may be seen in the final report of Dr. Owen, published at Washington in the year 1850.

In the Chippeway language the name for iron is *pewabik;* and I thought it proper to designate the mountains, where this metal exists in quantities that surprise all observers, as the "Pewabik Range." The compositor, however, transformed it to *Penokie*, a word which belongs to no language, but which is now too well fastened upon the range by usage to be changed.

Soon after the publication of Dr. Owen's report, the excitement of 1845-6 in reference to copper was repeated in reference to iron. The government was at last induced to make surveys of the region. Preemptors followed the surveyors, erecting their rude cabins on each quarter-section between the meridian and Lac des Anglais, a distance of eighteen or twenty miles. The iron belt is generally less than one-fourth of a mile in width, regularly stratified, dipping to the northwest conformable to the formations, and having its outcrop along the summit of the second or southerly range. Viewing this mountain region from La Pointe, or from the open lake, it has the appearance of a single crest. Its outline against the sky in a clear day is very distinct and regular. Along the range, this crest line is nearly level, its elevation above the lake being one thousand to eleven hundred feet. But there are two ranges, known in the country as the first and the second, or the "Copper" and the "Iron" range. There is not much difference in their elevation. The copper range being nearest the coast, covers the iron range, which, at the distance of thirty miles, is only visible through gaps and notches, the whole forming one blended line in the horizon. To the south, beyond the iron range, the country is lower and swampy.

Two roads were soon constructed to the mineral deposits through the dense evergreen forests of this latitude. One of them commenced at the lake, near the mouth of the Montreal river, and near the termination of the fourth principal meridian, extending thence south and not far from the meridian line. The other began on Chegoimegon Bay, at Ashland, pursuing also a southerly course, and, after reaching the second range, connected along it to the eastward with the first road, passing the cabins of the preemptors. In 1859, Mr. Daniels, of the Wisconsin Geological Survey, and Mr. Lapham, of Milwaukee, examined the iron range in behalf of a company which had made extensive purchases there, and had caused a survey for a railway to be made, with a view to the manufacture of iron.

Mr. Lapham's report was published in pamphlet form, but as yet no iron works have been erected there. The region was again examined by me in 1860, on the part of the state of Wisconsin. As my reports upon the Bad river country, and those of 1858, "Upon the rocks of the Menominee river, associated with iron ores," have not been published, I propose to offer in this paper a brief notice of the analyses of specimens from the "Penokie" range, etc.

By referring to the "Proceedings of the American Association, for 1859," a short article will be found relating to the azoic slates of the Menominee, in which iron is a constant and large ingredient. So many discussions have taken place during the last fifteen years upon the origin of the azoic rocks in Canada and in Michigan, that it becomes important to have all the results of chemical examinations before the public. I propose to do nothing more than present these results, with such a general description of the formations west of the Montreal river, on the south shore of Lake Superior, as will enable geologists to use them.

The profile accompanying my map for the Wisconsin report of 1860 is made across the stratification, from the village of Houghton, on Chegoimegon Bay, in a southeasterly direction, through the Dalles of Tyler's Fork, in Town 45 North, Range 1 West. The formations are lettered A, B, C, D and E, reckoning downward from the Potsdam sandstone, A, to the sienite and granite, E. But for present use, the profile will be taken along an ancient Indian trail, that leads from the mouth of Montreal river to Lac Flambeau, and the formations will be numbered 1, 2, 3, etc.

The provisional arrangement, which it is always necessary to make in the early stages of the examination of a new region, must of course be based upon the external characters of the rocks. In this case, it is not only convenient, but proves to be a correct arrangement.

ANALYSIS OF FORMATION 2. — TRAPPOSE.

Number.	Locality and Description.	Aspect.	Color of powder.	Specific gravity.	Moisture and loss.	Silex.	Oxide of Iron. Per.	Oxide of Iron. Prot.	Oxide of Manganese.	Alumina.	Lime.	Potash.	Magnesia.
	Member a.												
1†	Earthy; rough; dark gray. T. 46 N., R. 1 E.	Trappose...	Gray	2.604	2.19	72.16	14.40	—	1.25	4.00	0.85	—	—
2‡	Black and red; fine grain. Penokee road at Brunschweiler river	Trappose...	Greenish-gray..	2.838	1.16	85.20	6.39	—	0.68	0.80	0.95	—	2.57
3	Black; compact; flinty. Phelps' location, Opinike river.	Silicious ...	Blackish-green..	2.968	2.05	76.80	—	11.00	—	5.65	0.25	4.17	0.08
4	Sub-crystalline; red. At shaft, Phelps' location	Silicious ...	Brick-red	2.628	1.27	86.50	—	6.22	—	2.80	0.08	1.75	1.38
	Member b.												
5	Compact; red; jointed. Log Bridge creek, Lac Flambeaux trail	Porphyritic.	Reddish-brown .	2.342	1.00	86.60	—	7.65	—	2.80	0.15	0.80	1.00
6	Compact; dark gray. Phelps' location, above cabin	Flinty	Reddish-gray...	2.612	1.00	91.20	—	4.00	—	8.80	0.45	0.75	0.80
7‖	Crystalline; bluish-gray. S. E. qr. Sec. 15, T. 45 N., R. 4 W.	Feldspathic.	Dark gray	2.844	1.00	88.85	—	6.55	—	1.25	0.80	—	—

† Carbonate of Copper, 2,25. ‡ Bisulphuret of iron, 2.25. ‖ Soda, 1.50.

ANALYSIS OF FORMATION 3.—HORNBLENDIC.

Number.	Formation and Location.	Aspect.	Color of powder.	Specific gravity.	Moisture and loss.	Silex.	Oxide of Iron. Per.	Oxide of Iron. Prot.	Oxide of Manganese.	Alumina.	Lime.	Potash.	Magnesia.
1	Subcrystalline; color light red. Sec. 34, T. 46 N., R. 1 W.	Porphyritic.	Gray	2.725	1.69	91.65	2.16	—	0.45	0.60	0.40	1.60	1.45
2	Compact; dark red. Same section	Flinty......	Reddish-brown .	2.590	1.75	92.90	3.20	—	—	0.40	1.00	0.75	—
3	Subcrystalline; reddish-brown. N. W. ¼ Sec. 29, T. 45 N., R. 6 W	Coarse-grained ..	Reddish-brown .	2.900	2.18	89.50	4.50	—	0.44	0.80	0.95	2.57	—
4	Subcrystalline; black. Sec. 34, T. 46 N., R. 1 W.......	Hornblendic	Greenish-gray..	2.809	1.10	78.00	—	9.60	—	4.80	1.20	2.80	2.50
5	Subcrystalline and granular; dark gray. Lac Flambeau trail, 11 miles from Lake Superior	Dark gray trappose..	Pea green......	2.923	1.60	89.20	—	0.60	3.75	0.75	0.80	1.40	1.90
6	Earthy; tender; dark brown. Gorge of Balsam river....	Trappose ..	Bluish-black ...	2.768	1.06	56.00	—	24.00	2.88	10.00	1.26	2.50	2.00
7	Subcrystalline; tough; dark blue. Gorge of Balsam river.	Hornblendic	Bluish-black ...	2.928	1.39	84.20	—	6.00	0.46	6.00	0.20	1.75	—
8	Crystalline; very coarse; bluish gray. Inlet of Bladder lake	Sienitic	Ash gray	2.917	1.46	86.00	—	5.29	1.05	0.40	0.38	2.76	2.66
9	Crystalline; coarse; red and gray. Sec. 20, T. 45 N., R. 3 W..	Sienitic	Bluish-gray	2.609	1.05	88.80	—	7.00	0.60	1.40	0.80	0.40	—

The following is a general view of the structure of the formations in the descending order: —

Formation No. 1.[1] — *Potsdam Sandstone.*

On the Montreal river, *strike* northeast by east, in places N. 60° E.; *dip* northwest by north, 75° to 90°. It embraces four members, *a*, *b*, *c*, and *d*.

a. *Sandstone Proper*, corrected for bevel, thickness	8,500	feet.
b. Alternations of sandstone and black-slate, thickness..........	750	"
c. Conglomerate, thickness	1,800	"
d. Alternations of trap and sandstone, thickness	800	"
Total	11,850	"

This is not the entire thickness of the Potsdam at the mouth of the Montreal. The synclinal line lies an unknown distance out in the lake, perhaps one-fourth of a mile, and whatever this distance may be should be added to the above statement. At the Apostle Islands and in Chegoimegon Bay, the dip is reversed, having a direction towards the southeast; but the line along which the change occurs is covered either by the waters of Lake Superior or by drift. On the northerly side of the synclinal the plunge of strata is much less in amount. It presents the case of nearly horizontal beds on one side, and of nearly vertical ones on the other. Following the outcrop along the southerly shore to the west end of the lake, and thence along its northwesterly coast, the dip is everywhere conformable, and to the southeast. By estimates and measurements on that shore, combined with those at the Montreal, I regard its total thickness to be not less than fifteen thousand feet. No fossils have yet been found in the sandstone of the west end of Lake Superior. Its color is generally red, owing to the presence of oxide of iron. Where this is wanting, it is gray or a dull white, and in places mottled gray and red.

Formation No. 2. — *Trappose, in two members.*

a. Brown amygdaloid;[2] dip and strike conformable to formation 1; thickness along Lac Flambeau trail........................	3½	miles.
b. Compact red[3] and blue	2½	"
Total...	6	"

Formation No. 3.[4] — *Hornblendic.*

Compact, sub-crystalline and slaty; black or dark colored; strike N. 60° E.; thickness on trail.. 2¼ miles.

Formation No. 4.[5] — *Silicious, two members.*

a. Quartz, slaty and in layers; dark colored, but less than *F.* 3; thickness variable; separated from *b* by a bed of magnetic iron and iron slate.

b. Quartz, slaty, in layers and beds; more compact and lighter color (gray and straw color) than *a;* novaculite; strike N. 60° to 65° E.; dip variable, 30°, 45°, 60°, 75° to the northwest; breadth across the edges on trail.. 3½ miles.

[1] Colonel Whittlesey regards as belonging in one formation, the horizontal Potsdam sandstone, and the upper beds of the Keweenawan system.—R. D. I.

[2] Diabase and diabase-amygdaloid of Pumpelly.—R. D. I.

[3] Felsitic porphyry.—R. D. I.

[4] Gabbros of the foregoing pages, in part, and partly XXI of the Huronian.— R. D. I.

[5] Huronian of the foregoing pages, in part.— R. D. I.

Formation No. 5.[1]

Granites and sienites of Central Wisconsin.

Fifteen miles to the westward of the trail, on a parallel line from the mouth of Tyler's Fork to the Dalles, the total thickness of formations 2, 3 and 4, is reduced nearly one-half. The dimunition, however, comes principally from the upper member, *a*, of formation 2, which tapers out in that direction very rapidly. Formation 3 is also somewhat diminished; yet formation 5 is not materially changed in thickness.

Further westward, beyond the middle or main fork of Bad river, the rocks undergo such changes in external characters, that until the test of analysis was applied, the separate formations could not be disentangled. In the midst of black slates that appeared to be trachytic, were large patches of red and blue crystalline rocks, having clearly the aspect of sienites. I will notice them hereafter.

Formation 1 is nearly pure silex, and is evidently of sedimentary origin. Some foreign geologists have essayed to place it nearly at the summit of the geological system, not only without evidence, but against the most conclusive proof. Dr. Houghton, Dr. Jackson and Dr. Owen at first lent color to such a classification, but on examination both the first and last named gentlemen placed it in its true position, at the base of the paleozoic rocks. It has been traced stratigraphically beneath the Trenton and Calciferous strata of the New York Survey; on the St. Mary's river at Pictured Rocks; on the Escanawba, the Menominee, Oconto, Wolf, Wisconsin and St. Croix rivers.

At the falls of the St. Croix abundance of fossils are found in it, such as characterize the Potsdam in New York. To persist in denying the effect of such observations is to rob all proof of its value, when it comes in contact with theory and assumption.

The black slate intercalated with the sandstone differs little externally from the slaty portions of formation 3. This member is very persistent along the Copper Range to the eastward in Michigan. It is visible in about the same relation to the conglomerate, at the Black, Iron and Ontonagon rivers. At Black and Presque Isle rivers I have noticed specks of carbonate of copper, disseminated, as in the Mansfelt slate. But one analysis has been made of this rock (formation 1, *b*), which is as follows:

Specific gravity, 2,690. Color of powder, bluish gray.

Silex[2]	75.60
Protoxide of Iron	14.00
Manganese	0.35
Alumina	7.30
Lime	0.95
Magnesia	0.95
Carbonaceous matter, moisture and loss	1.05
	100.00

In the belts of sandstone that alternate with trap, it is common to find native copper out of the veins, disseminated in fine particles, crystals and spangles, in some places sufficient to pay for stamping and working the rock.

The analyses here given were made for the Wisconsin Survey by Professor J. L. Cassells, of the Cleveland Medical College.[3]

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[1] Laurentian of the foregoing pages.

[2] Several specimens of this rock from different points have been examined in the University laboratory, and in no case yielded over 55 per cent. of silica. The rock is a calcitic diabase mud. The carbonaceous matter is doubtful. R. D. I.

[3] Several of the specimens from which the analyses for these tables were made are preserved in the University Cabinet, with the analyses attached. From these I learn the following: In the analyses of Formation 2, No. 3 is a diabase of the Ashbed type; No. 4, a felsitic porphyry; and

Of formation 4, with the exception of specimens containing a large per cent. of iron and regarded as ores, only two were analyzed. This is a black fine-grained slate, with a silicious aspect, and dark gray powder. It was taken from near the iron belt above it, at a locality three miles southwest of the trail, and about twelve miles from Lake Superior.

1. Specific gravity, 3,049.[1]

Carbonaceous matter and moisture	1.55
Silex	80.00
Protoxide of Iron	17.60
Oxide of Manganese	0.35
Alumina	0.25
Magnesia	0.25
	100.00

2. Compact, tough blue slate. T. 45, N. R. 1 East. Specific gravity, 2,740.

Moisture and loss	1.25
Silex	89.60
Protoxide of Iron	3.60
Oxide of Manganese	0.22
Alumina	2.40
Lime	0.25
Magnesia	1.63
Potash	1.05
	100.00

No specimen of the above lists is without the oxide of iron. In the protoxides, fourteen in number, the percentage ranges from 3.60 to 17.60. Of the peroxides, five in number, the per cent. varies from 2.16 to 14.40. With one exception, lime pervades the entire list, the proportion in no case attaining to *one per cent.*[2] Magnesia is present in all but two specimens, the largest amount being 2.80.

A large portion of formation 3, west of Bad river, is coarsely crystalline, with a decided sienitic aspect. Around the west end of Bladder Lake it is of a light blue color; in other places flesh red. Specimens 8 and 9 of formation 3 represent this deceptive rock.

In composition, however, they range themselves with the other specimens of the formation, as substantially silex and iron. Five specimens show potash ranging from 1.45 to 2.66 per cent.

No. 7, uralitic gabbro. In Formation 3, No. 1 is a red felsite; No. 2, granitic porphyry; No. 3, a typical Keweenawan diabase; No. 4, an "Ashbed" diabase; No. 7, a typical (greenish) Keweenawan diabase; No. 8, coarse bluish-gray gabbro; and No. 9, a pink granite.

To any one familiar with the composition of crystalline rocks, it will be evident that the analyses by Professor Cassels here given are wholly worthless. The silica percentages given are alone enough to prove this, since they are, in nearly every case, from 10 to 30 per cent. or more, too high. This is true both of the basic gabbro and diabase, which, in fact, rarely reach 50 per cent., and of the more acid granite and felsitic porphyry, which probably never exceed 75 per cent. That the latter figures are the true percentages is shown not only by the now well known mineralogical composition of these rocks (in itself a sufficient proof), but by a series of tests made in the University laboratory. In two cases the specimens examined were the same as represented by analyses in the above tables. No. 2 of formation 2, given in the table as having 92.9 per cent of silica, contains in fact 72.5 per cent.; and No. 8, given at 86.00 per cent., contains 47.86 per cent. — R. D. I.

[1] A black aphanitic slate, probably from formation IV of the Huronian. It contains a large percentage of *magnetite*, and is therefore incorrectly respresented in the analysis. — R. D. I.

[2] That the analyses are incorrect in this respect is shown by the fact that the predominating ingredient of the gabbros is a *lime feldspar*. — R. D. I.

The absence of potash or soda in two of the trap rocks of formation 2, may be accounted for by the fact that in both cases the specimens were porous and exposed to the atmosphere.

The proportion of caustic alkalies is here much less than in the trap rocks of the same formation on Point Keweenaw, and the traps of other countries. The presence of both potash and soda is a characteristic of these rocks elsewhere, and also a much larger per cent. of alumina. In truth, the difference in mechanical condition, as well as chemical constitution, between these beds and those which contain valuable veins, is so great as to discourage us as to their practical value.

In No. 1 of formation 4, there is found carbonaceous matter like the black slate of the Potsdam sandstone, formation 1. Among the slates of this series there are no instances of the dark green color that characterizes chloritic and magnesian rocks, or which might indicate the presence of silicates of iron. The silex is evidently in excess over all substances that might act as bases, and thus the quartz and iron oxides are proven to be mechanical mixtures.

APPENDIX B.

MICROSCOPIC EXAMINATION OF ELEVEN ROCKS FROM ASHLAND COUNTY, WISCONSIN.

BY ALEXIS A. JULIEN.

1411. Chloritic Gneiss. LAURENTIAN. *Penokee Gap. Northwest quarter Sec. 14, T. 44, R. 3 W.* Blackish-gray, with black specks, mottled on cross-section by thin, irregular, grayish-white spots and streaks. A compact gneiss of medium grain and rather slaty structure, made up of alternations of whitish laminæ, one-thirty-second to one-sixteenth inch thick, rich in quartz, with some feldspar, and of thinner seams of black hornblende, in fibrous facets sometimes one-eighth of an inch long, with minute scales of a black mica. In some parts of the black laminæ the mica-scales predominate or entirely replace the hornblende. Powder greenish-gray. The rock is traversed by a few thin seams of quartz across the lamination. Weathers to a brick-red color, which also permeates the fissures. Specific gravity, 2.78.

Microscopic description. The predominating mineral, *orthoclase*, occurs in rather irregular grains, sometimes clouded by inclusions, with at least one very fine cleavage distinct in ordinary light and sometimes another more imperfect. The common inclusions in some grains consist of elongated granules (scales?) of kaolin irregularly distributed or along the cleavage lines; also tiny rounded scales of muscovite, granules of altered hornblende, and separated scales and blades of chlorite. In polarized light its occasional twinning is rendered evident, and, at +[1], the usual mottling with yellowish-white and maroon. The grains vary in diameter from 0.06 to 0.88 mm. A plagioclase feldspar, probably *oligoclase*, occurs in abundance, not only interlaminated with the orthoclase in the usual forms, distinct in polarized light, but also in angular grains and plates, a few of which are clear, but most are clouded almost to opacity by minute gray inclusions; the striation (by twin-lamellation) is often very fine, especially when the inclusions have a linear and parallel arrangement. The various stages of this alteration, apparently kaolinic, are everywhere shown, from grains in which the grayish material traverses the clear unaltered mineral in a few lines or envelops it with a thin fringe, to those which appear entirely granulated and opaque. In polarized light, at +, a few broad bars are generally seen, of gray and bluish-gray, traversing a yellowish-white, brownish-yellow, or maroon field. The usual diameter of the grains varies from 0.11 to 0.59 mm. *Quartz* is a common constituent, mostly in small, clear and colorless, irregular granules; but also in rounded grains, with a common arrangement of their longer axes parallel to the lamination, whose form and position at once suggest a sedimentary origin. The grains are usually from 0.04 to 0.39 mm. in diameter. The mineral is dotted with minute inclusions, many brownish-red and brownish-yellow particles of ochre, a few scales of chlorite, colorless needles and microliths (perhaps of apatite), a few crystalline granules and particles of magnetite, and a few liquid inclusions (× 500)[2] at wide intervals, many of which enclose a bubble, which appears sometimes stationary, sometimes in lively motion. *Hornblende* is abundantly dispersed through the section in grains and plates extremely irregular in outline; this is due to the scaly structure of the partially altered mineral, many of the scales having been loosened or removed in such a way as to leave rounded cavities and even a net-work.

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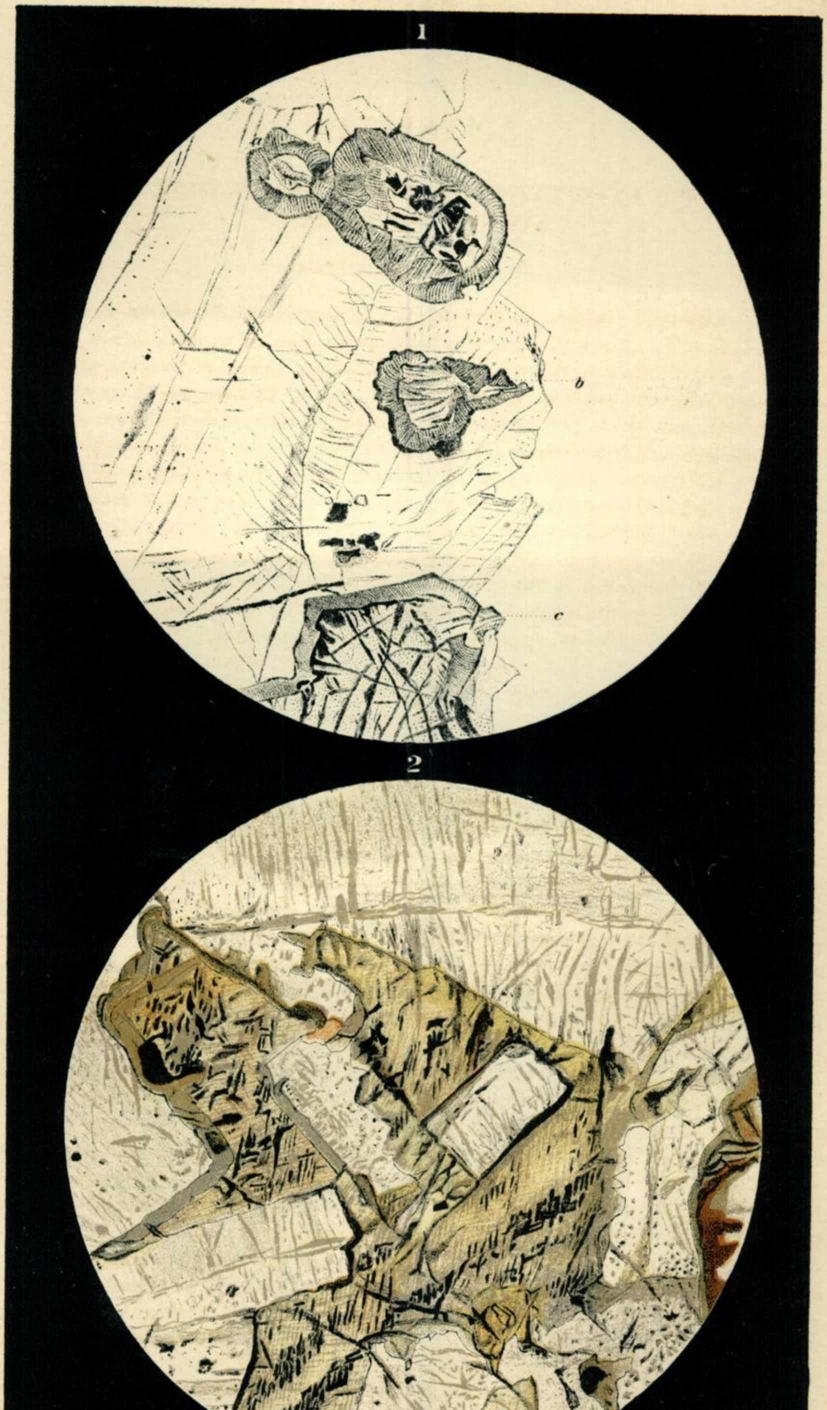
[1] This convenient sign for "crossed nicols" has been recently proposed by H. O. Lang in his "Grundriss der Gesteinskunde."

[2] Magnified 500 diameters.

PLATE XXII.

KEWEENAWAN ROCKS.



THE MILWAUKEE LITHO. & ENGR. CO.

Fig. 1. Chrysolitic Diabase. N.E.¼, Sec. 31, T. 45, R. 2 W.
Fig. 2. Chrysolitic Diabase, Outlet of Bladder Lake, Sec. 11, T. 44, R. 4 W.

The color is brownish-green, in part brownish-yellow and brownish-red by oxidation and permeation with ochre. The prismatic cleavage is generally distinct, and sometimes another less perfect. The ordinary inclusions consist of elongated granules and minute particles of magnetite, arranged in clouds or dusty groups parallel to the cleavage, scales and blades of chlorite and grains of quartz. The blades range in length from 0.09 to 1.38 mm. *Chlorite* constitutes the bluish-green pseudomorphous masses, often somewhat dichroitic, especially when retaining the hornblende cleavage, as well as the still more common scattered scales and blades, generally rounded, produced by disintegration of the larger masses. Its color sometimes passes by yellowish and reddish shades into a leather-brown, by oxidation, with the final product of thin films of ochre. Its inclusions are minute crystals and particles of magnetite, particles and films of ochre, and rounded granules of quartz. The scales are from 0.05 to 0.39 mm. in diameter. Here and there a few of the bluish-green chlorite scales pass into colorless scales and blades, often rectangular, which appear to be *muscovite*. *Magnetite* is mostly found, as above indicated, in close vicinity to the hornblende and chlorite, in grains or groups of crystals sometimes surrounded by an ochreous halo, 0.01 to 0.39 mm. in diameter, the latter being distinguishable in the thin section by the naked eye. The non-magnetic property of many of these black particles, on trial of the pulverized rock by a magnet, seems to refer them probably to *menaccanite*.

This rock is evidently a transition-variety, in the progress of alteration of a hornblendic gneiss. On ignition, its powder assumes a reddish-brown color and loses 1.08 per cent. of its weight, which, if attributed mainly to the chlorite, would indicate the presence of about 9 per cent. of the latter mineral. Hornblende-gneisses, of the same general character and with a greater or less development of the bluish-green chlorite, are quite common in this country; *e. g.*, on New York Island and at New Rochelle, N. Y.; on Poplar river, Wisconsin, etc.

1421. Crystalline Limestone. HURONIAN, FORMATION I. *Penokee Gap. Northwest quarter Sec. 14, T. 44, R. 3 W.* Fawn-colored. An aphanitic, compact, granular limestone, whose seams, covered with ochreous films, indicate a schistose structure. Minute yellow and glittering crystals of pyrite can be just detected by the eye, and are here and there represented — especially below and near the weathered surface — by ochreous particles and specks produced by decomposition. A few very thin veins of gray calcite traverse the rock. Under the loup the facets of calcite are distinguishable, a grain of greenish-white tremolite, about a quarter of an inch across, and a few tiny blades of a dark mineral. Weathered surface smooth but uneven, stained with brownish-yellow films, and seamed irregularly by many minute linear furrows, by the weathering out of the calcite-veins. Specific gravity,[1] 2.78.

Microscopic description. The texture remains aphanitic to the naked eye, even in the thin section. The predominant mineral, *calcite*, is present in minute, colorless, rounded to sub-angular granules, rarely with good cleavage lines, closely fitted into each other. About half of them are clear and colorless, the rest slightly grayish. Their size is usually 0.025 to 0.05 mm., varying from 0.013 to 0.10 mm. The inclusions ($\times 500$) consist of minute colorless granules, microliths of tremolite, and granules of reddish to blood-red ochre or göthite, 0.0006 to 0.004 mm. in diameter. The mineral polarizes at +, rather brightly, some grains more than others, with lively colors, irregularly mottled; many grains show simple twinning, on rotation of either nicol, and sometimes the stripes of twin-lamellation, with somewhat indistinct effect. Short needles of *tremolite* are scattered among the calcite-grains and sometimes gathered in radiating bunches. They vary in width from 0.002 to 0.025 mm., and in length from

[1] All the specific gravity determinations in this paper were made by the pycnometer, on the minerals in coarse powder, in distilled water at 62°, F.

0.006 to 0.15 mm. They are readily distinguished from the calcite by their strong double-refraction, polarizing brightly at +. On solution of a portion of the rock in acid, a rather large grayish insoluble residue is obtained, consisting of this mineral. *Pyrite* is sparsely but generally distributed in opaque granules, with square, rectangular, or irregular outlines, and a diameter of 0.008 to 0.076 mm. A small quantity of *magnetite* is also present in minute black crystals. The calcite-grains in this rock are smaller and less angular than those of Carrara marble, and without the general cleavage common in the latter. In size they more closely resemble those in the limestone at Radnor Station, Pa. But the rounded form, with the interstices occupied by the smaller particles, may be attributed to the mutual attrition of the granules during motion of the rock in its plastic condition.

1452. Tremolitic Magnetite-slate. Huronian, Formation II. *Penokee Gap. Northwest quarter Sec. 14, T. 44, R. 3 W.* Brownish-black. A magnetite of aphanitic texture, with feeble lustre on schist-planes, rather brittle, divided into angular masses by a few fissures covered with brownish-yellow films. Under the loup, it shows only the very minute glittering facets of magnetite, and appears at first to be perfectly opaque on the edges of thinnest splinters; but, by sufficient search, a few translucent particles can be detected. Fracture uneven. Powder, blackish-green. Streak grayish-black and shining. Weathers only superficially to deep shades of brownish-red and brownish-yellow, with the edges of the laminæ projecting in the cross-section and producing a rough rasp-like surface. Specific gravity, 4.24.

Microscopic description. The thin-section reveals a predominant quantity of magnetite, pretty uniformly and thickly distributed through a colorless ground-mass of quartz and tremolite. The *magnetite* occurs in black and opaque cubes and octahedra of various sizes, from particles just visible at a magnifying power of 170 up to crystals of a diameter of 0.13 mm. In some parts of the thin-section it is more thickly clustered together in opaque patches, and elsewhere more loosely, so as to leave small patches and long lanes or veins of the colorless ground-mass quite free from magnetite. The ground-mass appears to consist largely of granules of colorless *quartz*, about 0.01 mm. in diameter, polarizing in the usual method of crystalline aggregate. *Tremolite* occurs abundantly in very small blades, needles, scales, and still more minute granules, and occasionally in large grains, showing the usual cleavage of amphibole. The size of the blades rarely exceeds 0.004 mm. in width and 0.038 mm. in length. In some places the fine needles and microliths of the mineral are gathered in bunches, crossing each other in a close net-work. In polarized light, at +, polarizes richly with variegated arrangement of bright colors, the outlines of the blades and scales becoming distinct. A few colorless scales, sometimes with cleavage, which are interspersed among the tremolite-scales, polarize feebly and appear to be *talc*. *Hematite* was also distinguished in the form of a few very minute blood-red granules, adhering to magnetite, and also in brownish-red films and particles, forming cloudy fringes, usually about 0.01 mm. in width, to some of the magnetite granules. The scales of tremolite are also sometimes tinged yellowish or reddish by ochreous films. The entire bulk of the pulverized rock is taken up by the magnet, and on ignition of a weighed quantity it assumes a reddish-black color by absorption of oxygen and increases in weight.

29. Black Feldspathic Slate. Huronian, Formation V. *Penokee Gap. Northwest quarter Sec. 14, T. 44, R. 3 W.* Grayish-black, with minute glittering points. A compact, aphanitic rock of imperfect slaty structure, conchoidal fracture, grayish-white streak, greater hardness than that of an argillyte, and without any argillaceous odor on moistening. Under the loup, it appears to be chiefly made up of minute glittering facets, sometimes triangular, rarely large enough to be distinguishable by the naked eye. Also a very few minute yellow particles of pyrite can be distinguished. On the edges of thin splinters, a light-colored mineral may be identified in minute granules. Weathers smoothly and uniformly to a brownish-red color. Specific gravity, 2.81.

Microscopic description. The thin section reveals to the naked eye an abundance of transparent particles in a brownish cement. Clear and colorless *orthoclase* predominates in angular granules or plates, often rectangular or rhombic in cross-section, rarely hexagonal. Their longest axes are usually 0.1 to 0.2 mm., varying from 0.03 to 0.25 mm. In some granules distinct lines of cleavage, in two directions, are displayed, even in ordinary light. The few inclusions (often clouding the granules) consist of minute crystals of feldspar, colorless needles of amphibole, and especially minute particles of magnetite, gathered in dusty groups, and of the same, with scales of biotite, arranged in bands whose plane surfaces indicate in each, a thin seam of infiltration. The grains polarize feebly in most cases at +, on account of the thinness of the section, here and there display a twin-structure, and sometimes wavy lines produced by incipient alteration. The cement between these granules consists of a mixture of biotite and opacite. The *biotite* traverses the interstices in thin layers, made up of rounded scales and short blades of a brownish-yellow, brownish-gray, to light-brown color, feebly dichroitic (yellowish-white to brownish, or even opaque). Many of the leaves are very minute and thin, but they are generally from 0.005 to 0.076 mm. in diameter. Greenish-white needles of *amphibole*, 0.01 to 0.07 mm. in length, may be occasionally observed in the cement, and as an inclusion in the orthoclase. *Opacite* is commonly distributed in very minute dark particles, sometimes black, sometimes brownish-red to nearly opaque, often 0.02 mm. in diameter, and probably consists chiefly of *pyrite* and *limonite*, with a very small quantity of magnetite. It occurs as an inclusion in orthoclase, or, in the cement, gathered in bunches, or in thin layers around the grains of orthoclase, and marking their outlines where obscured by biotite. Brownish-red films of ochre sometimes fringe these granules. On ignition of the powdered rock its light brownish-green color passes into umber, with a loss of 1.59 per cent. of its weight. This rock is an interesting and rather unusual variety of schist, of distinct sedimentary appearance and origin, antecedent to the formation of an argillyte, but exhibiting no traces of metamorphism.

1439. Chloritic Dioryte. HURONIAN, FORMATION IX. *Penokee Gap. Southwest quarter Sec. 11, T. 44, R. 3 W.* Grayish-black, with tiny shining facets. A compact, hard, and rather fine-grained rock, with uneven fracture, gray powder, and a grayish-white streak, partly shining from abraded steel. Under the loup, it displays a prominent amount of blades of black hornblende, with minute scales of a black micaceous mineral, a very few particles of pyrite, and numerous crystals of brownish feldspar. Weathers to a light brown. Specific gravity, 2.99.

Microscopic description. The thin-section displays to the naked eye a predominant quantity of *plagioclase* in clear, sharply defined crystals, separated by minutely granular masses of a bluish-green to brownish-green color, usually 0.87 to 1.04 mm. across, which consist of the products of the alteration of hornblende, viz., more or less altered amphibole, chlorite, crystals of pyrite, and films of ochre. The tabular crystals of plagioclase are long and mostly unbroken and perfect, presenting clear rectangular sections, generally with good striation, and fainter cross-lines at right-angles. They vary in length usually from 1.0 to 1.9 mm., and in width 0.09 to 0.7 mm., commonly one-fifth of the length. These crystals are probably oligoclase, but many parts of them and many entire crystals display no striation, even in polarized light, and may possibly consist of a monoclinic feldspar. Their inclusions comprise scales of greenish chlorite, long needles or microliths of colorless or greenish-actinolite, a few particles of opacite, and rarely films and granules of brownish-yellow, sometimes blood-red ochre (× 925). Between the crossed nicols, the crystals show simple twinning or are traversed by stripes of a grayish, greenish-white, or yellowish-white color, passing, on rotation of a prism, into shades of maroon, or in some cases, to brilliant greenish-blue with crimson edges. The crystals of plagioclase often enclose green veins or bunches along the lamellation. The fissures have been widened into cavities of a lenticular and sometimes irregular shape, evidently by solution and removal of material; then lined by a thin bluish-green translucent layer of chlorite, slowly deposited from solution upon the walls of the cavities, and finally filled up by a minutely granular and more impure material, of a bluish-green to brownish-green color, and enclosing one or more cubes of pyrite, which is a crystalline aggregation from more rapid deposition. The pyrite has been the last mineral deposited, and is plainly a secondary product from the alteration of the hornblende of the original diorite. A similar permeation of plagioclase by infiltration has inclined some observers, erroneously in my view, to attribute the origin of viridite in part to the decomposition of the feldspar. The films and particles of ochre, in some of the veins in question, have evidently been produced by the decomposition of the chloritic aggregation by the subsequent passage of aerated waters. In the greenish masses which envelop the crystals of plagioclase, *chlorite* is the predominant constituent, in minutely granular masses, tiny scales (0.06 to 0.18 mm. across) and blades, of a bluish-green and greenish-white color, in part rendered brownish-green by incipient alteration and ochreous films. With sufficient magnifying powers ($\times$ 150) it is found to be everywhere decidedly dichroitic, passing from brownish-white to bluish-green. Its inclusions consist ($\times$ 925) of numerous particles of pyrite, tiny scales of actinolite, and films or granules of ochre. The outline of a green mass — a former crystal of hornblende — is often composed of a clear translucent border of bluish-green chlorite, 0.006 to 0.02 mm. in width, which is sometimes transversely fibrous, *i. e.*, made up of scales seen in cross-section. A similar fringe sometimes envelops the grains of pyrite. *Actinolite* is commonly dispersed among and through the green masses in aggregations of long parallel blades, greenish and strongly dichroitic, often altered to a brownish-yellow color or colorless. Such an aggregation only represents a form of alteration of the original hornblende, its fibrous texture (prismatic cleavage) surviving in the parallel arrangement of the actinolite needles. In width they vary from 0.003 to 0.01 mm., and in length up to 0.75 mm. Needles and microliths, greenish to colorless, are also scattered in the plagioclase or project into it from its green envelope. The similarity in optical properties renders it probable that the actinolite, at least in part, consists of pseudomorphous chlorite. *Pyrite* is abundantly distributed, almost entirely in the green material, in opaque grains, displaying a glittering steel yellow surface in reflected light, mostly of somewhat uniform size, 0.17-0.35 mm., varying from 0.02–0.69 mm., in longest diameter. Their form is mostly that of rhombic, triangular, or irregular crystalline grains — or thin tabular plates, giving long and rectangular sections or thin laminæ occupying fissures; their outlines are often ragged, and their interiors more or less cellular, so as to present skeleton or network forms, sometimes with apparent cleavage or gridiron-structure, and sometimes, from insufficient material in crystallization, with a geode-like interior partially occupied by minute crystals or plates. The action of the magnet on the pulverized rock establishes the presence of a very small quantity of magnetite, perhaps the opaque particles among the inclusions of the feldspars.

On ignition, the pulverized rock assumes a yellowish-brown color, and loses only 0.74 per cent of its weight, considerable oxidation having probably taken place among its ferrous constituents. The abrasion of soft steel along the streak of this rock, when scratched by a knife, seems to be due to the hardness of the unaltered feldspar. The unbroken condition and sharply defined outlines of the feldspar-crystals in this dioryte has only rarely been found in American rocks of this class, *e. g.*, in one from Woodbury, Connecticut. Either the constituent minerals are usually less perfectly crystallized, as in the dioryte of Stony Point, New York; or they have been much broken and blended by internal motion and metamorphism, as in the numerous varieties in the belt which passes through Greensboro, Salisbury, and Charlotte, N. C.

1429. Magnetitic Mica-Slate. HURONIAN, FORMATION XII. *Penokee Gap. Southwest quarter Sec. 11, Town 44, Range 3 West.* Blackish-gray, slightly reddish, with tiny black specks. An argillite of the usual fine texture, in which, however, the eye distinguishes many very minute sparkling black scales; through this dull groundmass are scattered many short black blades, somewhat glossy, rarely one-sixteenth of an inch in length and about one-sixteenth to one-eighth of an inch apart, lying chiefly in the planes of slaty-lamination. Under the loup, the groundmass appears to be made up of glistening scales of a blackish mica, disseminated through a grayish-white mineral and concentrated in greater abundance in certain alternating laminæ of the slate. Fracture hackly. Powder gray. Weathers only superficially to a brownish-yellow, smooth surface. Specific gravity, 2.78. On ignition of a weighed quantity of the pulverized rock, it assumes a light-brown color and loses 1.74 per cent.

Microscopic description. The thin section appears very fine-grained, displaying the lamination, to the naked eye, streaked with the darker films. *Biotite* is present in abundance in light yellowish-brown (by transmitted light) irregular scales, with sharp outlines, of which many of the smaller are nearly circular; all are more or less dichroitic when sufficiently magnified (× 175), especially the brownish to colorless striated cross-sections (× 800); the greatest dimensions observed were 0.038 to 0.076 mm. Brownish, yellowish and colorless blades of *tremolite* also occur, with square or pointed ends, from 0.001 to 0.011 mm. in width, and from 0.01 to 0.079 mm. in length. It generally polarizes brightly, from yellowish to brownish-red, sometimes bluish-green to deep-red. Colorless *quartz* appears to be the predominant material, in the form of the groundmass, displaying no outlines in ordinary transmitted light. It polarizes at + in part rather feebly, in part bright greenish-yellow, blue, or brown to dark, and, on rotation of the section, the dark patches become stippled with greenish-yellow, revealing the more minute constituent granules, which average about 0.019 to 0.026 mm. in diameter. Opaque particles of *pyrite* and *magnetite* are abundantly dispersed, mainly associated with the scales of biotite, included within them, and (the more minute) arranged along the lines of striation. They occur in grains of varying size, mostly irregular, some of the smaller being semi-crystalline in form and representing the magnetite, whose presence is confirmed by the action of the magnet on the pulverized rock. The larger grains appear to consist of aggregated groups of pyrite with ragged outlines, and angular, often rectangular projecting prongs; their greatest dimension averages about 0.019 to 0.03 mm. and sometimes reaches 0.19 mm. In reflected light, they exhibit a white to reddish-white color and sparkling lustre. The most minute particles are very generally dispersed, and also often concentrated in bands which streak the thin-section and mark its lamination; these particles are too minute for measurement, even when magnified 800 diameters. A very few blood-red granules (×800) may probably be referred to göthite; some are triangular and show a radiated structure, as though composed of minute radiating crystals. This rock resembles some of the finest-grained mica-slates of the Marquette region of northern Michigan.

1498. Chiastolitic Mica-Slate. HURONIAN, FORMATION XVI. *Northwest quarter Sec. 11, Town 44, Range 3 West.* Blackish-gray with elongated yellowish-white spots. An argillyte, with irregular schistose structure and the usual aphanitic slightly-shining material. Through this, at intervals of about one-fourth inch, are distributed numerous blades of chiastolite one-fourth to one-half inch in length and usually one-sixteenth of an inch in width, lying in all directions within the schist-plane, and sometimes presenting rhombic cross-sections. The seams usual in an argillyte are covered with dull reddish-brown ochreous films. Powder greenish-gray. Under the loup, the ground-mass appears to be chiefly made up of very minute glistening micaceous scales, sometimes in black bunches of a little coarser texture. The chiastolite blades all exhibit a more or less decided black line down the centre, which, under the loup, is found to consist of scales like those of the ground-mass; the chiastolite material on either side of the line is white or colorless, where undecomposed, but has usually been rendered yellowish by alteration. The black bunches of micaceous scales, above-mentioned, often have the same bladed form and are evidently pseudomorphs after chiastolite. Weathers irregularly to a light brownish-gray, spotted by the decomposed and brick-red blades of chiastolite. Specific gravity, 2.69.

Microscopic description. To the naked eye and under low-powers, the thin-section displays a few minute prisms of *chiastolite* scattered through a dark, minutely-speckled, brownish ground-mass, which is also occasionally traversed by short and narrow yellowish-white veins. Long, brownish, minute bodies, with rectangular sections, denote the last stage in the alteration of the chiastolite-prisms. With higher powers (×140), the ground-mass is resolved into a mixture of a predominant quantity of blades of colorless tremolite, with a somewhat smaller amount of scales of brownish biotite and black particles of carbon, with a colorless material diffused throughout their interstices. In some parts of a slide the elongated scales and particles of these minerals have a parallel arrangement, and a scaley structure is produced, probably by a contraction of the material of the ground-mass around the blades of chiastolite. Only a few crystals of this mineral occur in the thin section, mostly enclosing the characteristic prism of impurities (Haüy's "*macle circonscrit*"), with an outer envelope of the pure mineral. The impurities have sometimes a regular and parallel arrangement, so as to produce a well-defined prism, with sides parallel to that of the crystal, but are usually heaped together irregularly —perhaps disarranged by the alteration of the crystal. The dimensions of the prism are from 0.14 to 0.21 mm. in width and 0.79 to 1.39 mm. in length. The inclusions consist chiefly of brownish scales of biotite, with a smaller quantity of particles of carbon lying in all planes. In polarized light, at +, the adjacent angles of this inner prism and of the outlines of the crystal are, in some instances, connected by dim, dark lines, running diagonally. The brownish blades already mentioned are filled throughout with the same inclusions and show complete alteration of the chiastolite and diffusion of impurities. The outer envelope of the pure mineral constitutes the bulk of most of the crystals. Its material is clear and colorless, is traversed by two systems of cleavage-lines at right-angles (prismatic and basal), contains few inclusions (chiefly particles of carbon), and polarizes with lively colors — bright-green through yellowish-white to maroon, between the crossed nicols. In most crystals, however, the usual alteration has taken place, evidently from the outside, rendering the outlines more or less jagged and irregular, and leaving only a few rounded grains of unaltered mineral, distinguishable by their clearness, the absence of color, surviving cleavage, and especially their polarizing properties. The alteration material is yellowish-white, minutely granular, contains more or less impurities (chiefly carbon, with a little biotite), is often separated from the grains of unaltered chiastolite by a heaping up of a black line of carbon particles against the outlines of the latter, and appears to consist of the colorless material of the ground-mass, polarizing in a similar way. *Biotite* is commonly dispersed through the ground-mass in irregular, usually angular brownish scales (×140), lying in all planes, generally 0.01 to 0.04 mm. in diameter. Others, of greater length and lighter tint, with good striation and strong dichroism, are cross-sections sliced by the thin-section. Where the laminated structure appears in the section, the biotite scales are gathered together into bunches, sometimes 0.3 mm. in length. This mineral is also distributed through the altered crust of the chiastolite-crystals and forms the chief inclusion within their cores. The black and opaque particles of *carbon* are irregularly distributed through the ground-mass without arrangement. Even at a magnifying power of 925 diameters, their outlines remain irregular, and the larger flakes are especially ragged, and pierced with minute holes, which signify that they are mere loose aggregations of the smaller particles. Their usual diameter is

0.003 to 0.019 mm., but varies from the minutest particles to 0.21 mm., or larger. A few display fine lines, being either fine microliths or the edges of flakes. Both the particles of carbon and scales of biotite are concentrated more thickly around the periphery of a chiastolite-blade, and there render the thin section darkest; black layers, linear in cross-section, are also sometimes deposited in the cleavage fissures of the mineral. The colorless to yellowish-white grains of the altered chiastolite crystals, and the similar narrow blades of the ground-mass should probably be referred to *tremolite*. These blades are generally 0.002 to 0.008 mm. in width, varying from 0.0008 to 0.038 mm.; and in length, generally 0.05 mm., varying from 0.004 to 0.266 mm. The mineral polarizes like tremolite in a lively way, with bright crimson, brownish-red, yellowish, and bluish-green colors. In those chiastolite-crystals which are completely altered, the material has a fibrous or thready structure, parallel to the prism. Minute sub-angular granules, 0.002 to 0.005 mm. in diameter, apparently of tremolite, are also everywhere distributed through the ground-mass. Isolated, sharply defined scales of light-bluish-green *chlorite*, of hexagonal form, with barely perceptible dichroism, 0.03 to 0.04 mm. in diameter, may occasionally be distinguished in the ground-mass. Their color passes into a brownish-red tinge toward the edges, by ochreous alteration. The clear, colorless or yellowish material which is diffused as a cement in large quantity through the confused net-work of the other minerals, and is never individualized in distinct forms, may be referred to *sericite*. In certain spots, between the tremolite-blades, clear grains may be distinguished, of almost pure sericite. Its inclusions (×925) consist of colorless granules and blades of tremolite, the black particles of carbon, scales of bluish chlorite, delicate films and particles of brownish-red *ochre*, and blood-red to brownish-red, non-dichroitic, angular scales of göthite. At +, the mineral either remains dark in places or polarizes feebly, and is stippled with minute spots (×170) of a slight tinge of greenish-blue, revealing the constituent scales; and, on rotation of the section, the usual phenomena of aggregate polarization are displayed. From the powdered rock, a very few particles of *magnetite* may be separated by the magnet.

On ignition, the powdered rock assumes a yellowish-brown color, and loses 4.71 per cent. of its weight. In regard to the chiastolite-crystals in this rock, it may be concluded that their central impurities are not merely inclusions during crystallization, as often supposed, but perhaps, at least in the highly-altered crystals, the result of their progressive alteration. This rock strongly resembles the "chiastolite-schist" of Gefrees (Fichtelgebirge, Bavaria), but differs in the presence of biotite, the far greater abundance of carbon, and somewhat in the inclusions and mode of alteration of the chiastolite-crystals; in the Gefrees-schist the generally parallel arrangement of the constituents in the ground-mass (lamination) appears more regular and decided, and the tremolite is present in round and elliptical fibrous grains, and in shorter needles. On the other hand, the chiastolitic clay-slate of Lancaster, Massachusetts, is very similar, containing biotite in the same abundance and distribution; but it differs from the present rock in the entirely macroscopic size of its chiastolite-crystals, and in the fibrous masses of amphibole distributed through the ground-mass.

1487. Dioryte-Greenstone Schist. HURONIAN, FORMATION XIX. *N. W. ¼ Sec. 11, T. 44, R. 3 W.* Blackish-gray, minutely speckled with grayish-white. A compact, almost aphanitic rock, traversed by irregular seams, covered with dull brownish-red and brownish-yellow, ochreous films, which suggest a schistose structure. Streak grayish-white, powder greenish-gray. Fracture (between the seams) rather even, in part inclining to sub-conchoidal. Under the loup, the rock appears to be an intimate, intermixture of very minute particles of a black shining mineral and of another of grayish-white color, resembling a feldspar. Specific gravity, 2.87.

Microscopic description. The thin-section of this very-fine grained rock presents under low powers a confused granular ground-mass of brownish and greenish color with granules of opacite pretty uniformly dispersed and here and there a minute clear and colorless patch. With a higher power (×170) the ground-mass is resolved into scales and blades, distributed in apparent predominance through a clear, colorless, brownish or yellowish base, which is represented in its purest form by the minute clear patches. The mineral of apparent predominance, *chlorite*, consists largely of minute brownish-green scales and granules, in confused aggregation, interspersed with an irregular network of brownish-green to brownish-yellow blades, evidently pseudomorphous after actinolite, running in all directions. These blades are usually 0.006 to 0.01, rarely 0.02 mm. in width, and 0.02 to 0.11, sometimes 0.27 mm. in length. There are also in different parts of the thin-section larger aggregations or homogeneous scales of bluish-green chlorite, feebly dichroitic (brownish-white or light maroon to brownish-green), with very irregular but rounded outlines. The lighter colored or colorless forms of the mineral are non-dichroitic. The clear base appears to consist of *sericite*, permeating the interstices of the chlorite, and, at rare intervals, forming the clear patches of 0.06 to 0.15 mm. in diameter. The chief and abundant inclusion consists of minute scales of chlorite, often circular or elliptical, in which the delicate line, often seen along the rim, and curved lines within it, seem to denote minute wrinkles (probably produced by contraction, from mounting in hot balsam). Other inclusions are needles of *actinolite*, often with good pointed terminations, down to microliths barely distinguishable, and particles of ochre. Even in ordinary light, but far more clearly at +, certain grains are prominent with rectangular outlines and fibrous texture in direction of length, often 0.04 by 0.19 mm., bluish-white to bluish-gray, sometimes yellowish-white to light maroon, and occasionally greenish-blue; these denote the forms of the original crystals of feldspar. Some of the patches are dark, between the crossed nicols, and on rotation of the stage, an irregular stippling of the foregoing colors takes place, revealing the constituent scales of the sericite. An analysis of this rock is likely to show an absence or very small content of the alkalies. Small elongated and opaque grains are strewn over the thin-section, each of which, on examination by reflected light, is found to consist of a minute glittering core of steel-yellow *pyrite*, enveloped by an opaque layer of *limonite*.[1] Their forms are angular, but very irregular, and their diameters vary from 0.007 to 0.06 mm. Delicate ochreous fringes generally surround them, and also penetrate the interstices of the adjacent granules of chlorite, occasionally in the form of blood-red grains. From the pulverized rock, the magnet also separates a few particles of *magnetite*.

On ignition, the pulverized rock assumes a reddish-brown color, and loses 1.83 per cent. of its weight. The confused fine-grained ground-mass of this rock, and the complete alteration of the original hornblende into chlorite are of very common occurrence in American greenstones. The further alteration of the plagioclase almost completely into sericite of a brownish tinge also occurs in a greenstone, almost identical in appearance and constitution, from the vicinity of Greensboro, North Carolina.

2001. Magnetitic Mica-Schist. HURONIAN, FORMATION XXI. *S. W. qr. Sec. 2, T. 44, R. 3 W.* Reddish-gray and dull. A compact, aphanitic rock, with somewhat uneven fracture and apparently an imperfect schistose structure. Streak grayish-white, powder fawn-colored. Hardness about 6. Under the loup, it exhibits a small amount of very minute glistening light-brownish scales, distributed through a predominant brownish ground-mass, apparently feldspar. A few fissures and seams occur, covered with brownish-yellow ochreous films and larger scales of the mica. Weathers to a blackish-gray smooth surface. Specific gravity, 2.67. Loss on ignition, 1.91 per cent.

Microscopic description. This rock resembles 1429, but its thin section reveals an inferior content of magnetite, which is also indicated by the lower specific gravity,

[1] A common form of macroscopic pseudomorph elsewhere.

lighter color, and still smaller quantity of magnetite taken up from its powder by the magnet. *Quartz* appears to constitute the clear, colorless, and, in ordinary light, apparently homogeneous ground-mass, generally predominating in quantity over the biotite. It is also isolated in patches larger than those of 1429 and also clearer, the few inclusions consisting of tiny colorless rounded scales; in size, these patches vary from 0.07 to 0.11 mm. across, in one case 0.75 by 1.45 mm. In polarized light (the granules being larger than those of 1429 and the section a little thicker) it polarizes decidedly, yellowish-white or greenish-white, by blue, to brownish or dark, or sometimes from greenish-blue to brown and dark; at +, dark-gray or the colors just mentioned. Crystals and grains of *amphibole*, and sometimes perhaps of *feldspar* appear to be represented by occasional rectangular or rhombic patches, clear and colorless (clearer and whiter than the quartz of the ground-mass), which sometimes also retain traces of cleavage lines in one or two directions, and even a fibrous texture. They polarize brilliantly with a net-work of bluish-green and crimison colors, and appear to consist of tremolite. In diameter they vary from 0.09 to 0.15 mm. Their inclusions are few, viz., granules of magnetite and minute liquid-inclusions (×800), with circular or elliptical sections. The clear and rounded patches in the ground-mass, already described, appear to offer a condition of more complete alteration. *Biotite* is very abundant in sharply defined scales and blades, of a slaty-gray, brownish yellow, and maroon color, deeper than in 1429. The scales have an irregular but rounded to sub-angular form, and an average diameter a little greater than in the other rock, 0.03 mm. (0.006 to 0.12 mm.), and when very small generally possess a pale brownish-yellow tint to colorless; they usually display strong dichroism and absorption, even in the colorless scales, changing on rotation to deeper shades of maroon or to opacity; in polarized light, at +, they display lively colors. The blades are rare, rectangular in section (often slender needles have been produced by separation from larger scales), and display little or no dichroism and feeble polarization. Other similar scales, apparently blades, are cross-sections of the scales 0.006 to 0.01 mm. in width and 0.06 to 0.09 mm. in length, and are distinguished from the former by their striation and powerful absorption. Many of the larger scales of biotite suggest, by their form and fissuring, that there were originally large leaves of the mineral in this rock, whose disintegration, probably by motion of the mass in a pasty condition, has produced the present tiny scales. Some of the smaller scales appear to have experienced an ochreous alteration, and to this may also be referred a few large patches or films, in one case 0.66 mm. in diameter, varying in color from yellow to brownish-orange, minutely granular and non-dichroitic. A few of the slender colorless to yellowish-white blades and granules in the ground-mass resemble *tremolite*, in form and polarizing property. They are mostly gathered in the clear patches which seem to mark the position of former large blades of hornblende. Black and opaque hexagonal scales, apparently of *hematite*, are abundantly distributed through the ground-mass, averaging about 0.018 mm. in diameter. Also smaller granules and particles, of which those with square cross-sections probably denote the magnetite, which, in very small quantity, may be separated by the magnet from the finely pulverized rock. The smaller granules are often included in the scales of biotite, sometimes gathered in groups, and somewhat concentrated within and around the borders of the clear patches in the ground-mass. In reflected light many of these latter display sparkling whitish surfaces which may denote particles of *pyrite*.

12. Chrysolitic Diabase. KEWEENAWAN. *Northeast quarter Sec. 31, Town 45, Range 2 West.* Brownish-gray speckled with brownish-red. A somewhat decomposed and friable rock, resembling but coarser than the similar rock No. 84, chiefly made up of brownish-red plagioclase-feldspar, in facets sometimes half-an-inch across and not infrequently striated, but with lustre and translucency less than that of the latter rock. Coarse grains of black augite, with high lustre on fracture, may also be distinguished. Fracture very uneven. Powder greenish-white. Weathers to a depth of about $\frac{1}{32}$ inch to a light brownish-gray, speckled and roughened by projecting crystals and thin plates of magnetite. Specific gravity, 2.81.

Microscopic description. The coarse texture of the thin-section at once reveals to the eye that the feldspars largely predominate in quantity, and under a low power in polarized light, that they consist chiefly of labradorite, with a smaller amount of orthoclase. The *labradorite* occurs in sharply defined and distinct crystals, quite clear and colorless, with twin lamellation (striation) plainly and often strongly marked in ordinary light, and with their terminations and angles sometimes sharp and sometimes gracefully rounded. Under sufficiently high power (× 140), many inclusions are observed, viz: greenish viridite, as films and scales in the fissures, as narrow ribbons across the clear fields, and many nearly colorless and generally disseminated minute scales and grains; brownish biotite, in delicate scales between the grains; magnetite, in tiny black granules; and colorless talc in abundant short blades and minute fragmentary granules, in the close vicinity of the olivine grains. In polarized light, at +, the usual magnificent lineation (twin-lamellation) of labradorite is displayed, with the greatest variety in the width and alternation of the bands of brilliant colors. *Orthoclase*[1] occurs in a few distinct but small grains, also as bands interlaminated with plagioclase, sometimes exhibiting the characteristic comb-like markings and generally good cleavage, at least in one direction. A very common and interesting inclusion consists of small colorless needles, apparently of plagioclase (× 175 to 800), which appear dark or opaque at low powers and impart a cloudy appearance to many of the orthoclase-grains. They vary greatly in length from short microliths to long needles, and lie mostly parallel to the cleavage-lines of the feldspar. The terminations are generally sharply defined, and appear, in cross section, as minute spots (× 1000 to 2550) of rhombic, square, or rectangular form, and 0.008 to 0.027 mm. in diameter. Commonly a long needle is not found to be continuous, but consists of beads or short rods; 120 were counted in a single needle, lying at various intervals and in the same line; they suggest, not the fragments of a disjointed needle, nor its partial removal by subsequent solution, but rather a development from material insufficient in quantity for their growth.

Augite is the chief constituent after the feldspars, in irregular masses of brownish white to brownish-gray color, non-dichroitic, with a strongly marked prismatic cleavage (even fibrous, like diallage, in some places);[2] another less distinct cross-cleavage at right-angles to the first, and a third still more indistinct and oblique. All these cleavages are beautifully accentuated by the abundant opaque inclusions, occupying short fissures, and the common direction of the cleavages in different grains shows that they are but parts, sliced by the thin-section, of a single mass, which occupies the interstices of the feldspar-grains, and therefore is later in origin than the latter. These grains are 0.5 to 1.0 mm. in width, and sometimes 2 to 8 or 10 mm. in length, and are also traversed by irregular wide fissures filled with opaque substance. Many inclusions are dispersed through the augite, viz., granules of viridite, magnetite, and filmy scales of biotite. Much of the augite shows more or less alteration. First, it assumes a greenish

[1] It is well known that simple crystals of a plagioclase, when cut nearly parallel to the brachypinacoid, present monochromatic areas between the crossed nicols, which may very easily cause them to be mistaken for a monoclinic feldspar. Rosenbusch calls attention to the possibility of this mistake in examinations of gabbro (Mikr. phys. d. mass. Gest. 460), but still admits the presence of orthotomic feldspar in two Italian gabbros (op. cit. 468); Zirkel, Rutley, etc., also find orthoclase in the Norytes of Sweden, etc. In the absence of confirmation of its presence in the chrysolitic diabase (or gabbro) of Wisconsin by chemical or other means, I only intend to state that certain feldspathic grains, subordinate in amount to those which are distinctly triclinic, often present the optical phenomena most commonly attendant upon the monoclinic feldspar: such as cross-hatching, depolarisation in complementary colors on either side of the median divisional plane through a twin, saturation to cloudiness by included microliths of a plagioclase feldspar, etc.

[2] H. Rosenbusch: Mikroskopische Physiographie der massigen Gesteine, p. 354.

shade, with numerous irregular short cracks, indistinct cleavage, and roughened surface (like that of olivine); at +, the distinction between the two varieties is very marked, the unaltered augite being usually traversed by stripes of color coincident with the cleavage, while, beyond a sharp line, the altered mineral displays a uniform sheet of bright color. Secondly, the altered mineral passes insensibly into a confused field of viridite, loses the fibrous structure, but retains the stronger cleavage-lines, becomes greenish-white to colorless, and is filled with granules of magnetite. Or, it is surrounded by a similar border of viridite, with the magnetite granules gathered along the original cleavage-lines or in an irregular band of ragged grains along the outlines. A similar passage into biotite may be also observed. *Viridite* is a common constituent, in small quantity (probably in part only a form of biotite), generally greenish-white and with a watery appearance, sometimes bluish-green, and generally, but not always, more or less dichroitic. It occurs in broad scales, deep-colored, in the vicinity of the augite, in long filmy bands traversing the feldspars, and in granules disseminated, generally in the vicinity of the augite, as a greenish to colorless dust or cloud. Sometimes a delicately fibrous or thready texture is presented, probably by the edges of the leafy scales. Its common inclusion is magnetite, in granules or dust.

Chrysolite *(olivine)* is commonly distributed through the grains of augite, or sometimes in the feldspar in its vicinity, in rounded grains, generally elongated or elliptical, and sometimes hexagonal in section when small. The major axis is from two to six times the length of the minor, the former varying from 0.49 to 1.33 mm., and the latter from 0.10 to 0.26 mm. The mineral is clear and colorless (and so distinguishable from the brownish augite when unaltered), with the delicately roughened surface characteristic of olivine, often displaying an imperfect cleavage by short parallel fissures, and is generally traversed by more irregular and strongly marked cracks, often nearly at right-angles; in polarized light displays the brilliant chromatic polarization, with lively colors, from maroon at + to yellowish and to bright bluish-green, on rotation of either nicol, but in some grains the polarization is not so brilliant or is more irregularly stippled.

The grains are almost always more or less altered, at least superficially or along the cracks — *never* into serpentine, as commonly described in the literature of lithology, but by a mode of alteration, I believe, new to the science — *into biotite, viridite and talc.* Sometimes there are strongly-marked veins, consisting of the greenish mineral (viridite), sometimes of brownish-yellow to brownish-red biotite, together with abundant granules of magnetite. Again, one side of a grain, or an entire grain is altered into biotite, which, where it happens to have been sliced in cross-section, presents the usual strong dichroism and the striation from side to side, without regard to the structure of the original olivine; this also is dotted with magnetite, and the contour of the grain is also sometimes marked by a thin laminated layer of dichroitic viridite. Again, a thin grayish-white, often cloudy, crystalline crust, generally 0.11 mm. in thickness, either forms a lining to one side of an olivine-grain (or adjacent angles of augite) or even completely envelops the smaller grains; it is made up of thin, delicate, wavy scales (×170) perpendicular to the encrusted surface, and consists of a colorless glassy mineral, with aggregate polarization between the nicols, and the changes of color on their rotation (yellowish-white to light maroon) which identify it with talc. An interesting illustration of the expansive force of crystallization is exhibited in some of the olivine-grains (and represented in Fig. 1, Plate XXII) by a rupture of the talc crust at one point or at several along the edges of lamination of the biotite. The outline of the talc-crust represents the crystalline contour of the olivine-grain and was evidently the first formed. At certain points fragments are sharply broken off and projected and even disintegrated into scattered scales, between which the pointed edges of the laminæ of biotite are thrust forward from the mass within the grain. In the sketch (Fig. 1, Plate XXII) three altered grains of olivine are represented near the edge of the thin section and enclosed in feldspar. The upper one consists of a core of biotite and surrounding shell of talc, the latter simply fractured on its upper edge, at *a*. The two lower grains exhibit the projection of the biotite laminæ through the shell of talc to the right hand at *b* and *c* (along the plane of easiest fracture — the cleavage-plane of the feldspar). The lower grain also retains much unaltered olivine, traversed by the usual ochreous veins, only partially converted into biotite in the upper corner near the point of rupture in the talc-shell. The mode of alteration thus suggested consists, first, of the attack on the olivine-grain by simple atmospheric waters, the removal of the iron constituent (possibly as carbonate) and its deposit as ochre within the cracks of the olivine, and the re-crystallization of the remaining constituents in the form of the envelope of talc — the subsequent permeation of the interior by alkaline solutions, probably derived from the decomposition of the surrounding feldspars — the gradual conversion of the olivine-core into biotite, with an accumulating force of expansion outwards and a final rupture of the crust. In one grain (in another part of the thin-section) there has been apparently an alternation of these processes, as the core of the crystal, chiefly biotite, is on one side enclosed, first, by a thin layer of talc, then of biotite, and finally of talc — the latter ruptured at several points.

The *biotite* presents a yellowish-brown color with little or no dichroism, when its leaves lie in the plane of the thin-section; in cross-section it is mostly brownish-yellow and clear, striated, and with powerful dichroism and absorption; often also of greenish shades, but distinguished from true viridite by its dichroism and striation. Besides its occupation of the olivine grains, it is found in minute isolated hexagonal scales or long filmy bands in the interstices of the feldspar grains. Its few inclusions consist chiefly of granules of magnetite. In size its scales vary from 0.05 to 0.42 mm. *Magnetite* is distributed through all the minerals in granules or dust, rarely 1 mm. in diameter, especially in the viridite, with which it appears to have had a contemporaneous origin, during the alteration of the augite. In many grains of the latter mineral the prismatic cleavage is emphasized at equally distant planes, by dusty layers of magnetite and ochre, which also are lined, as in a comb-like arrangement, on either side, by short projections in the plane *i-i*. *Ochre* is commonly disseminated in small quantity in brownish-red and brownish-yellow particles through the other minerals, imparting its color — especially in films through the cleavage-planes, or gathered in numerous clouds among the congeries of viridite-granules. The *talc* encrusts not only the olivine grains but adjacent surfaces and angles of the augite. In the latter case the plates are generally flat, but, on the olivine-grains, more or less curved and wrinkled, always inclining toward the nearest point of rupture, and evidently bent by the same force.

On ignition of the powdered rock, it assumes a yellowish-brown color (probably by absorption of oxygen) and loses 0.80 per cent., which may be taken as an *approximate* indication of the amount of water represented by the hydrated minerals, viridite, talc, and ochre. The order of succession, in which the several minerals have crystallized out, seems to have been as follows: olivine, orthoclase, labradorite, olivine and augite, talc, viridite and magnetite, biotite, and ochre. So far as American lithology is concerned, this appears to be, with one exception, the first published observation of a rock of this class, in fact everywhere of rare occurrence. But in Sweden, at Asbyn, Elfsalen, occurs an "olivine-diabase" containing exactly the same minerals and with the same peculiar alteration of the olivine grains into biotite. The latter rock differs from this, however, in the general cloudiness of the feldspars and in the occurrence of the talc in large hexagonal and clear plates. The frequent tendency of the augite to a fibrous structure, wine-colored tint, and feeble dichroism, suggests the process of alteration into diallage, to which the latter mineral probably always owes its origin,[1] and it is possible that here,

[1] G. Bischoff, Lehrbuch der chemischen und physikalischen Geologie, II, 654, 1866. F. Zirkel, Lehrbuch der Petrographie, II, 113.

as apparently in Sweden, there may yet be found a petrographical transition into and association with the "olivine-gabbros," if not with the norytes so common in the laurentian terranes of this continent. The exception, to which reference has just been made, is the similar chrysolitic doleryte and diabase, rich in labradorite, pyroxene, and olivine, with a little biotite and magnetite enclosing metallic iron, from Dog river and Ossipee, New Hampshire. But there are marked differences, especially of alteration, in the presence of augite and orthoclase, the passage of the olivine into biotite and talc, etc., in the rock of Wisconsin, and, on the other hand, in the abundance of viridite and of the anamesitic ground-mass in the New Hampshire variety.[1]

84. Chrysolitic Diabase. KEWEENAWAN. *Outlet of Bladder lake, Sec. 11, T. 44, R. 4 W.* Blackish-gray, coarsely speckled with grayish-white. A compact rock of medium grain, which appears to the eye to be chiefly made up of a gray to grayish-white, almost glassy feldspar, in small plates with fine cleavage, lustre, and sometimes striation, lying in all planes. Especially with the help of the loup, the augite may be distinguished as in 12, and also more minute grains of magnetite. Weathers like 12, to a light brown color, showing particles of ochre on edges of fracture. Specific gravity, 2.92.

Microscopic description. The chief characteristics are identical with those of the other rock, and attention will be called only to the points of difference. *Labradorite* predominates as in the other rock, but in rather coarser plates, which usually vary in width from 0.35 to 0.69 mm. and in length from 0.52 to 4.0 mm. Inclusions as in the other rock, with the exception of talc; and a few black needles like those in the orthoclase were observed, also a few short colorless microliths which may be apatite (?), and a very few gas-cavities. *Orthoclase*[2] occurs much more abundantly than in the other rock, in rather large grains, often of rounded outlines, and sometimes in crystals. One large crystal measured 1.26 mm. in width by 4.91 mm. in length. It is sometimes clear and colorless, with fine cleavage-lines in one direction and occasionally more faintly marked in another; but in general it may be distinguished from the clear and glassy labradorite sections by its cloud of inclusions (except around the margin of the grain), viz.: short minute needles of plagioclase, arranged mostly parallel to the strongest cleavage-lines, but in part irregularly or parallel to another cleavage. Other inclusions, far less abundant, are particles of ochre, striated rods of labradorite, wine-colored scales of biotite, grains of magnetite, and black arborescent films of pyrolusite along the cleavage-planes. In polarized light, passes from yellow or straw-colored to greenish-blue and to shades of brownish-red or maroon, and often shows twinning, interlamination with labradorite, and the predominance of one or the other feldspar on either side of a twin; the labradorite also often appears to envelop an irregular grain of orthoclase as a nucleus. The plagioclase needles above mentioned lie, in some grains, all in the plane of the thin-section with their full length and both terminations displayed; in others, they have all been sliced obliquely by the section, and in others again, they are nearly all seen in cross-section. They vary in width from 0.002 to 0.018 mm., and in length from 0.002 or less up to 0.11 mm. Their terminations at either end always exhibit a perfect crystalline form, somewhat pointed, whether the needle is short or long. Most of the needles in some grains, are dark and opaque, even at magnifying powers of 1,000 to 1,500 diameters, apparently in part on account of their small size, since the larger needles are invariably the clearer. Still it appears from a study of both cross and longitudinal sections that in this rock they consist of two materials, the one clear, colorless and predominate — plagioclase, and the other of a reddish color and in small quantity, ochre. Often a needle possesses

[1] Am. Jour. Sci. XIII, 34, 1877. — G. W. Hawes. His full description of this interesting rock may be seen in Vol. II of the Report of the State Geological Survey of New Hampshire.

[2] See foot note on page 234.

the jointed structure, as with those of 12, or is made up of spherulites about 0.002 mm. in diameter, so that its sides and terminations are irregular. The ochre often occurs as minute films between the component spherulites, especially near the middle of a needle, and so accentuates its jointed structure; or it appears both in the longitudinal and cross-sections to occupy a central core along the needle, possibly an optical deception; or it appears in a diffused form, imparting a reddish tint, *i. e.*, probably in particles irregularly disposed and too minute to be resolved by the powers employed. The *augite* occurs in brownish to wine-colored grains, from 0.52 to 2.97 mm. in length, with the fibrous cleavage rather more distinct than in 12, with sometimes a weak dichroism ($\times$ 170) — light wine-colored to greenish-yellow — and with the same method of alteration as in the other rock, into viridite and biotite, and with similar inclusions, with perhaps the addition of ragged granules of pyrolusite. Rectangular sections of labradorite crystals may in both rocks be often observed completely enclosed in augite. *Viridite* is inconspicuous, but with the same mode of occurrence as in the preceding rock, and exhibiting the same genetic relationship to biotite, both by intimate association and actually observed transition. *Olivine* in this rock (at least so far as shown by the two thin-sections studied) occurs only as rounded grains. Its general characteristics are the same as in the preceding rock. But in polarized light it rarely displays the characteristic chromatic polarization, but mostly an alteration of its optical constitution which produces a feeble polarization at +, with tints of slate-color and yellowish-white. Nor are its alteration-products exactly the same as in the former rock. Talc is nowhere observed, and the dark material, deep brownish-red to opaque, which traverses the grains in veins or envelopes them with a fringe, seems in part to be an ochreous biotite, where it shows dichroism or at least absorption by differences in depth of the reddish tint, but in large part simple ochre. From the augitic magma which occupied the interstices of the feldspar during the solidification of these rocks, the crystallization of the olivine evidently preceded that of the augite. *Biotite* is present in somewhat less quantity than in the preceding rock, and is here also certainly and entirely an after product. It occurs in scales, rarely hexagonal, mostly 0.09 to 0.17 mm. in diameter, and irregular films distributed through the fissures and interstices of the other minerals, or adhering as a fringe, about 0.05 mm. in width, to the grains of magnetite, etc. *Magnetite* commonly occurs imbedded in the augite, in grains 0.03 mm. or less up to 3.48 mm. in diameter, with imperfectly crystalline outlines; also in groups of the smaller granules, interspersed in feldspar with the viridite granules. Its presence was confirmed by its separation, by means of a magnet, from the powdered rock. *Ochre* is chiefly confined to the veins and vicinity of the olivine-grains, and intimately associated with biotite.

On ignition of a weighed quantity of the powdered rock, its color changed to a reddish-gray and it lost 0.48 per cent. in weight, confirming the microscopic observations of a smaller content of the hydrated minerals in this rock than in the preceding (12). It may be remarked that the rock represented by this and by the preceding specimen differs widely from the Mesozoic diabase, which forms so important a feature in the geognosy of the Appalachians, in both the nature and arrangement of its constituents. In the latter rock, olivine is but an accessory and often wanting, and the method and results of its alteration, as well as that of augite, are quite different from those in the Wisconsin rock. Again, even in the hand specimen, and still more distinctly in thin-section, the eruptive diabase of the Mesozoic always presents an exceedingly confused aggregate of fractured minerals, while that of Wisconsin is characterized by the sharp and perfect outlines of its crystallized minerals (Fig. 2, Plate XXII). This latter characteristic is also often found in the metamorphic diabase (meta-diabase) of the Appalachian belt, where it may be considered to indicate gradual and uninterrupted crystallization in repose.— SCHOOL OF MINES, COLUMBIA COLLEGE, *New York, February, 1878.*

PART IV.

THE

HURONIAN SERIES

WEST OF PENOKEE GAP.

BY C. E. WRIGHT.

INTRODUCTION.

It was an open question, for some time, as to the best manner in which to present the results of this season's work to those interested in the future of the Penokee Range, since it is desired that the report may possess as much interest to the practical man as to the scientific.

To fulfill these conditions, the following plan has been adopted: First, to give a geological section, so far as made out, of the rocks across the range, and to correlate, as near as may be, its members with those of the Michigan series — numbering the divisions to correspond with those in the Michigan Geological Report for 1873 — then to give a detailed description of the country gone over, referring whatever ledges of rocks were seen to this geological section.

I deem it essential, however, to first give a description of the dipping needle and dial compass, and how to use them, since, as before stated, many of our most important results are dependent on the magnetic attractions observed along the range. In fact, were it not for these instruments, it would have been quite impossible to trace the series across some of the long covered areas of this belt.

HURONIAN SERIES WEST OF PENOKEE GAP.

CHAPTER I.

DIPPING NEEDLE AND SOLAR DIAL COMPASS, AND THE METHOD OF EMPLOYING THEM.

As the results obtained on the Penokee Range during the season of 1876 are, in a large measure, due to the use of the dipping needle and the dial compass, we will describe the construction of these instruments, and the methods of employing them, before proceeding to a detailed report of the observations which I have made in that district; and of the results deduced from them.

The dipping needle, like all other inventions susceptible of modification, has a variety of forms. The simplest of all is the Swedish, no doubt suggested by the dipping of the surveyor's compass needle when placed over any mineral deposits possessing magnetism. This instrument consists of a brass cylindrical box about three inches in diameter, and of nearly the same height. The needle supports have a double joint, after the manner of the mariner's compass, which allows a complete revolution in a horizontal plane, and an inclination all around the entire circumference of about 30°. This instrument is very convenient for rough work, when accuracy is not essential.

Another form, and the most common of all, is a brass box from three to six inches in diameter, and from three-fourths to one inch in thickness. The two faces of this circular case are formed of plain glass plates. The needle is a narrow piece of steel, with a small hardened steel axis passing at right angles through its center. The extremities of this axis are nicely pointed and polished, and rest in concave centers (supports) of agate, or finely hardened steel, so set that the needle revolves freely in the plane of the instrument.

To the inside rim is attached a graduated circle, which is divided into quadrants, and each of these into 90°, so that when there is no attraction to influence it, the needle, if properly adjusted, and held in a vertical position, facing east and west, will mark zero upon the graduated circle. If the attraction is such as to cause it to assume a position at right angles to the horizon, it will point to 90° on the scale.

These instruments, though apparently simple, are, if not well made, very liable to get out of repair. This trouble, in the woods, is a constant source of annoyance and uncertainty, and cannot be fully appreciated until experienced. I have tried a number of these instruments, from different makers, and find that they generally answer well at first, but what is most desirable, and, in fact, indispensable, is that they should give *always* the same result under the same conditions, so that we may compare the results of one portion of our work with those of another.

As the sensitiveness of the compass depends entirely on the action of the needle, it is only necessary to briefly consider that part of the instrument. The chief trouble with the needle is, that the points of the axis upon which it revolves become blunted or injured by use, thereby increasing the friction, and thus, in like ratio, retarding its movements. Could we by any means eliminate the friction completely, the dip compass would be, within certain limits, perfect.

This being impossible, however, in the form of the compass which we are considering, let us examine the cause of this evil. It is plainly evident that the heavier the needle is, the greater the friction will be, and also the liability of the fine bearings to become blunted. To obviate this difficulty, we must have a needle as light as possible without impairing its magnetism. The nearest approach to this, I consider, is an instrument made by Messrs. W. & L. E. Gurley, Troy, N. Y., after a sketch sent them by myself. The needle of this instrument is constructed of two very thin plates or ribbons of steel. It is therefore light, and has a large amount of surface, which latter renders it very powerful. This combination of lightness and power, make the needle sensitive and durable.

There is the objection to this style of dipping compass — wherein the needle revolves in only one plane — that it necessitates the bringing of this plane into a vertical plane which passes through the magnetic meridian at the point of observation. With a little experience, however, we will be enabled to do this with considerable readiness and accuracy.

Another form frequently met with, is a combination of the Swedish dipping compass and the one just described. By means of a universal joint, it has, in addition to a complete revolution, a limited lateral motion. The main objection which I have to this compass is that it requires more time for the needle to "settle," and the glass face of the instrument must be protected from all friction, or great care must be taken to remove the effects of friction, otherwise the glass becomes electrified and the needle will either adhere to it, or be influenced by it so as to destroy the accuracy of the observation. There are other forms of the dip compass, but these three styles are the most common ones in use.

The dial compass, which I have used for the past two years, was designed by Major T. B. Brooks and myself. The needle is 2½ inches long, and is light, and extremely sensitive. The graduated ring has a movement of 20° to either side of the zero point, and so may be adjusted to the normal variation, so that the true local deflection may be read directly from the instrument. The gnomon, or coarse black silk thread, which casts a shadow on the dial plate, is fastened to the compass plate at a point on the south side of it, while the other extremity of the thread is attached to a hinged standard on the north side of the compass. When the standard is upright, the angle included between the thread and the compass plate should be equal to that of the latitude of the place in which the instrument is to be used.

There are several accessories to this instrument, but this alone is all that has any bearing on the subject in hand. It may be used on a tripod, or for rapid work held in the hand, which after some practice can be accomplished with very good approximate results, sufficiently accurate for this kind of work. It is necessary that the observer should be provided with the correct local time.

The application of the dipping needle and dial compass is simple, and the results, when rightly interpreted, are very satisfactory. We will suppose a covered magnetic belt, having a strike of north and south, and dipping vertically. If the magnetic attraction is strong, either instrument will answer. If, on the contrary, the attractions are slight, we are liable to pass them with the dipping needle; but the dial compass needle, being far more sensitive, will, even where the attractions are exceedingly faint, give a variation to the west, on the east side of the belt, and to the east, if the compass be taken to the west side of this line. Should the variation be only three or four degrees, we must then cross the line of attraction at every two or three hundred feet, and draw a line through the maximum of these attractions.

It will be noticed that the dial compass is more useful in this case than the dipping needle. We will suppose, however, that the magnetic belt has a trend of east and west, and dips as before, as we approach it from the south side; the needle begins to vibrate more rapidly, and the north end of the dipping needle gradually dips downwards, until we are directly over the belt, where, if the attraction is sufficiently strong, its position will be vertical, or 90°.

The vibrations of the needle are now the most rapid. Continuing to move northward, the lower end of the needle will move into the south quadrant, and continue moving to the south until the local force by which it is thus influenced, ceases to predominate over the normal attraction of the earth. But owing to the well known law of magnetism, that the magnetic power increases and diminishes, nearly, as the square of the distance, the needle slowly retraces its path and passes the 90° point again. The number of vibrations of the needle during a unit of time are greatly lessened, and if the pivots are at all blunted, the needle will frequently settle indifferently in any position. From this we have two 90° dips, the south one, directly over the local attraction, and the north dip, the resultant of two magnetic forces, the local attraction to the earth, and the terrestrial magnetic force. But let us observe the dial compass under these conditions. Commencing again on the south side, the vibrations of the compass needle become accelerated as we near the magnetic belt, but the moment we cross it, the needle will be reversed, if the attractions are sufficiently strong. If not, the vibrations will fall far below the normal number, and the needle will possess but little directive force. In this instance, therefore, the dipping needle answers the purpose best.

We will now assume one more case where the magnetic bed has a strike of southwest, and a dip of say 50° to the northwest. Starting again from the south side of the belt, with the dial compass, we observe a westerly variation as the line of attraction is approached, and the vibrations of the needle are likewise increased. Crossing the line, the needle suddenly turns to the east, but this easterly variation will gradually decrease as we proceed north; and the north zone of attraction will be found to be much broader than the southerly one, because of the influence exerted by the underlying masses of magnetic material. Returning to some distance south of the belt, and again proceeding north with the dipping needle, the first attraction which we notice, will often be a negative dip. This I at first supposed to be due to the boulders detached from the iron belt, but its frequent occurrence leads me to conclude that it is to be attributed to another source. It is well known that the magnetic rays emanating from the extremity of a magnet, are sent forward in direct lines, parallel to the axis, or resultant line of the magnet; but owing to the repellant nature of these similar polar rays, the axial rays are slightly deflected; those nearest these latter are deflected still more, while they in turn deflect those next in order from the axial line, and so on repeating and increasing the deflection, until we find the outer rays on opposite sides of the axis making an angle, with each other, exceeding 180°. These are not straight lines, but are curved, as may naturally be inferred.

The dipping needle, if brought within their influence, would, if the terrestrial magnetism were entirely neutralized, assume a position corresponding with the direction of these rays; hence the negative dip.

If we continue northwest the needle will come down to 90°, if the attraction is strong enough, as in the former case, and we may also have a second ninety-degree dip. Northwest of the line of the magnetic deposit there will often be, over a large area, a decided negative dip. This is, probably, locally occasioned, by the undulating character of the underlying magnetic rocks.

The cases thus far considered are the simplest with which we meet; for, usually, we have small parallel belts of attractions to trace out. Then, too, instead of the magnetic beds being continuous, they are, mostly, lenticular in form, or are faulted, causing the needle, frequently, to reverse its direction in passing along the line of attractions. Still, in a general way, much can be learned of the deeply covered magnetic beds, and we are thus enabled, by the use of the needle, to connect isolated ledges belonging to series having one or more magnetic members.

CHAPTER II.

GEOLOGICAL CROSS-SECTION OF PENOKEE IRON RANGE.

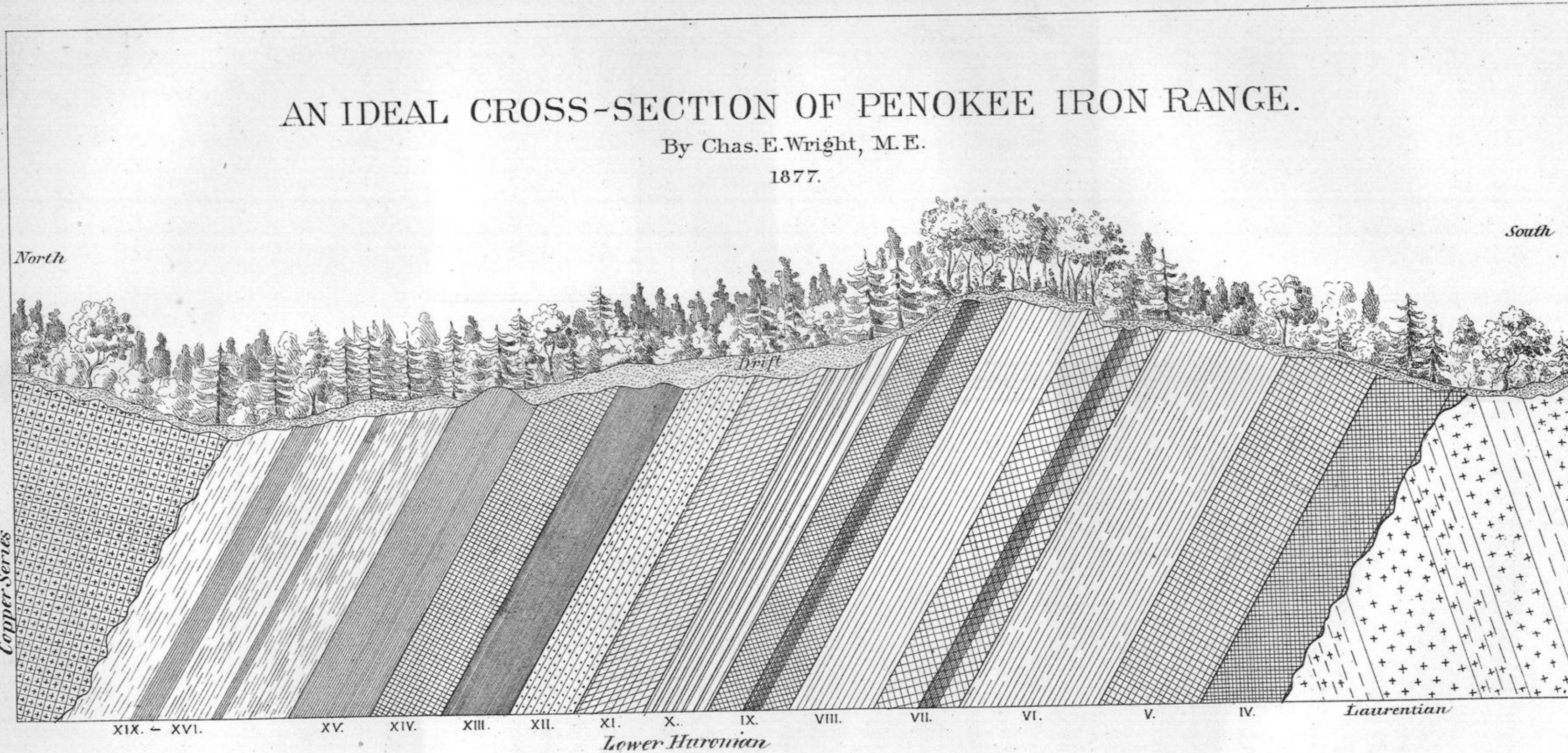
The rocks described in the geological cross-section of the Penokee series, given on the opposite page, were not found outcropping on any one line crossing the range, but were projected, as near as may be, on an imaginary one. In fact it would be quite impossible to embody in any local section the characteristic rocks of this range; owing to the limited number of outcrops, and the variable nature of some of the beds. As an illustration of this latter fact, it was found that the black slates at the Penokee Gap are replaced by diorites and hornblende rock to the west in Sec. 16, T. 44, R. 5.

In this geological section it has been my endeavor to correlate the Penokee Iron-bearing series — Lower Huronian — as near as possible with those of Michigan, assumed to be of the same age, as they undoubtedly are.

We will adopt, for convenience of reference, the numbering first employed in the Geol. Rep. of Michigan, 1873, to designate the Lower Huronian beds.

The first rocks we will consider, however, are those of the Laurentian series, found outcropping on the south side of the Penokee range. These rocks are granites, gneissoid granites, and gneisses. At the Gap, they have a strike a little to the south of west, and dip from 65° to 80° to the south. The granites are dark gray to reddish, depending on the predominance of the mica or feldspar. They are fine to very coarse grained, the medium grained varieties being, however, the most common. The essential mineral ingredients are usually easily recognized. The bedding planes, or "grain," of the granite, even in the massive varieties, may, generally, after careful examination, be made out. The quartz is present in grayish or glassy grains, and in blotches; constituting, in the latter instance, the matrix of the rock. The milky color of the quartz is, no doubt, largely due to internal checks, or flaws, with minute cavities distributed along the irregular planes, which are frequently filled with a liquid, having a very small bubble moving about within it.

PLATE, XXIIIA.



In the liquid carbonic acid inclusions, the bubble is more lively than those of the water-filled cavities. The rim around the bubble in the former is less distinct than that in the latter, while the dark outline of the cavity itself is narrower in the water than in the liquid carbonic acid inclusions. This, of course, is due to the difference of the respective refractive indices of the liquid carbonic acid, water, and air, or vapors.

Orthoclase is the prevailing member of the feldspar family. *Under the microscope* it presents a more or less cloudy to dense milky appearance, owing to the different stages of decomposition; which begins, as can be nicely observed, along the cleavage planes, imparting to the section of the crystal a mossy texture. This gradually thickens, and we finally have, in place of the crystal, a micro-granular mass, indistinctly outlined, which appears grayish white between the crossed nicols.

The mica is chiefly biotite, and of a dark color. Some of the black scales, when viewed under the microscope, resemble chlorite; but when the section makes an oblique angle with the principal axis of the former, its dichroism readily distinguishes it from the chlorite. An apparent dichroism may, however, occur in a very thick section of granite. Muscovite is almost always present in these granites; though the thin, limpid leaves require a good defining microscope to discover them. As accessories may be added amphibole, magnetite, pyrite, menaccanite and chlorite. Frequently there is a strong resemblance between biotite and amphibole, especially in the dark green biotite, where the section happens to be parallel to the principal axis. The dichroitic test cannot be applied here, as both possess dichroism; but the positions of the optical bisectrix in relation to the principal axes of the crystals readily separate them.

The gneisses, like the granites, vary from dark gray to reddish. Usually they are distinctly laminated with the layers of quartz, feldspar and folia of mica. It is sometimes slaty, but more generally it is heavily bedded, and passes almost imperceptibly into a gneissoid or a massive granite. The dark, fine grained, slaty varieties resemble hornblende gneiss and hornblende schist; in fact, I have been obliged to make microscopic sections before being able to decide which it was.

Under the microscope, in the dark varieties may be recognized hornblende, and, in some instances, we have a hornblende gneiss. The quartz grains are angular and enclose liquid-filled cavities. The feldspar consists of orthoclase and plagioclase, the former largely predominating in the micaceous gneisses, but in the hornblende gneisses the difference is not so great. The mica is chiefly biotite, though muscovite is usually present. The accessory minerals are pyrite, chlorite and magnetite.

Nonconformably overlying the Laurentian rocks are those of the Huronian series. We have at the Penokee Gap, where the Wisconsin Central railroad crosses the range, one of the best opportunities I have ever chanced upon for observing this interesting fact. This non-conformability on the Penokee, I believe, was first noticed by myself in 1875. The Huronian series at the Gap are plainly bedded, and have a strike of a little north of east, and dip very uniformally 66° to the north.

The lowest member which I have seen on the Penokee range is a marble, or dolomitic limestone, which we will consider as **No. IV.** There may be other members below the marble, as is the case in the Huronian rocks of Michigan, but I have never found them.

At the Penokee Gap, the marble is silicious; in color, light drab to grayish white, with shades of green; also light red and pink, not uncommonly. This diversity of colors is often observable in a hand specimen. The marble is fine grained, and strongly bedded, or massive, depending on the degree of metamorphism. When massive, it is usually jointed, and weathers to a light drab. Some portions of the rock contain pale green to almost white, radiated bunches of actinolite, resembling, in the latter instances, clusters of arragonite.

Under the microscope, a section of the rock shows a granular structure, and presents, between the crossed nicols, a grayish field sprinkled with a few bright grains of silica and an occasional fragment of actinolite. Scarcely any calcite can be seen, since the granules, almost without exception, are unstriated (dolomite).

No. V. Immediately overlying the marble at the Gap is a quartzite, varying in color from grayish white to white, and from saccharoidal to vitreous in texture. It is massive and highly jointed.

Under the microscope, it presents a very pretty chromatic field, composed of irregular shaped grains of quartz. In the section are patches, wherein the granules of quartz are much smaller, similar to those in which has occurred a replacement of the original mineral substance from a silicious solution, suggesting the supposition that this quartzite formed once a portion of the marble bed. The rock has evidently crystallized *in situ*. In the quartz are fluid inclusions.

West of here, in ranges 4 and 5, are several ledges of dolomitic marble, which are much coarser grained than the silicious marble above described, and which are less silicious. See description of specimen 176 in the following chapter.

No. VI. Next in order above the quartzite we have a chloro-silicious schist. This member was notable for preserving its individuality wherever we found it outcropping, and was therefore easily and quickly recognized. It has a dark grayish green color, fine grain, and is jointed, and usually more or less slaty. Along the jointing planes, it is often finely corrugated, and has an unctuous feeling. It cleaves readily into thin parallel and wedge-shaped plates. Examined with the lens, it is difficult to distinguish any of the chlorite.

Under the microscope, in the polarized light, numerous chromatic grains of silica, partially enveloped with folia of chlorite, appear to dot the field. The greenish leaves of chlorite are plainly visible, also a few grains of magnetite. With a power of five hundred diameters, there may be seen several minute crystals of rutile.

Nos. VII, IX, and probably **No. XI,** are represented in the near vicinity of the Gap by argillites, or black slates, while west of the Gap, from ten to fourteen miles, as has been already noted, the slates are replaced by diorites and hornblende rocks. My impression is that these slates and greenstones do not vary greatly in their chemical composition, the texture and structure being due to different conditions or degrees of metamorphism.

The argillites are brownish to bluish black, and have a micro-granular texture. Some of these are quite slaty and cleave freely; others are more compact. The slates are thicker, and the fracture uneven to conchoidal. On the cleavage planes they have a bright, lively luster, but a fracture across the cleavage is of a dull brownish black. Disseminated through the slate is considerable carbon, which appears ragged under the microscope. Numerous slender blades resembling microlites of feldspar are visible. Small angular grains of silica are present, also brownish and slightly dichroitic leaves, resembling biotite.

The diorites, above alluded to as constituting in part Nos. VII and IX of our scheme, are massive, and strongly jointed, rarely ever showing any signs of bedding. They are fine to coarse grained in texture; the cleavage planes of the hornblende in coarse varieties being unmistakable; also grains of magnetite. The other mineral ingredients are not so readily distinguished.

Under the microscope, can be easily recognized, plain and striated crystals of feldspar, of amphibole, and an occasional one of pyroxene; also a few grains of magnetite.

The crystals of orthoclase are quite large; and, thickly strewn in them, are fibrous fragments of amphibole. The slender crystals of plagioclase are often partially within the orthoclase, while other portions of the same are embedded in the amphibole. Some of the hornblende crystals are twinned. As accessory minerals, may be added grains of magnetite and groups of parallel-arranged narrow blades or filaments resembling magnetite or menaccanite.

The last of the greenstone family we will consider at present, is the hornblende rock, which we have already designated.

No. XI. This member, like the diorite, forms high, bold ledges. It is massive, but generally the bedding planes can be made out, and the fine grained crystalline textures are the most common. A fresh fracture across its grain sparkles, and feels rough and jagged to the touch. The rock is jointed; and coursing through it are frequently veins or dykes, of the upper granite (see cross section).

Under the microscope, a section of the hornblende rock consists of feldspar and amphibole; also quartz, a little chlorite, and a few grains of magnetite. The amphibole and feldspar are contained nearly in the same proportion. The former is of a pale green color and only slightly dichroitic; the latter consists of plagioclase and orthoclase in about equal quantities.

Returning now to **No. VIII,** of our cross section, we find it and **No. X** represented by actinolo-magnetic schists. These members are more or less magnetic, depending on the percentage of magnetite, and other conditions. When dipping at a high angle, and very silicious, they are as a rule found outcropping, and form high ranges, which, owing to their strong magnetic attraction for the needle of the dipping compass, too frequently play strange freaks with the explorer, who, in his imagination, even if he be a fair judge of iron ore, imagines that just beneath these leaner schists must lie concealed large deposits of rich ores, and that a little more perseverance on his part will unearth it. If his stock of pluck, however, is greater than his capital, he is simply digging his financial grave.

This, I regret to say, is no fancy sketch, as the several test pits and trenches on the Penokee range attest. It would not be so deplorable, if the individual loss were the only one sustained; in fact, it is only a fractional part of the injury done; for the individual failure reflects upon the entire range, and thereby retards enlightened, legitimate explorations, and the same may be said of any unwarranted adverse criticisms, from whatever source, the higher the authority, the more damaging.

The magnetic schist is banded, with layers of lean ore impregnated by actinolite; also layers of arenaceous quartz, and occasionally a thin one of magnetic ore. The bands vary in thickness from a mere line to one or more inches. Some portions of it are quite slaty and jointed. The texture on a fracture is usually fine grained. The color varies from gray to brownish black.

Under the microscope, in a thin section of the magnetic schist from the Penokee mine (550 paces west from the northeast corner of Sec. 15, T. 44, R. 3), there appears to be about an equal mixture of magnetite and actinolite arranged in alternate bands. The fibrous crystals of actinolite are thickly matted, making it difficult to distinguish the separate crystal blades. It is possible that there is considerable anthophyllite intermingled with the actinolite. It is not easy to distinguish between these minerals when they are intimately associated; then, too, the dichroitic test cannot with certainty be relied upon, since the lighter colored actinolite shows but very little dichroism; neither can the position of their respective optical axes to their crystal axes be readily determined. Scattered through the section appear, in the polarized light, bright chromatic grains of silica.

No. XII, usually represented in the Marquette iron district by a banded jasper, which forms the "foot wall" of the iron ore, we did not find outcropping west of the Penokee Gap, but since we were on the range, I have been shown by exploring parties several samples of jasper, and specular and magnetic ore (probably No. XIII), which they found east of the Gap.

One sample of a fine steely specular ore afforded me on partial analysis:

Metallic iron	63.100
Phosphorus	.025
Silica	6.100

Another analysis of steely magnetic ore from near the same locality gave me:

Magnetic oxide of iron	86.70
Alumina	3.10
Lime	1.40
Magnesia	2.70
Oxide of manganese	trace.
Sulphur	.04
Phosphoric acid	.34
Silica	4.70
Undetermined and loss	1.02

Metallic iron	62.60
Phosphorus	.15

No. XIV. I have also seen specimens of gray quartzite from east of the Gap, which were very similar to that forming the hanging wall of the Marquette iron ore mines, and for this reason we will for the present refer it to No. XIV. The next member in the regular order, **No. XV,** a micaceous argillite, or slate, is found outcropping in sections

9, 10 and 11, town 44, range 3 W. The outcrops were small, and formed, at most, only low, narrow ridges, which is no doubt due to the perishable nature of the rock. In many respects it resembles the argillites, described under Nos. VII and IX.

The rock is dark brownish-black, has a dull, slaty texture, is strongly jointed, cleaves into imperfect slates, the thicker ones having a conchoidal fracture. Examined on a fresh fracture, the surface appears thickly sprinkled with very minute, shiny scales.

Under the microscope, the base of the thin section is densely strewn with small brownish scales of biotite; and, besides, there is a very finely but unevenly distributed substance resembling carbon. The thin section, without the aid of the microscope, presents an oölitic structure, due to small oval-shaped particles of a lighter color than the ground-mass, which average about 1-32 of an inch in size.

Under the microscope, again, they appear to be altered crystals, belonging to the orthorhombic systems; possibly they are those of andalusite. The leaves of mica are scattered as evenly in these crystals as within the ground-mass.

Nos. XVI to XIX. Within these numbers are embraced a large group of micaceous quartz schists, micaceous slates and schists, and chiastolite schist.

These, with No. XV, no doubt could consistently be comprised under one head, but in order to reach No. XIX, which corresponds very nearly with the chiastolite schist of the Michigan series, we will, for the present, retain the numbers without attempting to classify the different schists.

The most important member of these is the micaceous quartz schist. It has an immense development immediately west of the Gap. It is of a dark iron-gray color, and has a very even, fine grained texture. It weathers to a light drab. Under the lens, the dark colored mica is plainly visible. Some of the exposed surfaces are minutely pitted, owing, apparently, to the partial decomposition and washing out of the mica. In hand specimens, the structure appears massive, but, by uncovering the ledge, the fresh surface frequently shows a slightly banded structure.

Under the microscope, the section appears to be composed chiefly of quartz and biotite, with a little feldspar. As accessories, may be recognized magnetite, and a few scattered colorless leaves of muscovite. The chiastolite schist forms a high ridge on the east bank of Bad Water river, near the west line of the N. W. $\frac{1}{4}$ of Sec. 11, T. 44, R. 3 W. It has a dark brown to brownish-black color. A fresh fracture glistens with tiny scales of biotite. The chiastolite crystals are long and slender, some of them measuring an inch in length and an eighth of an inch in width. Their centers are traversed by a dark line, and the broken ends of the crystal present a square section, the corners of which are nearly black. The crystals also possess more or less cleavage parallel to their longer axis, and the fresh fracture has a semi-vitreous lustre. The crystals are usually tapered at either end.

This comprises all of the rocks which I am satisfied belong to the Iron series. Overlying these, apparently non-conformably, are diorites, uralites, diabases, hypersthene, and granitoid rocks. The diabases are massive and fine to very coarse grained. In some of them the crystals of labradorite are two inches across; in fact, this mineral in nearly all of them is the principal one. A weathered surface of the rock is frequently rough and knotty, with projecting grains of titanic iron ore. The augite is best recognized under the microscope. The diorites are also massive. The coarser varieties are easily distinguished from the diabases by the cleavage planes of the hornblende.

In Sec. 3, T. 44, R. 3 W., are several large ledges of granite and gneissoid granite. Their bedding planes are very much contorted; but the average strike is about southwest. The prevailing color of the granite (spec. 150) is pinkish, due to the orthoclase feldspar. The quartz occurs in dull glassy grains; and black scales of mica are thickly scattered in the matrix. It is usually coarse grained, and often porphyritic, with crystals of feldspar. It is strongly jointed, showing little, if any, signs of bedding.

Under the microscope, in a thin section, may be easily recognized the plain and striated crystals of feldspar, and also the quartz and biotite. The feldspar crystals are somewhat altered, and frequently enclose grains of quartz and, apparently, in a few instances, leaves of biotite. The grains of quartz are rich in fluid inclusions, and their tiny bubbles move about briskly within the cavities. One exceedingly interesting, and probably important fact, is, that some of these inclusions are filled with a strongly saturated solution of salt, out of which has formed a small crystal cube. These inclusions are easily distinguished from the others by the presence of the faintly outlined, colorless crystal of salt, and, besides, a dark bubble having a bright center; whereas, in the other inclusions, the bubble is much lighter, and has a relatively much larger bright space in the center. This, of course, is owing to the fact that the difference of the respective refractive indices of the bubble and of the salt solution is greater than in those containing only bubbles and water.

It seems to me that in those minute crystal cubes, measuring, as they do, scarcely 1-8000 of an inch across, we have an important distinguishing feature between the Laurentian granite and this upper member.

The biotite includes, frequently, small grains of quartz; and, if we assume that the rock has crystallized "in situ," we would have what appears to be the following order of the formation of the mineral constituents: first, the quartz; then, the mica; and lastly, the feldspar.

Respecting the non-conformability of what are unquestionably lower Huronian rocks, and the ones just described, we have in the south half of Sec. 4, east of English lake, a large development of micaceous quartz schists very plainly bedded, with a remarkably regular strike of nearly east and west, while only a few hundred feet to the north are ledges of gneissoid rocks having a strike of N. 30° W. to N. 45° W.; also in the east half of Sec. 14, on the east shore of Bladder lake, we find the diabases in close proximity to the magnetic schists. Whether these latter rocks belong to the Copper series, thereby forming their base, or are an independent outflow, so to speak, I will not attempt to say, having seen too little of them to even warrant the expression of an opinion.

It is certainly an exceedingly interesting problem, and I sincerely trust that whoever endeavors to solve it will consider well all the attainable facts relating to it, and give them that careful study to which they are certainly entitled.

CHAPTER III.

SPECIAL EXAMINATION OF PENOKEE IRON RANGE WEST OF THE GAP.

On the 22d day of August, 1876, Prof. Chamberlin and myself arrived at the Penokee Gap, and met there Prof. R. D. Irving and F. H. Brotherton, Esq., who were doing some geological work immediately about the Gap. The next day Professors Chamberlin and Irving returned to Ashland, en route for the Montreal river, while Mr. Brotherton and myself turned to our field of labor. My instructions from Prof. Chamberlin were to trace the iron-bearing rocks from near the Gap as far westerly or southerly — depending, of course, on where the range should lead us — as a limited time would permit, my work to commence where Prof. Irving had ended his. In compliance with these instructions, Mr. Brotherton and myself made our first camp in the N. E. qr. of Sec. 15, T. 44, R. 3 W., about one hundred paces easterly from the so-called Penokee Iron mine. This location consists of a good frame house and a mine shaft nearly full of water. Out of this shaft has been taken some two or three hundred tons of second class magnetic ore. The ore is really a magnetic schist; that is, a schist banded with layers of magnetite and silicious material. Some of these bands, which are rarely two inches in thickness, are quite rich in iron oxide. It is jointed, and presents a very fine grained texture. It is strongly magnetic, and usually exhibits a decided polarity. The silicious laminæ are mostly of a grayish color, or are often densely impregnated with actinolite and minute particles of magnetite. Scattered through this stock pile are some small pieces of iron ore, which contain considerable manganese. There are no exposures of rock immediately about the mine, but traveling northerly from the shaft a hundred paces, with the dip needle in hand, two or three covered belts of attraction can be made out. These probably correspond to formations VIII and IX. See geological section. As the formation is here covered up, it is impossible to say what lies between these belts, but it is, probably, an argillite, or a magnesian schist.

We will now proceed, according to the plan already suggested, to present in detail the results of this season's (1876) work on the range, giving the dates, the better to preserve the connection.

August 23. We commenced our examinations near the south quarter-post of Sec. 10, T. 44, R. 3 W., and found on the north edge of the ridge some outcrops of magnetic schist, dipping to the north. We proceeded from this point in a northwest direction. The ground for a distance of about four hundred paces[1] is gradually descending, and the timber is a fine quality of hard wood that will yield about fifty cords to the acre. For three hundred paces more, the ground becomes rolling, and the timber consists of hemlocks, birch and sugar maple, that will cut about the same amount, exclusive of the hemlock, but, probably, two-thirds of it is soft wood.

We continue for seven hundred paces, and come into low land timbered with cedar, spruce and hemlock. After passing over this, we pursue our northwest course and ascend a low ridge, having nearly an east and west trend, on the south side of which is the west quarter of the section (10).

About three hundred paces northwest from this quarter-post, are some low ledges of micaceous quartz schist, the bedding planes of which are quite distinct, and, on the weathered surface, they present, often, a pitted appearance, probably occasioned by the dissolving or washing out of small bunches of mica, or of some other perishable mineral. The strike of the bedding varies from N. 75° W. to direct east and west, and the dip is 82° to the north (spec. 126). The rock is of a dark grayish drab color, fine grained, even, semi-crystalline texture, and weathers to a light drab, schistose structure, which is barely perceptible in a hand specimen. A freshly broken surface glistens with tiny scales of black mica and with minute facets of feldspar — also jointed, uneven fracture. A thin section of the rock, placed *under the microscope*, and examined in polarized light, appears composed, chiefly, of small angular grains of silica, brownish leaves of biotite, and a few partially altered crystal fragments of orthoclase feldspar. As accessories may be recognized a small quantity of magnetite, and also some colorless scales of muscovite. We proceed on the same course and cross over the ridge and descend its northerly slope, reaching a point eight hundred and fifty paces northwest from the east quarter-post of Sec. 9, where is another low ledge of micaceous quartz schist (spec. 127), very similar to No. 126, just described. The bedding planes are distinct and have a strike of N. 75° W., and a dip of 82° to the north. No more outcrops were found until we came to the north quarter-post of the section. The timber along the line, so far as could be seen, consists of sugar maple, birch, hemlock and ironwood, and will yield fifty cords to the acre — three-fourths hard wood. Just before

[1] 2,000 paces to the mile.

reaching the north line of the section the ground gradually ascends, and soon forms a low ridge about fifty feet high, on the south side of which are some ledges of micaceous quartz schist (spec. 128), similar to No. 126. The bedding is easily made out, the strike being N. 80° W., and the dip 80° to the north. Thence west along the north line of Sec. 9, we soon leave the ridge and pass over some low, wet ground, timbered with spruce and birch. About six hundred paces from the quarter-post on this line is English lake. A fine view of this lake can be had from its east side. The south shore is low and skirted by evergreens, comprising balsam, hemlock, cedar, spruce, and scattered among them are beautiful slender white birches. On the west and northwest shore, over a mile away, the land becomes higher, and is covered with hard-wood timber; but as we follow around the lake and reach the north side, the timber is more mixed, being about half soft wood; and here is also found a low ledge of greenstone. From the lake we took a south and southwesterly direction, reaching the west quarter-post of Sec. 9, which is situated on a rise of ground surrounded by low lands, covered mostly with hemlock, birch and spruce. Going from this point to the southeast, the country is low, and for a distance of three hundred paces is timbered with hemlock and birch — yield about forty cords to the acre, one-fourth hard wood. From here, for about one thousand steps (one-half mile), the ground is more rolling and is covered with sugar maple, birch and hemlock — yield fifty cords of wood to the acre, one-half hard wood. We continue up the, at first, gentle ascent of the range, and soon reach the south quarter-post of Sec. 9. Here we hastily adjourned to camp, to await the result of a threatened thunder storm. In proceeding to our camp we followed a trail that leads from Penokee Gap to English lake.

Along the lines which we traversed during the day, we took, at each fifty paces, magnetic observations, except the diagonal lines, on which these observations were made at every seventy steps, but we found no attractions worth noting after leaving the "range."

August 25. This morning we went out along the wagon road to the Gap. In the road, eighteen hundred paces north, and three hundred and fifty paces west from the S. E. corner of Sec. 15, we found a ledge of chloritic quartz schist. The strike is nearly east and west, and it dips to the north. The rock (spec. 140) has a dark grayish drab color tinged with green; it is fine grained, and somewhat arenaceous in texture, of a slaty-schistose structure, cleaves readily into plates of unequal thickness, weathers to a light drab, and is very jointed.

Under the microscope, the section of the rock appears to be composed of quartz grains and thin folia and scattered leaves of chlorite. As accessories may be added magnetite, and yellow membranes of limonite. From here we proceeded to a low granite ridge, located about six hundred paces north, and one hundred west, from the S. E. corner of Sec. 15. Thence, turning due north, we commenced taking magnetic observations with the dipping needle and dial compass at every fifty paces. This ridge is about thirty feet in height, and, in traveling north, we passed across a wet piece of ground fifty paces in width; and then, by an easy ascent for four hundred paces, we reached the summit of the range. The first magnetic attraction which was found was at one hundred paces south of the summit, but the attractions increased rapidly, with some variations, to the north line of the section. At this point a large trench has been dug, but it was partially filled up again with dirt, concealing whatever was found. From the numerous pieces lying about, I should judge the bed-rock to be a magnetic schist.

Leaving this point we descended much more rapidly on the northern side of the range, the slope being greater than on the southern side.

The magnetic attraction gradually weakens, but at two hundred paces north of the section line it again revives for a short distance. The variations given by the solar compass were to the east and to the southeast. It will be noticed that the magnetic belt is about four hundred paces wide on this line. Continuing north, the attraction of the dipping compass became zero, while the variations of the solar compass gradually ceased. At three hundred paces from the north line of the section, and on the north side of the range, we came upon flat ground again, and, at three hundred and fifty paces to the north, is a low, narrow ridge, having nearly an east and west trend, on the north side of which is a low ledge of black slate. This is, no doubt, the same bed that appears in the railroad cut some hundred paces northerly from the Penokee station. We continue our course and cross a small stream, the bed of which is thickly strewn with angular boulders of micaceous quartzite (No. 130) similar to No. 126, before described, and a black argillite, which is slaty to flaggy and not as cleavable as a true slate. Still some pieces of very fair slate can be obtained with a little care.

On the edges may be often seen very thin seams and gashes of iron pyrites, and, besides these, there are scattered in the argillite small dark grains or crystals, which, under the microscope, are, apparently, crystal fragments of orthoclase, impregnated, possibly, with graphite. They often appear rounded, but the cleavage marks or lines of the crystal may be recognized, and the optical bisectrix obviously makes quite an angle with these lines. The base of the rock is semi-crystalline, and has a decided laminated structure. We follow up the stream in a westerly direction for one hundred and fifty paces, and find the ledges from which these boulders came. The ledges are located eight hundred and fifty paces north, and two hundred west, from the S. E. cor. of Sec. 10. At this point the ledge crosses the stream, causing it to form a series of small cascades. To the north is quite an abrupt ridge. The strike of the ledge is S. 75° W., and the dip is 30° northerly. It was taken, however, on a ledge outcropping on the side of this ridge, and as it dips into the hill it is possible that the rocks have been crowded over. The strike, however, is reliable, as it was taken on the low worn surface of the ledge in the bottom of the creek.

Returning to where we had left our line of operations, we proceeded north again over a rolling surface for three hundred steps, when the ground begins to ascend very gradually, and at fifteen hundred paces from the south side of Sec. 10, we attain the summit of a high ridge, which has a trend of a little south of west. To the west only a few paces, by following the ridge, we clambered up a ledge some thirty feet high, which proved to be a round bald knob of rock, commanding a fine view of country. To the north can be seen parallel ranges of hills of somewhat less height than the Penokee. The first of these, as will be directly seen, is made up of granite and greenstone rocks. The country to the east, for a distance of eight miles, is easily made out. The seared course of a windfall is plainly visible. Last year we saw this windfall, in passing down the Chippewa river, as far south as in Sec. 23, T. 40, R. 5. In the southeasterly direction, the eye wanders over a steep rolling country. Bad river cannot be seen, but still we can trace it, in its serpentine windings, by the valley it has formed, which shows it to flow in all possible directions, at times running parallel with the ridge, and then suddenly turning at right angles and breaking through at some weak point, it doubles upon its former course, flowing along the base of another ridge, as if seeking some vulnerable place to cut its way beyond; and so it flows onward, repeating again and again the same operation. To the west our view is obstructed by the timber which covers the ridge. The bald knob upon which we are standing is about one hundred feet in height above the general level of the country below us. On the northeast and southeast it is limited by nearly vertical walls of rock; but owing to the large accumulation of debris, the slope at the base is probably not more than 45°. The bedding of the rock on the top of the knob is somewhat contorted and indistinct. On the south side, the ledge has a strike of N. 85° W., and a dip, apparently, to the south; while on the north side, the strike is about the same but the dip is somewhat variable, averaging 50° to the north. The rock (spec. 133) on the south side is a micaceous schist, of a light brownish color, sprinkled with gray. When examined closely with the lens, it appears arenaceous; and brownish scales of mica may be easily recognized. The dark color is, undoubtedly, due to finely disseminated carbon, for in a thin section placed under the microscope may be seen minute particles of this mineral; in other respects, the rock resembles No. 126. On the north side the rock (spec. 132) is a micaceous feldspathic schist, of a dark grayish drab color, and of an even, fine-grained texture, and somewhat jointed. To the unaided eye, it resembles, strongly, the micaceous schist; but with the lens, the difference is plainly visible. *Under the microscope*, a section of the rock appears to be composed, chiefly, of slender crystals of orthoclase, and dark brown leaves of biotite. Occasional grains of magnetite are also found. Thence on our northern course, we cross a stream about two hundred paces from the summit of the ridge; and at three hundred paces more, we come to the north line of the section (10), and go east one hundred paces to the N. E. corner of Sec. 10. A little further, perhaps sixty steps, is a small stream running southerly.

To the north, along the stream for some distance in Sec. 2, are almost continuous ledges of micaceous quartz schist. The bedding planes are quite plain and tolerably regular; their strike varying less than five degrees from N. 82° W., and the dip 45° to the north. The rock (spec. 134) is a light grayish drab, of a fine grained, even, arenaceous texture. It is faintly banded, has a schistose structure, and is sometimes flaggy. On the cleavage planes may be easily seen bright scales of mica. It weathers to a light drab.

Under the microscope, a thin section examined in polarized light, presents a very pretty chromatic field, composed of angular grains of quartz, crystal fragments of plain and striated feldspar, and leaves of brownish biotite; also a little muscovite.

Following up the stream over the ledges of rock, we find their northern limit to be about 250 paces north from the southeast corner of Sec. 3, T. 44, R. 3 W. At this point, the stream crosses the east line of Sec. 3; and at a distance of 500 paces, and for the following 200 paces, the line runs along the banks of the creek. At 600 paces from the S. W. cor. of Sec. 3, however, are the first of some ledges of reddish granite and gneissoid rocks, intersected by veins of hypersthene rock. These ledges are very similar to those found three and one-half miles northeast from this point, along the line of the railroad near Willis' camp. They are very much contorted, and some of the gneissoid rocks resemble the micaceous quartz schist which we had just passed over; but, unlike them, these beds are very much contorted. At one point the strike was S. 70° W., and the dip 50° to the south; a second observation taken at another point a short distance from this, showed the strike to be nearly east and west, and the dip vertical.

To the north and northeast from this place, for several hundred paces, the ground is ascending to the summit of the ridge which we observed from the top of the "bald knob." Occasionally a low ledge of granite may be seen outcropping on the side of the hill, thus indicating the character of the underlying rocks. From the first granite ledges, above noted, we go southeast about four hundred paces and examine some ledges of gneissoid rocks. Their bedding planes are very irregular. The following are the average of several observations: Strike S. 45° W., S. 65° W., and dip 70° to north, to vertical. As this is upon the ground to be examined by Prof. Irving, I will leave it, and return to that part of the range allotted to myself. Starting from the S. E. corner of Sec. 3, T. 44, R. 3 W., we proceeded westward, following the south line of the section, and soon began to climb, diagonally, a steep ridge having a trend of west by south. At a distance of about 500 paces from the starting point, we reach the summit, which is perhaps 150 feet high. Here we find a dark grayish drab micaceous quartz schist. We took the strike with our solar compass, but, ascertaining afterward that a mistake had been made in the time, we rejected the result. The timber consists of birch, hemlock and other fir trees, and will cut about 45 cords to the acre.

Continuing on the ridge, we came to the north quarter-post of Sec. 10, from which point we started southward, and descended for 400 paces, which brought us again upon low land, and, at 150 paces further, we crossed a small stream, upon the opposite side of which we met with a low ridge; and thence across a short stretch of low, wet ground, we came to another low ridge; and, at 1,350 paces, we crossed a second small stream, and soon began the ascent of the range, which rises very gradually. On attaining the summit of the range we proceeded to camp. During the day, at each 50 or 100 paces, we made magnetic observations with the dipping needle and solar-dial compass, but found no attractions after leaving the Penokee range.

August 26. We spent the day in examining the rocks and ledges of the "Gap," and along the line of the railroad, and, also, some ledges on Bad river, in the N. W. ¼ of Sec. 11. Although I had examined these rocks the year previous, I nevertheless wished to revisit them before proceeding further west with our work; but as I have described them in my preliminary report of last year, and also as the same ground will be covered by Prof. Irving in his report, I will only mention one member of the ledge already referred to in the N. W. ¼ of Sec. 11. The rock in question is a chiastolite schist, or, in other words, appears to be a partially decomposed argillaceous mica schist, with crystals of chiastolite strewn irregularly through it (for a full description, see chiastolite schist in preceding chapter, page 254).

August 27. Starting this morning from our camp, we traveled due west along the range for about one-third of a mile, when it bends slightly to the south for a distance of nearly a hundred paces, and then assumes a west-northwest course for two hundred paces further. At this point, three-quarters of a mile from the S. E. corner of Sec. 10, the range begins to descend, and, at two hundred paces more, a small stream is crossed, which has cut its way through the range. Ascending the steep bank on the west side, and following along the section line on the ridge, we come to the S. E. corner of Sec. 9, T. 44, R. 3 W. South from this corner some fifty paces is a ledge of magnetic schist, beyond which, a short distance, is another similar ledge; and, at one hundred paces south, is an outcrop of slaty quartz schist having a strike of S. 85° W., and a dip of 40° to the north. From here the ground descends gently to the south for a distance of two hundred paces, to low swampy land. From the section corner we proceeded north on the east line of Sec. 9, and observed outcrops at points fifty, one hundred, and one hundred and fifty paces, respectively, from the corner. These outcrops consist of magnetic schist; and, for a distance of two hundred paces beyond, we found the magnetic attractions to be quite strong; but they gradually ceased as we continued north. The timber is chiefly sugar maple, birch, hemlock, etc., and will cut forty-five cords of wood to the acre — two-thirds hard wood. As soon as the range is fairly passed, or at about four hundred paces from the above corner, the country becomes flat, and more or less swampy, and the timber consists of cedar, spruce and hemlock. Just before arriving at the east quarter-post of Sec. 9, we cross a couple of small streams less than one hundred paces apart, and running to the eastward. After passing the quarter-post the ground gradually rises, and, in two hundred paces more, we mount the crest of the ridge, some eighty feet above the level of the country just passed over. The ridge has a general direction of east and west, and is probably a part of the high abrupt one already noted on the east line of Sec. 10, one mile east, and three hundred paces north from here. On the south side of this ridge is a low ledge of micaceous quartz schist. It is plainly bedded, faintly banded, and has a strike of S. 85° W., and a dip of 65° to the north. The northern limit of the ridge is reached at four hundred paces from the quarter-post. The land is slightly undulating, and is covered with hemlock, birch, and fir, which would yield fifty cords of wood to the acre — one-fourth hard wood.

When within two hundred and fifty paces of the N. E. corner of Sec. 9, we crossed a small stream running eastward. Proceeding northward from the corner, the land becomes higher and is covered with sugar maple, birch and fir, and will yield fifty cords of wood per acre, one-third hard wood.

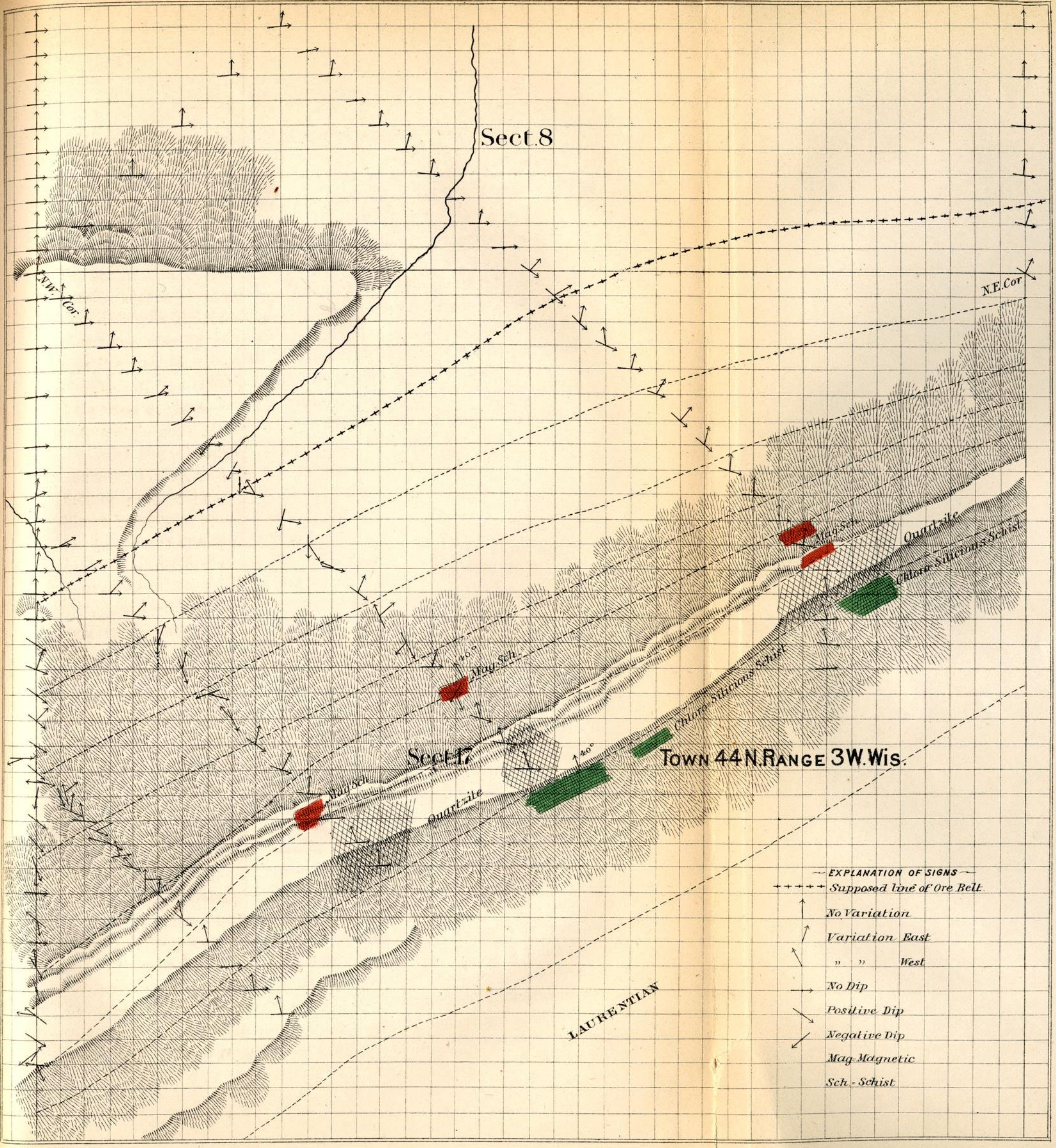
Turning westward, and proceeding for five hundred paces, we cross the east line of Sec. 4, T. 44, R. 3 W., and continuing on this course, we find on the southeast side of the above ridge, an outcrop of massive diorite, which is 530 paces north and 540 west from the corner above mentioned. It affords no signs of bedding, and, to the unaided eye, it appears very similar to some of the fine grained diabases of the Menominee region, south of Quinnesec Falls. The rock (spec. 151) has a dark-green color, and a fine-grained, crystalline texture, is very tough, not easily fractured, and only slightly jointed.

Under the microscope, it is seen to consist of slender, striated crystals of feldspar, and amphibole. The latter occurs in bushy fragments; still, it is easily made out by the position of its optical bisectrix with reference to the axis of the fibers composing the crystal fragments. A few opaque grains and long, narrow fragments resembling magnetite and titanic iron ore (menaccanite), are contained. On the north side of this ridge, but not more than twenty paces from the diorite ledge, is an outcrop of a coarse grained diabase; and a little further west, in Sec. 4, 500 paces north, and 950 west, are some other ledges of diabase (spec. 152). The rocks are of a medium to coarse grained texture and of a dark-greenish gray color. The facets of labradorite are plainly visible and constitute at least nine-tenths of the rock. Scarcely any augite can be seen, but scattered through the mass are some black grains of menacconite, which have a bright metallic lustre. They are only slightly magnetic, but give the titanic reaction with phosporus salt and tin. On a weathered surface these grains form knotty projections. There is also contained a little biotite.

Under the microscope, the beautiful striated crystals of labradorite cannot be mistaken. The other minerals above mentioned are easily recognized, as is also a little chlorite. This rock bears a strong resemblance to the greenstone found associated with granite at Willis' camp on the line of the railroad, and possibly may be considered as hypersthene rock. Going now south, the next ledge of rock found outcropping is on the west end of a ridge, 325 paces north and 1,025 west from the S. E. corner Sec. 4, T. 44, R. 3 W. A fine exposure is here seen, owing to the overturning of a tree, which has uncovered a good space of the ledge. It is a gnessoid rock, or, perhaps, a micaceous quartz schist. The bedding planes are very much contorted. The average strike appears to be N. 35° W., and the dip vertical. The rock (spec. 153) has a dark steel gray color and is fine grained; disseminated through it are small bronzy colored scales of biotite.

Under the microscope, the section resembles a micaceous quartz schist. Considerable orthoclase and oligoclase feldspar are contained, though quartz constitutes at least two-thirds of the rock. Next in abundance is the biotite; and numerous opaque grains of either magnetite or menacconite are present. One fact should be observed here, and that is the similarity of this ledge to the gneissoid rock already noted, located 700 paces north and 50 west, in Sec. 3, especially as regards their relative position to the micaceous quartz schist to the south. I endeavored to detect under the microscope the presence of some salt solution inclusions, hoping thereby to aid in establishing a nearer relationship between this and the upper granite, but failed to discover any. Continuing the same course and passing over a ridge, we came to the south quarter-post of the section, which locality has been described in the foregoing pages. We then proceeded south through the center of Sec. 4, and very soon came to a ridge; and, at 300 paces, crossed a narrow swamp about 100 paces in width; and, at 500 paces from the north line of the section, is the west end of a ridge, the same one we crossed five hundred paces to the east. For the succeeding five hundred paces, to the center of the section, the country is slightly rolling and is timbered with hemlock, birch, and sugar maple, sufficient to yield about fifty cords of wood per acre, one-half hard wood. The following five hundred paces is through a cedar swamp, on the south side of which is the trail to English lake; and, at three hundred paces beyond, begins the long slope of the Penokee range. Here we find the first magnetic attractions which we have detected since leaving the range in the morning. The attraction increases rapidly as we move forward, and in one hundred paces more our compasses indicate a variation of 86° to the east, and a dip of 50°. The south quarter-post is on the north side of the range, about one hundred and fifty paces from its summit. Following on the ridge, easterly, we returned to camp. An occasional ledge of magnetic schist shows itself above the surface along the ridge.

On the morning of the 28th we packed our effects and moved camp to the east line of Sec. 18, T. 44, R. 3 W., five hundred paces in a southerly direction, from its northeast corner, but owing to the difficulty which we experienced in finding the section corner, it was quite late before we reached our new camping ground, and, also, the weather being cloudy, we were unable to make any observations with the solar



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compass. Near our camp was a small stream which has its source in the range.

August 29. We started this morning to the north, making magnetic observations as heretofore. See diagram of Sec. 8, T. 44, R. 3 W., plate XXIII.

The country between our camp and the N. E. corner of Sec. 18 is rolling, and from the corner, north, we descend an easy slope for two hundred paces or upwards. The timber is sugar maple, birch, hemlock and other fir trees, sufficient to yield fifty cords to the acre, two-thirds hard wood. Succeeding this is low ground, which is more or less swampy and covered with hemlock, cedar, etc. We pass around the west side of English lake, and cross a small stream running into the lake. The land continues to be of the same character to the northwest side of the lake, when it becomes much higher and the timber is an excellent quality of hard wood. Near where the section line intersects the lake, is an old clearing; and, at three hundred paces to the northeast, is another clearing with a good log cabin. The shores of this lake were probably once a fine hunting ground, judging from the number of old dead falls and other devices for entrapping wild animals. A low ledge of massive diabase, the first we have seen this morning, occurs one hundred paces north, and fifty paces west, of the N. E. corner of Sec. 6. The rock is coarse grained and resembles that seen north of the south quarter-post of Sec. 4.

Proceeding three hundred paces north from what would be the S. W. corner of Sec. 5, T. 44, R. 3, which corner is in the lake, we turned east and continued on this course to the outlet of English lake, passing over several outcrops of diabase, some of which are large and form ridges of from fifty to one hundred feet in height. The rock is fine to coarse grained. Among the latter varieties, the labradorite crystals are frequently two inches across. It is probable that some of these are diorites and uralites. Near the mouth of the outlet on the west bank, three hundred paces north, and one thousand paces west, from Sec. 5, T. 44, R. 3 W., is a bluff of massive greenstone some sixty feet high; the rock is dark greenish black, and has a medium crystalline texture; the hornblende is deep greenish black and the cleavage facets are easily made out.

Under the microscope, the rock (spec. 157) appears to be composed chiefly of dark green hornblende with a little oligoclase and augite.

Following down this stream for five hundred paces, we pass over some ledges of greenstone, causing in the stream small falls or cascades. From here we skirted along the west bank and ridge, examining the massive outcrops of greenstone which occur in the vicinity, and which are chiefly diabase, though some of the finer grained ones may be diorites and uralites. The timber is of good quality, consisting of sugar maple, birch, hemlock, elm, ironwood and fir, and will yield fifty-five cords of wood per acre — three-fourths hard wood.

The creek crosses the north line of the section at a distance of five hundred and fifty paces from the northeast corner. There are bluffs of diabase here having an apparent strike of N. 20° W., and a dip of 60° to the south. The bedding planes are very obscure and consequently cannot be made out with certainty. Going east on the section line some one hundred and fifty paces, we found a ledge of diabase, and at one hundred paces farther a small creek; beyond this, about fifty paces, occurs another ledge of diabase.

Traveling now for two hundred paces along the north slope of a ridge, gradually ascending, we arrive at the N. E. corner of Sec. 5, T. 44, R. 3 W., and turning thence to the south, we reach, in about one hundred paces, the summit of the ridge, which is about one hundred feet above the general level of the surrounding country; at the foot is a ledge of diorite traversed by granite veins having a northerly direction. The diorite (spec. 160) is of a greenish black color, speckled with gray, and of an even, fine grained texture. It is massive and jointed, but it is difficult to distinguish any of the mineral ingredients. *Under the microscope*, however, the section shows about an even mixture of hornblende and feldspar, the latter consisting of orthoclase and of oligoclase, each in nearly the same proportion.

Following the section line south along the ridge, we come to a ledge of syenite sytuated at seventeen hundred and fifty paces to the north, and two thousand paces west of the S. E. corner of Sec. 4, T. 44, R. 3 W., having a strike of north 45° west, and dipping at a high angle to the north.

The rock (spec. 161) is of a reddish gray color mottled with black, and is of an even, medium-grained texture; many of the feldspar facets are a quarter of an inch in length, while the crystals of hornblende are seldom as large. The orthoclase, quartz, oligoclase and hornblende, are easily made out under the microscope, and are contained in quantity nearly in the order mentioned, the orthoclase being most abundant and the hornblende least so. The orthoclase crystals are quite large and are much more altered than the smaller crystals of oligoclase. The quartz grains are large and angular, and seem to have crystallized *in situ*. Under a magnifying power of eight hundred diameters, there may be observed in the quartz grains numerous fluid inclusions, which are of a saline character and contain a small crystal cube of salt, and frequently two dark bubbles are also seen.

The bubble has only a slow motion when compared to those of pure water or liquid carbonic acid.

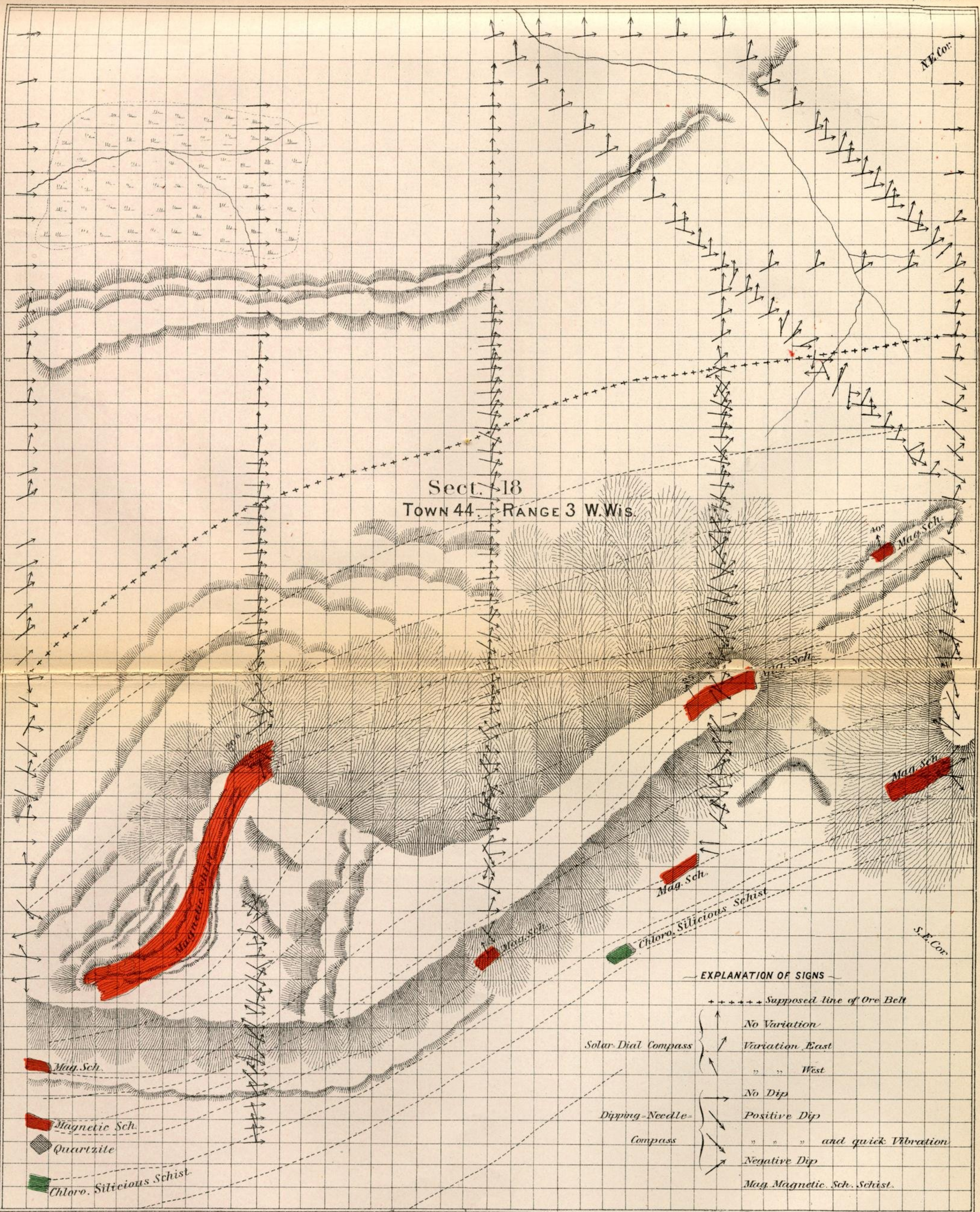
Proceeding again southward, we find another granite ledge, fifteen hundred paces north and nine hundred paces west from the S. E. corner of Sec. 4, T. 44, R. 3 W. This ledge is composed of granite on the east side and of greenstone on the west, the line of junction having a trend of N. 30° W. to N. 45° W., and dips to the southwest. From the strike, it would appear that this ledge and the one which is two hundred and fifty paces to the north, are of the same bed. Advancing two hundred paces, we turn eastward to avoid a swamp, which, apparently, extends in a southwesterly direction to the lake; and, continuing this course for one hundred paces, we find a ledge of diorite outcropping on the west side of a ridge. The rock (spec. 162) has a very dark green color, and a fine grained, crystalline texture; is massive and jointed, and weathers to a medium drab. The mineral ingredients cannot, even with the aid of a strong lens, be satisfactorily made out; but, under the microscope, this uncertainty disappears, since the essential minerals, oligoclase and amphibole, are then easily recognized. The former presents slender striated crystals, which are frequently enclosed by the amphibole; a little magnetite is also contained. From this point we changed our course, and proceeded in a southerly direction, passing over a low, undulating surface, covered principally with birch and fir. At a point four hundred and sixty-five paces north and sixteen hundred paces west from the S. E. corner of Sec. 4, T. 44, R. 3 W., is an outcrop of diorite on the edge of a swamp. The ledge is massive, the rock having a dark green color mingled with gray. The facets of the hornblende are plainly visible, and in the grayish, fine grained base the smaller ones of feldspar may be recognized with the aid of a strong lens; while evenly distributed in the mass are bronze colored scales of mica. Following around the east end of the lake, we passed over some swampy ground to the west quarter-post of Sec. 9, T. 44, R. 3, and from thence to the S. W. corner of the section. After leaving the above west quarter-post, the timber is mostly hemlock, birch and fir, and would yield forty-five cords of wood to the acre, one-fourth hard wood. Before reaching the corner, the magnetic attractions were again observable. (See accompanying diagram of Sec. 8.) Returning to camp, along the south side of Sec. 8, we crossed, at a point three hundred and fifty paces from the quarter-post, a small stream, having its source in the range, and at thirteen hundred and fifty paces we crossed another similar stream.

Some idea may be formed of the character of the drift by examining the beds of these streams. Their banks are often high, and very seldom has the water worn its way to the solid ledge. The beds of the streams are strewn with rounded boulders of granite, or coarse grained diabase, and I did not observe among them any rocks belonging to the lower Huronian. This latter fact, however, is precisely what we should expect, since the Iron-bearing series are simply altered sedimentary rocks, which were tilted up after they were formed, and subsequently the upper anticlinal folds were worn away, in part, no doubt, by glacial action. The glaciers passing over them from the north bore the abraded material to the southward, this, in turn, being replaced by the foreign drift from the north.

August 30. Going south from our camp the ground rises very gradually, and we enter immediately upon fine hard-wood land. The magnetic attractions near the camp give a decided variation to the east, and a negative dip; but the latter soon changes to a positive dip as we proceed south. It will be seen from the accompanying diagram of Sec. 18, Plate XXIV, that these attractions cover a wide belt of country.

Following the east line of Sec. 18, we come to the southern edge of the range, where it is terminated by a steep ledge of magnetic schist, having a strike of S. 60° W., and a dip to the north. This point commands the broadest view I ever chanced upon in the woods, extending to the south for twenty miles, and to the east for a still greater distance. In this direction may be seen a high range running southwesterly, and the old windfall may be traced as far as the eye is able to distinguish it. This bluff, upon which we stand, is about two hundred and fifty feet above the general level of the country adjacent. With one more sweeping glance over the broad plain which we have been contemplating, we turn reluctantly to the westward, and, proceeding for five hundred paces across a valley, we reach another ridge having a trend to the southwest, which we follow, reaching the south quarter-post of Sec. 18, which is on the south side of the range. We passed an occasional ledge of magnetic schist; and a short distance to the east is an outcrop of chloro-quartz schist (VI), similar to those further east. Following now the section line west, we soon pass the ridge and cross another valley, which is about two hundred paces wide, and which is succeeded by another ridge, and in two hundred paces further on we arrive at the S. W. corner of the section, situated on the north side of the range. There are several ledges on this line, but they can be best understood from the diagram of Sec. 18.

From this corner, going north, we took magnetic observations at each fifty paces, which are shown on the accompanying diagram of



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Sec. 18, T. 44, R. 3 W. The range drops off very gradually for some seven hundred paces, and the country becomes rolling. At thirteen hundred paces north from the corner, we pass over quite a ridge, covered with fine hemlock timber. This ridge is probably underlain by micaceous quartz schist, though we saw no outcropping of rocks. This ridge is succeeded by a cedar swamp, where a small stream crosses the line at sixteen hundred and fifty paces from the corner from which we set out. The northwest corner is located on a ridge, which is set off from the line. Turning east, we proceed along the north line of Sec. 18, through land that is low, and often swampy. The high land is timbered with hemlock, birch and fir, and the swamp with cedar and birch. At two hundred paces east from the quarter-post is a small stream, running past our camp. Its banks are quite high, but no ledges could be seen. Proceeding three hundred paces further along the north bank of this stream, we then changed our course, and went southeast to camp, following along the bed or banks of the stream.

August 31. Starting this morning from the N. E. corner of Sec. 18, we went due northeast, to the center of the S. W. $\frac{1}{4}$ of Sec. 8, a distance of seven hundred paces, and thence due southeast the same distance, arriving at the south quarter-post of this section. The north half of Sec. 8 is swampy, but the southerly portion is rolling, the timber consisting of hemlock, sugar maple, birch, ironwood, fir, and cedar; and yielding fifty cords to the acre — one-half hard wood. We continued in a southerly direction, and began immediately the easy ascent of the Penokee range; and, at eight hundred and fifty paces, the summit of the narrow ridge is reached, where, outcropping on the north side of the crest, is a ledge of magnetic schist, and fifty paces to the south is a heavily bedded quartzite. On the south side of the slope, about twenty paces from the top, is a ledge of chloro-quartz schist. These ledges have a strike of S. 68° W., and a dip of 45° to the north. The range descends rapidly to the south into low, wet ground. This is a characteristic topographical feature of the country in the Marquette iron region lying between the lower magnetic schist and the granitic. Usually, in that district, this low belt of ground is underlaid by magnesian limestone (V) and mica schist, which, owing to their perishable nature, are seldom found outcropping. The same, I think, is true here. We travel S. 68° W., and skirt along the southern edge of the range, and observe the chloro-quartz schist (VI) outcropping at several points. Just east of the center of Sec. 17 is a ledge of chloro-quartz schist (V), and overlying it is a gray quartzite (V?) which, because of its unchangeable appearance, and from its occupying geologically the same position along the range, is easily recognized (spec. 164). It is of a light greenish gray color, speckled with a few minute bunches of chlorite, and possesses a semi-vitreous texture. Some portions of the bed are arenaceous, and present the appearance of a highly indurated sandstone. It is jointed and heavily bedded, though the bedding planes are not apparent to the unaided eye in the hand specimens.

Under the microscope, the section presents, in the polarized light, a very pretty field, composed chiefly of almost limpid, brightly colored, angular grains of quartz. The dark green bunches consist of chlorite, with a few fibres of actinolite, which may be readily distinguished by the respective positions of their optical bisextrices to their crystal axes, or simpler still, by using only one nicol and testing their dichroism.

Turning northwest from the center of Sec. 17, we pass over the range. On the ridge is a windfall, and, three hundred paces from the centre, is a ledge of actinolo-magnetic schist, which is twelve hundred paces north, and twelve hundred west from the S. E. corner of Sec. 17, T. 44, R. 3 W., and which has a strike of S. 65° W., and a dip of 40° to the north. As this ledge appears to be quite characteristic of the magnetic schist already noted, we will examine it a little more closely. It (spec. 166) is dark bluish gray, aphanitic in texture, and has a banded, slaty structure, cleaving readily into small plates of variable thickness. The actinolite cannot be recognized in the hand specimen, even with the aid of a strong lens, but under the microscope, the base of the rock appears to consist entirely of minute fibres of actinolite and quartz, evenly distributed, but having no common direction. An occasional radiated bunch of anthophyllite may be seen, and in the reticulated mass are scattered the grains of magnetite. On the same course, we descend the range through fine hard wood country, which, just before reaching the centre of the N. E. ¼ of Sec. 17, suddenly changes to hemlock, birch, maple and fir, and will cut fifty cords per acre—one-fourth hard wood. This change in the quality of the timber is very noticeable all along the range. Crossing a small stream at about two hundred paces further on, we ascended a broad, low ridge. Reaching the N. W. corner of Sec. 17, we returned to camp, and thence went due southeast. The ground suddenly rises as we approach the range in this direction; and on the summit we find two outcrops of magnetic schist, having a strike of S. 60° W., and a dip of 40° to the north. On the south slope of the range is a ledge of chloro-quartz schist, which is eight hundred feet north, and thirteen hundred feet west from the S. E. corner of Sec. 17, T. 44, R. 3 W.

Proceeding now southwesterly to the center of the southwest quarter of the section, we turn northwest and descend the range on its northern slope to the west quarter-post of the section. Here is a windfall about one hundred paces wide, having an easterly and westerly direction. We continue the same course, and descend a gradual slope for three or four hundred paces, when the land becomes rolling, but, at ten hundred paces from the quarter-post, it drops off into low ground. This slope has a trend of east-northeast. From the north quarter-post of Sec. 18, we went south, and, at five hundred paces, ascended the opposite slope. Just south of the center begins the north slope of the Penokee range, though its summit is not reached until passing one hundred and fifty paces further, beyond the south quarter-post of the section. At this point is an outcrop of magnetic schist.

Following the south line of the section for three hundred paces east, we come to a low ledge of chloro-quartz schist (VI), and traveling along the south side of the range for two hundred paces more, we turned north and passed over the crest of the range, at a distance of six hundred paces. Near here are several ledges of magnetic schist, which dip 25° to the northwest. Continuing north down the gentle slope of the range, we came to the center of the N. E. ¼ of Sec. 18, and then turned east; and, at three hundred paces, crossed the small stream that flows past our camp.

September 3. We started this morning with our camp equipage and proceeded to the east quarter-post of Sec. 18, and thence in a southwesterly direction about two hundred paces, we reached some low ledges of magnetic schist, having a strike of S. 50° W., and a dip of 40° to the north. Continuing on the range, and following the south line of Sec. 18 for a distance of eighty rods from the quarter-post, we laid down our packs and went north. It will be seen by examining the diagram that the variation is to the west, and that the dip is negative until reaching a point three hundred paces north of the south line of the section, when the variation changes to the east and the dip becomes strongly positive, showing that the line passes over a strongly magnetic belt. At six hundred paces north, the variation was wholly west, owing to the influence of a high ledge of magnetic schist, which has an extent of nearly a quarter of a mile. (See plate XXIV.) This ledge terminates very abruptly on its east and southeast side, and is from ten to thirty feet high. Its strike is about as appears on plate XXIV, and the dip of its bedding planes, on the southwest portion of the ledge, is 45° to the northwest; but it gradually becomes less, and is only 20° at the northeast end of the ledge. This flattening out in the dip of the strata, necessarily makes the formation appear much broader on the surface, and the range being very regular on its southern edge, causes the overlying strata to make a sharp bend to the north, as is represented on plate XXIV.

Descending the north slope of the range, which is quite sharp, we proceeded north, and found that the magnetic attractions continued until we had passed the center line of the section, when they nearly ceased.

At fourteen hundred paces north from the south line of the section, is the low ridge already noted further east, and, continuing, we soon reached a cedar swamp, which extends beyond the north line of the section. Returning now to the range, we went westward again along the south line of Sec. 18 to the southwest corner of the section, and, continuing this westerly course, we proceeded along the south line of Sec. 13, T. 44, R. 4 W., on the north slope of the range, which turns a little to the northwest; and, at three hundred paces from the corner, the section line crosses the ridge, but at this point the range suddenly terminates, and we descend, in the next two hundred paces, a hundred feet. (See plate XXV.) At four hundred paces further is a low ridge, formed of magnetic schist. Passing this, and also another similar one at one hundred paces still beyond, we cross a narrow valley and begin the ascent of the opposite side, and at one hundred and fifty paces west of the quarter-post we descend, diagonally, a steep side hill, having a northwesterly trend, which is about one hundred and forty feet above the general level of the country. At five hundred paces west from the quarter-post, we camped on the edge of a cedar and tamarac swamp. On plate XXV is noted an outcrop of magnetic schist, located two hundred paces west from the S. E. cor. of Sec. 13, having a strike of N. 80° W., and a dip of 65° northerly. Four hundred and fifty paces west from the above corner is another ledge of magnetic schist, with a strike of N. 65° W., and a dip of 85° northerly; but only fifty paces further west from this point the strike is N. 30° E., and the dip 20° northwesterly. Five hundred and fifty and six hundred paces, respectively, are other ledges of magnetic schist having a similar strike and dip, but at seven hundred and fifty paces the strike on an extensive ledge of magnetic schist is N. 20° E., and the dip is 20° northwesterly. At about fifty paces west from the south quarter-post of Sec. 13 is a large outcrop of magnetic schist having a strike of N. 20° W., and a southerly dip of 45°. We should naturally expect this dip to be northeasterly. The singularity of the structure became understood, however, when we found in the N. E. qr. of Sec. 24, T. 44, R. 4 W. (see plate XXV), a continuous ledge of

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magnetic schist having a strike of N. 47° W., and at its northwest extremity the dip was 55° southwesterly, and at seventy paces southeasterly therefrom the dip is 70°. At one hundred and ten steps the bedding planes become vertical; at fifty steps further the dip is 70° northeasterly, and at seventy steps more we have a dip of 60° northeasterly. The bedding planes are not contorted and the formation is very regular. It is plainly evident the rocks at the northwest end of this ledge are turned over, that is, the hanging wall has become the foot wall. Two hundred and fifty paces from this ledge are outcrops of magnetic schist, of which the strikes of the bedding planes are from N. 20° E., on the east side of this sharp horseshoe-like bend, to N. 55° W. on the west side, and the dip, as in the former case, 20° northerly, and in the latter 80° northeasterly.

This bend, in the formation, can be nicely observed on these ledges, which are from ten to twenty feet high. South of these are some low outcrops with contorted bedding planes, and at thirteen hundred and fifty steps west of the S. E. cor. of Sec. 23, is a loose ledge of angular boulders of mixed magnetic iron ore, of a medium granular variety. The ledge from which these come cannot be far distant.

At twelve hundred and fifty paces, and at one thousand paces west from Sec. 23, is a ledge of magnesian limestone (spec. 176). The ledge outcrops for a distance of nearly three hundred feet and has a trend southeast. Its northeast face is rough and knotty, with radiated bunches of a very pale-greenish mineral. The ledge is composed of two distinct varieties of dolomitic limestone, the one bluish-gray and having a very fine grain, and, coursing through it, narrow, pale, greenish-white veins and bunches of tremolite. *Under the microscope*, it presents an even granular structure, the granules being small, averaging about .08 of an inch across. No striated ones of calcite are visible, but an occasional slender blade of tremolite may be seen. The other variety of this bed is a tremolitic dolomite, and has a grayish-white color, with a shade of pea-green. Its structure is coarsely radiated from the large bunches of tremolite, some of which are two inches or more in size. Coursing the specimens are pale-greenish seams of tremolite. *Under the microscope*, the base appears to be composed of granules of dolomite and of small angular grains of quartz. The tremolite is easily recognized; an interesting feature of it is that part of it belongs to the amphibole variety, and about an equal share to the pyroxene group, as may be easily seen by the respective positions of the optical bisectrixes and crystal axis.

Going south from the N. E. cor. of Sec. 23, we pass over the crest of the range at one hundred paces and then descend to a deep, narrow ravine. At two hundred and fifty steps from the corner is a ledge of magnetic schist on the side of the hill having a strike of N. 75° W., and a dip of 35° northerly. At fifty paces further we cross a small stream and then ascend a broad ridge, and find at three hundred and fifty paces from the corner a ledge of magnetic schist which is fifty paces wide. This is succeeded by a massive ledge of quartzite (V), similar to spec. 161, and at five paces south from the corner are several low ledges of chloro-quartz schist (VI), which aggregate a thickness of 60 paces. Their strike averages N. 75° W., and they have a dip of 60° northeastly. The ground immediately to the south is low and timbered with hemlock, birch and other soft woods.

September 4. We went north from a point five hundred paces west from the S. E. corner of Sec. 13 (see plate XXV), and, at two hundred and fifty paces distant, found ledges of magnetic schist; the ground descends to the north, and the formation makes a turn; the magnetic attraction continuing for six hundred paces further. At five hundred paces from the south line of the section is a small stream, and at nine hundred paces is another stream. A short distance to the east is a log cabin, surrounded by a small clearing. The country is rolling, the timber mixed, and comprises sugar maple, birch, hemlock, cedar, spruce and balsam, sufficient to yield forty-five cords to the acre, two-thirds hard wood. Continuing our course, we came to a small lake, located in the N. E. qr. of Sec. 13, about one-fourth of a mile wide north and south, and one-third of a mile east and west.

Turning west from the south side of this lake we enter a cedar swamp, and at fifteen hundred paces north and one thousand paces west from the S. E. corner of Sec. 13, we turn north again and pass out of the swamp three hundred paces from this point. At a short distance to the east is a ledge of diabase similar to those on the north side of English lake; and, at a few steps further, we cross a small stream. Along the north line of the section are large exposures of greenstone. After examining several of them, we proceeded to the east end of Bladder lake; and then went southwesterly to where the west line of Sec. 13 intersects the lake.

It will be noticed on plate XXV, that the magnetic attractions begin almost as soon as we leave the lake shore, and that they directly become very strong, causing the north end of the needle to point nearly due south. The source of this great deflection we found to be a ledge of magnetic rocks outcropping on the north edge of a broad ridge that is about fifty feet high. The magnetism of these rocks, as will be seen from plate XXV, is very decided.

There are no exposures on the top of the ridge, but from the attraction, the belts appear to be altogether about three hundred steps wide. The rock (spec. 174) is a magnetic augite, of a brownish black color, medium grain, and semi-vitreous texture. At first glance it resembles a magnetic ore. It is massive and tough to break. Coursing through the bed are very vitreous veins of quartz. The streak power is gray, and the specific gravity is 3.90.

Under the microscope, the section of the rock appears, in polarized light, to be an aggregation of more or less rounded, or partially formed crystals of augite and hornblende; also grains of magnetite. This section affords an excellent opportunity of comparing dichroism of the augite and the hornblende; the former showing it very slightly, while in the latter it is very marked; and to confirm the value of these dichroitic differences we have only to note the position of the optical bisectrix in each. The dichroitic test (first suggested by Zirkel) is often very convenient in cases of this kind, in distinguishing quickly between these minerals, where the biotite is present. This locality is a very favorable one for exploring. The timber in the immediate vicinity is of a fair quality of hard wood, and will yield about fifty cords to the acre, two-thirds hard wood. Continuing south on the west line of Sec. 13, the variation of the magnetic needle very quickly, though gradually, ceases. The section line south from the quarter-post is not blazed, neither is the southwest corner of the section marked, nor the south line of the section, from the quarter-post to this point.

Traveling north from the south quarter-post of the section, we gradually ascend for five hundred paces, when the country becomes rolling and the timber is about the same as it was eighty rods east from this line. At twelve hundred paces we enter the swamp already noted, and at one hundred paces further we turn to the west.

The variation of the solar compass on this line is to the west, and increases as we continue south, showing that the magnetic belt is to the west.

Returning to camp on a line eighty rods west of the quarter line, we cross over the range near the center of the southwest quarter of the section, and then proceed diagonally down the long slope of the side hill.

September 6. We went with our camp equipment N.-N. W. to the west quarter-post of Sec. 13, and then proceeded due west six hundred paces to Bladder lake, and there prepared a raft. A variation of 25° to the east was observed, and along the northwest shore of the lake may be seen ledges of rock, which, at the time, we supposed were, possibly, those of the Iron-bearing series, but which subsequently proved to be diabase. Coasting along the southeast shore we encountered a variable dip, with the dipping needle, of 20° to 50° for a distance of eighty rods. These attractions, however, very soon became zero.

We camped on the west shore near the center of the N. W. qr. of N. W. qr. of Sec. 14. It is evident that this lake was not meandered by the government surveyors, for the shores are very dissimilar in reality from what they appear on the U. S. plats. This proved to be an unfortunate camp, for we had a week of rainy weather, though that should be charged to the elements and not to the location. Bladder lake abounds in bass, and along the shores are well beaten bear trails. We paddled our raft around on the north side of the lake, but found no magnetic attractions. The diabase ledges are of a coarse grained variety. We proceeded on the raft a mile or more up the inlet of the lake, but could not detect any variation with our magnetic needles. Starting from the west quarter-post of Sec. 14, and going south, we found no magnetic attraction, but to the west are several ledges of diabase. Five hundred paces to the south is a cedar swamp, which is three hundred paces wide and extends to the east for a quarter of a mile. A short distance north of the S. W. corner of Sec. 14 is a low ledge of diabase.

September 12. This morning, as the sun once more deigned to shine upon us, we concluded to return to the west quarter-post of Sec. 13, where we left the magnetic belt, and endeavor to trace it from there. We found that it turns to the southwest, or that the greenstone covered it to a considerable depth. This latter supposition, however, appeared hardly consistent, as we could find no magnetic attraction along the north shore of the lake, or up the inlet.

In going to the quarter-post, we traveled on the south side of the lake, making our observations, but found no attractions until reaching a point nearly west from the quarter-post. Going first two hundred and fifty paces west and fifty paces south, from the east quarter-post of Sec. 14, to a ledge of magnetic rock, similar to that north of the quarter-post, we turned southwest. At one hundred and forty paces, the dipping needle showed a strong dip of 60°. Just here is a small stream, which empties into Bladder lake. Seventy paces further the dip is 30°, and the variation 6° west. At one hundred and forty paces more, the dip is the same, but the variation is 20° east. At the succeeding station, the dip is the same, and the variation 10° east; but at the next station the dip is 20°, and the variation only 2 east. Turning now south, the dip at one hundred paces becomes zero and the variation 6° west, showing that the magnetic belt is to the west. Going another one hundred paces south, the dip remains zero and the variation is very slightly to the east. Changing our course to southwest, we proceeded to the south quarter-post of Sec. 14; the attraction remained the same. The timber on the S. W. qr. of Sec. 14 is mixed, consisting of hemlock, birch, cedar, spruce and balsam, and will yield about forty-five cords to the acre, one-half hard wood. There is also considerable white pine of good size and quality.

Continuing our course in a southwest direction across the N. W. qr. of Sec. 23, to the west quarter-post of the section, and making observations at every one hundred and forty paces, we found no attraction until arriving at the west quarter-post, the variation there being 7° west. The land is slightly rolling, and, at about one hundred paces north of the quarter-post, there is a small stream running north. Continuing a southwest course through the S. E. qr. of Sec. 22, the magnetic declination varies from 4° W. to 8° W., and along the center line of the southeast quarter of the section, there is a magnetic dip of 10°. The timber consists of hemlock, balsam, birch, etc., and will cut forty cords per acre, one-half hard wood, with some white pine of good quality. Turning west and going along near the south line of the section, we proceeded to the S. W. corner of Sec. 22. The solar compass gave a variation of from 7° to 12° west, and a positive dip was observed of 50°. At fifty paces west of the corner, we crossed the inlet of Bladder lake, and at fifty paces further, we found a variation of 16° west and a positive dip of 15°. The variation to the west gradually diminished to 2° on reaching the southwest quarter-post of Sec. 21. The dip, however, remains the same until near the quarter-post, when it decreases to 10°. The land is low and somewhat swampy, the timber consisting chiefly of cedar, tamarac, etc. The quarter-post is on the west bank of a small stream running southeast. Upon turning north the variation changes to 2° east, after going two hundred paces; but at three hundred paces from the quarter-post it becomes zero and the dip is only 5°. Proceeding five hundred paces north, we enter an open spruce swamp, which is about four hundred paces across. The magnetic attractions cease and do not again occur for at least one mile north from the center of Sec. 21. The ground to the north quarter-post of this section is slightly undulating, and the timber comprises hemlock, birch, maple, etc., sufficient to yield about forty cords per acre, one-half hard wood.

Passing to the north, in Sec. 16, we cross a stream at a distance of five hundred paces, from the south quarter-post of this section, which flows to the southeast. The country is gently rolling and the timber is birch, sugar maple, hemlock and spruce, and will yield forty-five cords per acre, two-thirds hard wood.

Going east from the center of Sec. 16, we crossed the section line and proceeded to the east quarter of Sec. 15. There are no magnetic attractions along this line nor outcrops of rock. The land is rolling, and the timber a mixture of hard and soft woods.

September 13. This morning we broke camp and proceeded southwestward to the south quarter-post of Sec. 15, finding no magnetic attraction. The timber, as before stated, is mixed, about one-half soft wood, and will yield fifty cords per acre. Going thence west for a distance of two miles and a half, we pitched our tent on the north and south line of Sec. 17, at a distance of five hundred paces north from the southwest corner of the section. We found no attractions on the route traversed. The land is low and slightly undulating, and the timber is a mixture of the kinds previously mentioned. Along the south line of Sec. 15, it will cut forty cords per acre, one-third hard wood. In Sec. 16 the quality is somewhat better, but on the south line of Sec. 17, it will average only one-sixth hard wood. Having found no attractions on this route, we concluded that the Iron Range must be to the south. Proceeding, therefore, to the S. W. corner of Sec. 17, which is in a tamarac swamp, we went S. 26° E. to the south quarter-post of Sec. 20. The tamarac swamp extends only a short distance, and four hundred paces from the above corner, we enter an extensive open spruce swamp. As the quarter-post is approached, the magnetic attraction begins to exert a feeble influence on the needle, the dip becoming 5° positive and the variation 3" to the east. Changing our course, we traveled east, finding the attraction increasing and becoming 4° west, and the dip 15° positive, at the S. E. corner of Sec. 20. The swamp continues for four hundred paces east of the corner. The variation increases until at five hundred paces east of the corner it is 90° west, but the dip is only 5°. For the next five hundred paces the country is rolling and the timber mixed. The westerly variation decreases somewhat, but the 5° positive dip remains constant. It is evident from the above, that there is a broad magnetic belt underlying this section, and its course is a little to the south of west. Turning now southwest from the south quarter-post of Sec. 21, we passed diagonally through the N. W. qr. of Sec. 28 to the east quarter-post of Sec. 29. The land is rolling, the timber consisting of good pine and other varieties. The magnetic attractions grow less and, at the quarter-post, disappear. Proceeding now due west through the center of Sec. 29, the magnetic attractions do not manifest themselves until within four hundred paces of the west quarter-post of the section, where the solar compass gives a variation of 4° west, and the dipping needle a positive dip of 8°.

Changing our course to a northwest one, we enter again the open spruce swamp. At a point near the center of the N. W. ¼ of Sec. 30, the variation is 9° east and the dip 5° positive. We leave the swamp at about one hundred paces northwest from where we entered, and find the country thence to the north quarter-post, and along the line to the northwest corner of this section, to be rolling, and the timber capable of yielding about forty cords to the acre, one-fourth hard wood.

The magnetic variation is small, and to the east, until within four hundred paces of the corner, when it becomes westerly. At one hundred paces north from this corner, and on the town line, is a ledge of syenitic granite. This is an important outcrop, as it verifies the correctness of our magnetic work, and shows how indispensable are the solar compass and dipping needle in tracing faint lines of attraction, indicating the trend of the formation, covered deeply by drift. They are to the geologist, in instances of this kind, what the mariner's compass is to the sailor. The granitic ledge is very much decomposed; so much so, that it was impossible to procure an unaltered specimen. Still the quartz and feldspar could be readily distinguished. Going now northwest, we cross into a cedar swamp, at about one hundred and fifty paces from the corner, and leave it near the S. E. ¼ of Sec. 24. Continuing in the same direction, we skirt along the side of quite a high range, but before reaching the center of Sec. 24, we mount to the top of it. The attractions are variable, but are more decided than they were for some distance back. At the center of the section, the variation is 16° to the west, and the dip is 20°. The timber, since leaving the swamp, consists of hemlock, birch, sugar maple, elm, basswood and balsam (fir), and will cut fifty cords per acre, two-thirds hard wood. To the west of the center of the section, the range drops off into low ground. Proceeding now northeast on the broad table land on the crest of the range, the westerly variation becomes less, and the positive dip of the needle changes to a negative one, in some instances being 15° negative. The timber, along the range, is a fine quality of hard wood, and will cut fifty-five cords per acre. Near the center of the N. E. ¼ of Sec. 24, we descended upon low, rolling land, timbered with hemlock, birch, cedar, etc. Turning east from the N. E. corner of Sec. 24, we went along the north line of Sec. 19. The magnetic attraction crossed the line; and at three hundred paces easterly from the corner, is a large outcrop of diabase, similar to those on the north shore of Bladder lake; and farther east and south of the line are other ledges of diabase. The timber along this line is mixed, consisting of hemlock, birch, sugar maple, spruce and cedar, and will cut forty cords per acre, one-fourth hard wood.

September 15. We broke camp and went west to the N. W. corner of Sec. 19, and, continuing west along the north line of Sec. 24, we cross a small stream, at three hundred and fifty paces, running northwest. This same stream crosses the line again at five hundred paces, and runs thence into a small lake (see map). We skirted along the north line of the lake for nearly a mile, and went thence to the N. W. corner of Sec. 24, and continued west along the north line of Sec. 23 for a distance of thirteen hundred paces. We camped on the margin of a small creek near where it empties into Marengo river. At this point there are some falls on the river which aggregate about sixty feet total descent. The river flows from the southeast and plunges down a narrow granite gorge, and immediately below the falls the water has worn out a wide basin, which abounds in fine speckled trout. The pool is limited on the south and east sides by nearly vertical walls of granite more than fifty feet in height. To the west (see plate XXVI) is the narrow valley of the river, hemmed in by ledges of reddish granite and massive greenstone. To the northwest, not far away, are high bluffs of greenstone, and to the north is a deep valley down which flows the pure spring waters of the brook already mentioned, making altogether a very interesting and pleasant camping ground. Following up the small brook to the north line of Sec. 25, we turned east and ascended the steep sides of the valley. The north quarter-post of this section is near the summit of the hill. Attractions are strong, owing to low ledges of magnetic ore outcropping a few paces to the east.

Turning south, we passed over the summit of the range, which is about one hundred and fifty feet high, and made magnetic observations every fifty paces (see plate XXVI).

Five hundred paces to the south of the quarter-post is a ledge of granite (spec. 179), having a pale reddish color and medium grained texture, resembling some marbles. It is massive, showing only faint lines of bedding. *Under the microscope*, there may be seen in the section, the quartz, feldspar, and a little chlorite; the quartz grains are angular and contain numerous fluid inclusions; the feldspar consists of the plain and striated varieties; the former, however, is in excess of the latter, and each is much altered and presents a *bronzy* appearance. The chlorite is not easily recognized. To the south, the range drops off into low ground. Proceeding eastward, we saw, at two hundred paces, a low outcrop of chloro-silicious schist, similar to No. 141. It has a strike of N. 80° W., and a dip of 60° northerly. At three hundred paces more are several ledges of actinilo-magnetic schist, the first having a strike of N. 70° W., and a northerly dip of 60°; but at one hundred paces further east the dip is 30°.

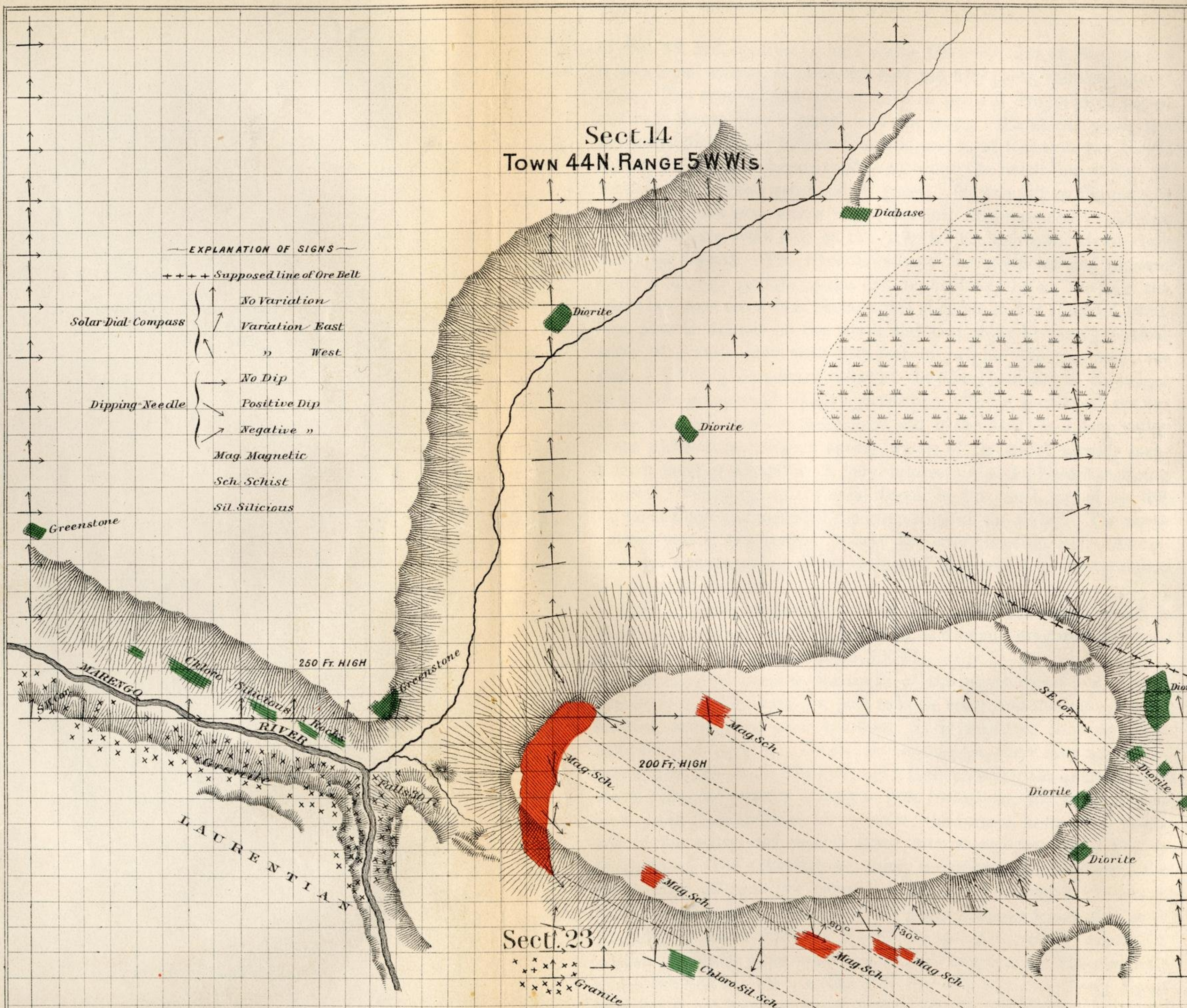

Sect. 14
Town 44 N. Range 5 W. Wis.
Explanation of Signs
+ + + + Supposed line of Ore Belt
Solar-Dial-Compass
No Variation
Variation East
" West
Dipping-Needle
No Dip
Positive Dip
Negative "
Mag. Magnetic
Sch. Schist
Sil. Silicious
Diabase
Diorite
Diorite
Greenstone
Greenstone
Chloro-Silicious Rocks
250 Ft. High
Marengo River
Sil. Con.
Granite
Laurentian
Falls 30 Ft.
Mag. Sch.
Mag. Sch.
200 Ft. High
S.E. Cor.
Diorite
Diorite
Diorite
Diorite
Mag. Sch.
80°
30°
Mag. Sch.
Mag. Sch.
Chloro. Sil. Sch.
Sect. 23
Granite

PLATE XXVI

The magnetic schists are very similar to those near the Penokee Gap; only these contain more anthopyllite, and perhaps might more properly be named anthophyllo-magnetic schist. It is not easy to distinguish between these minerals when they are intimately mixed; then, too, the dichroitic test cannot always be strictly relied upon, since the lighter colored actinolite shows but very little dichroism. Continuing east, we pass over several outcrops of magnetic schist, and at a point four hundred paces south of the northeast corner of the section (23), we turned north. At two hundred and fifty paces south of this corner, is a ledge of diorite. The rock is a very dark green, speckled with light gray, is very tough, and has an indistinct coarsely-crystalline texture, some of the crystals of amphibole being nearly an inch across. Still it is difficult to distinguish their cleavage planes. *Under the microscope,* the cause is readily determined, for at first glance the amphibole has the appearance of being broken and the fragments separated, but this is hardly possible, since the optical bisectrices of all these fragments belong to the same crystal, *and are exactly parallel,* as may be shown by crossing the *nicols,* and revolving the slide. A careful examination, however, shows that the amphibole originally enclosed numerous slender crystals of feldspar, which are now more or less completely granulated, from decomposition. Besides these may be seen several small crystals of amphibole mingled with the larger ones. There are also many netted forms of magnetite scattered in the section. Proceeding north to the corner, we pass over other similar ledges of greenstone. The magnetic attractions are very strong here, the variation indicated by the solar compass being 60°, with a very quick vibration (see plate XXVI).

Continuing north from the corner, we ascend a low rise of ground, but at one hundred and fifty paces it begins to descend. At a hundred paces more, we cross an open bog swamp about one hundred paces wide, and, at five hundred paces north of the corner, is the south edge of an open spruce swamp; after passing which, we turn west from the east quarter-post of Sec. 14, and skirt along the north edge of the swamp, and found at five hundred paces on this line, the small brook, which runs past our camp, and on either side of which are ledges of massive greenstone. Going west from the center of Sec. 14, we ascend about one hundred feet to the high table lands, and turning south we began to descend almost immediately, and, at three hundred paces, crossed the small brook again, and thence went diagonally across and down the valley. Descending the southeast slope of the valley we return to the south quarter-post of Sec. 16, proceeding thence westward down the Marengo river to the S. W. corner of Sec. 14. On the south side of this valley are steep ledges and bluffs of reddish granite and syenite, and on the north side is a high hill on which are outcropping ledges of greenstone. The variation of the solar compass on the granite is to the east, while on the north side of the river it is to the west.

The S. W. corner of the Sec. (14) is about one hundred and fifty paces south of the river.

Upon turning north from the corner, we go down, for one hundred and thirty paces, a steep bank to the river, and then ascend the opposite bank, or side hill, to the table lands above.

At three hundred and fifty to four hundred and fifty paces from the corner, are low outcrops of greenstone, where the variation of the solar compass was about 7° west.

Thinking that the Iron range might possibly have taken a bend to the north, we continued northerly for two and half miles, but the westerly variation still remained. In Sec. 11, at five hundred paces from its southwest corner, is a low ledge of reddish granite, and at one thousand paces north of here, is another similar granite ledge.

In Sec. 3, at five hundred paces north, and nineteen hundred paces west of its southeast corner, is a large outcrop of *diorite*, having a greenish black color, and a very coarse grained, crystalline texture.

The hornblende crystals are very large, and frequently have a smooth, jet black surface. The hornblende has only an imperfect cleavage, owing to the fact of its having a finely fibrous internal structure, as may be seen, *under the microscope*. The fibres are not strictly parallel, but are very slightly inclined to each other; the plain and striated feldspar are more abundant than appears to the unaided eye. The latter variety is in excess of the former, and a little titanic iron ore is contained. The land is high and rolling, and the timber fine hard wood, which, through Secs. 14 and 11, will average fifty cords to the acre, and in Sec. 2 sixty cords, two-thirds hard wood.

Turning east, and then south, to the south line of Sec. 2, we proceeded east. Sixteen hundred paces east of the S. W. corner of Sec. 2, is a ledge of diabase. It is of a dark green color, sprinkled with gray, and has a medium grained, crystalline texture. *Under the microscope*, it appears to be about an equal mixture of pyroxene and of *triclinic* feldspar. As accessories, may be reckoned hornblende and possibly a little hypersthene. The trend of this ledge, and of the ridge which it forms, is S. 45° W. At about two hundred paces further east, there is a ledge of reddish granite. The solar compass persistently maintains its westerly variation. At the south quarter-post of Sec. 2 it is 15°, but the dipping needle gives no indication of any magnetic attraction. The timber along, and near, the south line of the section, is mixed, and will cut sixty cords per acre, two-thirds hard wood. Near the N. E. corner of Sec. 2 is a low ledge of granite, and, going south, we find, at fourteen hundred paces from the N. E. corner of Sec. 11, a ledge of greenstone. The timber along the east line of Sec. 11 is of a mixed character, and will cut fifty cords to the acre, one-half hard wood. Changing our course, we went S. 26° W., from the above corner, to the south quarter-post of Sec. 14. On this route, and in the N. E. qr. of Sec. 14, are several ledges of greenstone. From the south quarter-post of this section, the magnetic attractions proved to be quite strong. Going east from this corner, on reaching a distance of four hundred paces, a large ledge of diorite, similar to those just southwest of this point, is found. This ledge extends nearly a hundred paces to the north; and to the south are three or four smaller ledges of diorite. It will be noticed on plate XXVI, that the dipping needle shows scarcely any dip on this line for five hundred paces to the south of the north line of Section 24. Neither are the attractions much stronger, as indicated by the dipping needle, when we turn west, for a distance of two hundred paces or more. From this, it would appear that the iron ore deposit of this locality is large and lenticular shaped. Following around southwesterly from the north quarter-post of Sec. 23, we find a steep bluff of lean magnetic ore facing the valley, and extending for a distance of three hundred paces. The rock in some portions of the ledge has a fine steely texture, and would assay 65 per cent. of metallic iron.

I regret that we could not spend more time in this locality, but having been already detained here by rainy weather, and as my purpose was to trace the range as far westward as possible, I hardly felt justified in doing as much detail work as a complete examination would involve.

September 18. We started west this morning with our camp equipage. The Marengo river bears away to the northwesterly from the S. W. corner of Sec. 14. At four hundred paces west of this corner, we cross a small stream running northerly, and then enter a cedar and tamarac swamp, some two hundred paces wide. On the west side of the swamp, at a distance of seven hundred paces west from the corner, and just to the north of the section line, is a ledge of tremolitic limestone (No. 190) similar to 174 from Sec. 24, T. 44, R. 4 W. As we continue, the country becomes more rolling, and at three hundred paces west from the south quarter-post of Sec. 15, we find a low ledge on the crest of a ridge, which extends northeasterly. The ledge consists of a grayish white marble, with the faintest tinge of green, and has an even, fine-grained (saccharoidal) texture. To the touch, it feels rough, and, scattered through it, are numerous glistening facets. The rock is a coarse variety of No. 190.

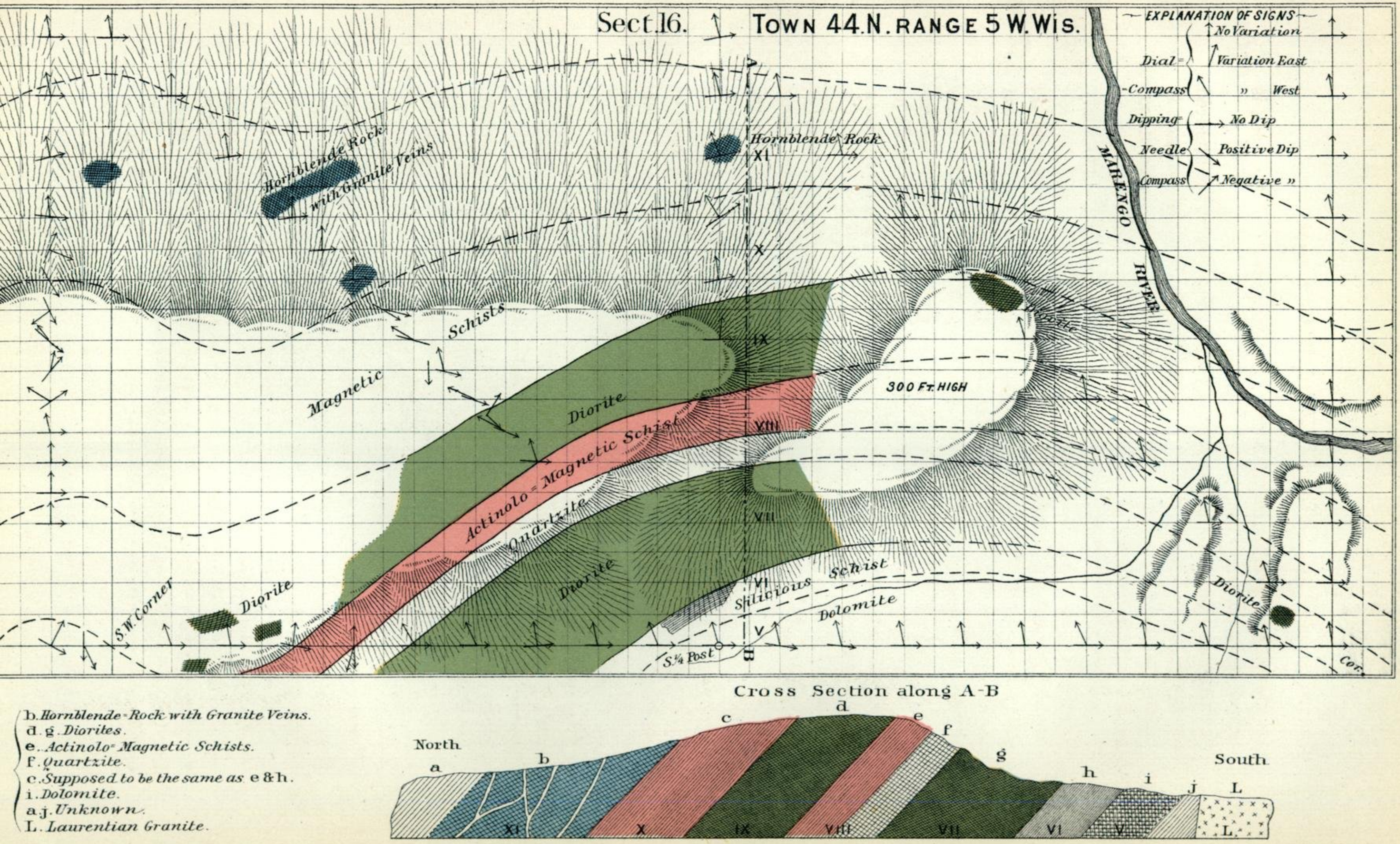
Continuing again our course, we cross a small stream at six hundred paces west from the quarter-post, and, at one hundred paces more, is found a ledge of diorite (spec. 192). It is of a dark green color, and has a medium grained, somewhat indefinite crystalline texture; is jointed and massive, having an uneven, jagged fracture. The only mineral ingredient that can be recognized is amphibole.

Under the microscope, the section presents an interesting field, especially in some of the amphibole crystals, that are twinned. These crystals enclose numerous fibrous bunches of actinolite, which, apparently, are of a secondary nature; that is, recrystallized from the large original crystal. What suggests this is, that when these fibrous forms are confined to one side of the crystal they are then sharply defined or limited by the twinning or dividing line, which would hardly have been the case were they mere inclusions.

Ascending a low ridge, brings us to the S. W. corner of Sec. 15. The timber, adjacent to this line, for the first quarter of a mile, going west, was of a mixed character, and will cut forty cords to the acre, one-half hard wood. After passing the swamp, for a distance of six hundred paces the timber consists of pine, spruce, hemlock and balsam, and is of but little value, but, for the remainder of the distance, it is good and will yield fifty cords per acre, two-thirds hard wood. The solar compass gave a variation to the west, from the quarter-post to the southwest corner, but the dipping needle stood practically at zero.

Proceeding west along the section line, we pass a low ledge of greenstone, at one hundred and fifty paces from the corner. This is succeeded by a small, rapid stream. The country to the south quarter-post is rather flat, and, just before arriving at the quarter-post, we cross and recross a small stream several times. To the north of this line, about one hundred paces, and at about eight hundred paces to the west from the S. E. corner of Sec. 16, is a low outcrop of chloro-silicious schist having a strike of S. 80° W., and a dip of 65° north. There are other ledges of diorite at about one hundred paces to the west of the quarter-post, which continue for one hundred paces.

The rock (spec. 197—VII) is of a dark green color and a fine-grained texture. The mineral ingredients can scarcely be recognized. *Under the microscope*, the section appears to be composed of plain and striated crystals of feldspar and of irregular fragments of amphibole, and also several groups of narrow filaments resembling magnetite, or possibly menaccanite, arranged in parallel manner. The magnetitic attractions rapidly increase, as we go westward, and on


Sect. 16.
TOWN 44. N. RANGE 5 W. Wis.
EXPLANATION OF SIGNS
Dial-Compass
No Variation
Variation East
» West
Dipping-Needle-Compass
No Dip
Positive Dip
Negative »
MARENGO RIVER
Hornblende Rock with Granite Veins
Hornblende Rock
Magnetic Schists
Diorite
Actinolo-Magnetic Schist
Quartzite
Silicious Schist
Dolomite
300 FT. HIGH
S.W. Corner
S.¼ Post
Cor.
A
B
XI
X
IX
VIII
VII
VI
V
Cross Section along A-B
North
South
b. Hornblende-Rock with Granite Veins.
d. g. Diorites.
e. Actinolo-Magnetic Schists.
f. Quartzite.
c. Supposed to be the same as e & h.
i. Dolomite.
a. j. Unknown.
L. Laurentian Granite.

PLATE, XXVII

ascending the steep slope of the range, we find near the summit, six hundred paces to the west from the quarter-post, large exposures of magnetic schist. The bedding planes are easily made out, as the ledge is banded; and the strike is S. 65° W., and the dip 65° northwesterly. The ledge extends to the northeast for eighty rods or more; but to the southwest, the range gradually drops off into lower land. The crest is quite broad, and is about two hundred feet above the general level of the country. The timber is fine hard wood, and will cut fifty cords per acre.

Continuing westward, we descend the long gentle slope, and, at seven hundred and fifty and eight hundred and fifty paces west from the quarter-post, are ledges of diorite, which, as may be seen, overlie a portion of the magnetic schists. They are massive, and have a dark green color, mixed with gray; are of a medium crystalline texture. The amphibole can be made out with a little care, and, *under the microscope*, the section presents about an equal mixture of plagioclase and amphibole; and also a little orthoclase, pyroxene, and magnetite. The plagioclase is in slender, finely striated crystals. The amphibole crystals are of a very pale green color, and are inclined to a bushy structure. Many of them are twinned.

The variation of the solar compass at the S. W. corner of Sec. 16, is 60° west, and the dip is zero; but, at only fifty paces west of here, it is 160° east, and the dip 90°. The attraction decreases to the west — see diagram XXVII — and at three hundred paces on the line west from the corner, the solar compass and dipping needle each stand at zero; but as we continue west, the needle of the solar compass swings gradually around to the west, while the dip needle remains at zero, but the vibrations become quicker until at eight hundred paces west from the corner, where it gives a dip of 10° with quick vibrations, and the solar compass indicates a westerly variation of 30°. At one hundred paces farther, the dip needle indicates 90°, and close by the north quarter-post of Sec. 20, the variation is 105° east. At one hundred paces west of the quarter-post, the variation is 80° east, and the dip is 40°; and at one hundred more the variation is 45° east, but the dip is 10° negative.

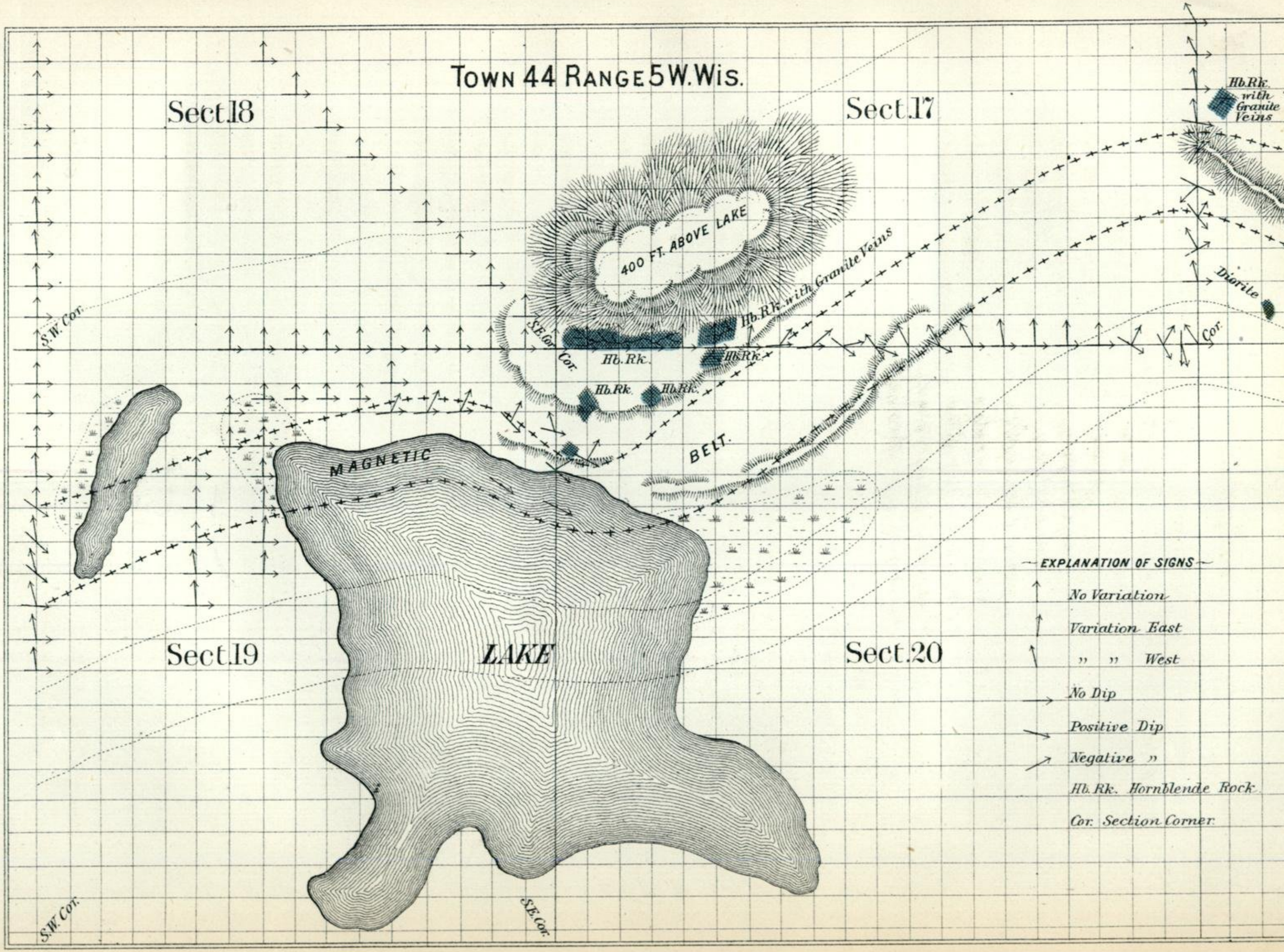
It will be seen that we crossed the range again, and that it is somewhere to the south. Farther west, we pass several ledges of greenstone, and when within three hundred paces of the N. W. corner of Sec. 20, we skirt along the south slope of a high, isolated point or sharp ridge of hornblende rock, at the western end of which is the corner. It forms a prominent land-mark and may be recognized for a long distance away, being about four hundred feet above the general level of the country. The hornblende rock which forms this ridge is massive and jointed, and traversed by granite dykes. The hornblende rock (spec. 193) is of a dark green color, fine grained, crystalline in texture, and the mineral ingredients are too small to be made out. A fresh fracture is rough and jagged to the touch. *Under the microscope*, the section is seen to consist largely of feldspar and amphibole, and also of quartz, a little chlorite, and a few opaque grains of magnetite. The feldspars, plagioclase and orthoclase are about equally divided and are rather in excess of the amphibole, which is of a pale green color and only slightly dichroitic. The granite veins intersecting this ledge are reddish in color, and medium grained, and have a semi-vitreous texture. On a fresh surface may be seen numerous small facets of feldspar and vitreous grains of quartz; also an occasional dark greenish bunch of what appears to be altered biotite; fracture sub-conchoidal. *Under the microscope*, the section, apparently, consists of about two-thirds of decomposed feldspar, and one-third of limpid quartz grains; also a few groups of some mineral resembling biotite; the latter mineral is dichroitic, and its optical bisectrix appears to be parallel to the cleavage lines on some of the fragments. The feldspar has a dirty brownish appearance, and some of the outlined masses are faintly striated. The grains of quartz contain numerous minute cavities filled with a salt solution, out of which has crystallized a small transparent cube. The minute bubble, always present, has scarcely any visible movement. See description of granite on page 248.

The country near the north line of Sec. 20 is slightly rolling, and the timber will average forty cords of wood per acre.

Turning south from the N. W. corner of Sec. 20, we went four hundred paces to a small lake and camped. The lake is about half a mile wide by three-fifths of a mile north and south. The water is pure and clear, and the bottom clean and sandy.

The magnetic attractions are here quite strong, and believing that they extended across the lake, we constructed a raft to determine the fact. Tracing the attractions eastward along the shore, we found that they continue but a short distance, taking, apparently, a northeasterly direction. Coasting along the east shore to the southeast corner of the lake, and finding no more magnetic attraction, we returned to camp, and afterwards paddled around the northwest shore. The attraction, though feeble, still exerts an influence on the needle until we reach the northwest corner of the lake, but from thence to the south, it very soon ceases.

September 20. Desiring to learn something more of the extension



PLATE, XXVIII.

of the Iron range in Sec. 16, and to the east, we proceeded to the southwest quarter-post of Sec. 15, and thence due northwest. See plate XXVII. The magnetic variation at the quarter-post is 60° to the west, and the dip is zero. At three hundred and eighty paces, however, on this northwest course, the variation is 4° west, and the dip is 16° positive. At one hundred and fifty paces more, the variation is 5° east and the dip 5°. Three hundred and fifty paces north, and thirteen hundred and fifty paces west from the southeast corner, we cross the Marengo river, the current of which is rapid and the width about twenty feet. Further to the northwest, the magnetic variation changes to the west, and the dip, at first zero, becomes slightly negative. Turning south, we follow the west line of Sec. 15 to its southwest corner.

To illustrate how poorly the government surveys have, in some instances, been done, especially through this region, I will mention that the west line of Sec. 15 is only three-fourths of a mile long; in other words, it is only eighty rods from the southwest corner to the quarter-post on the west line of the section. Probably the government surveyors undertook to run with the compass needle, and the results are, as might readily be supposed, very unsatisfactory.

Three hundred paces north of the S. W. corner of Sec. 15, we again cross the Marengo river, and on its south bank we ascend a sharp hill; and, at a short distance to the west, is a large, abrupt bluff, facing to the north. The ridge has an east and west trend, and its highest point is about two hundred feet above the river. The rock is a diorite, very dark green in color, of medium grain and crystalline texture, and weathers to a dark drab color. The cleavage planes of the amphibole can be readily made out; also a few black, metallic-like grains of magnetite.

Under the microscope, there may be recognized plain and striated crystals of feldspar, amphibole, and an occasional crystal of pyroxene, and a few grains of magnetic ore. The crystals of orthoclase are quite large, and thickly strewn in them are fibrous fragments of amphibole. The slender crystals of plagioclase often lie partially within the orthoclase, while the other portion of the same crystal lies within the amphibole. North of the river, near the route we traversed, is some good pine timber.

Turning northwest again, we pass over the ledge just mentioned, and, at two hundred paces, came to a small, clear brook; and thence we pass over a narrow ridge, and, at seven hundred paces, we cross another small brook, and at a few paces further along, is a ledge of greenstone very similar to No. 193. This ridge is about seventy-five feet high, and terminates very abruptly on its northwest side. Skirting along the foot of a high range to the west, we finally reach a point fourteen hundred paces from the southeast corner of Sec. 16. The variation along this route averaged about 8° to the west, and the dipping needle indicated zero until we reached the center of the section, where it gave a negative dip of 10°.

Changing our course to due south, we ascend the, at first, easy rise of the range, which very soon becomes steeper, while the negative dip increases, and at seven hundred and twenty-five paces north of the south quarter-post of Sec. 16, on the steep side of the ridge, is a ledge of hornblende rock, similar to 193. The ledge is intersected by granite veins, similar to the ledge near the northwest corner of Sec. 20, described on page 287. Continuing south for one hundred and twenty-five paces, we ascend to the summit of the range, where is a loose ledge of magnetic schist. There can be no doubt but that there is a narrow belt of magnetic schist underlying this. Twenty-five paces further south is a low ledge of hornblende rock; and on the summit of the range are numerous boulders of coarse grained diabase. The range is about three hundred feet above the general level of the country.

At four hundred and seventy-five paces from the south quarter-post, the range begins to descend to the south. There are several ledges of diorite about here, similar to 197, and, at three hundred and seventy-five paces north of the quarter-post, is the junction of the diorite and the banded magnetic schist. The strike of the magnetic schist is N. 45° W., and the dip 35° northwesterly. The bands are broad, and some of them are an inch in width. The magnetic belt is one hundred paces wide, measured on a north and south line. Adjacent to this is a massive quartzite.

Fifty paces further south occur numerous ledges of diorite, which extend to within seventy paces of the quarter-post. Proceeding northwest from the south quarter-post of Sec. 16, we climb again the range, and find the ledges of rock about in the same order as before. See plate XXVIII for magnetic attractions.

At one hundred paces northwest of the center of the southwest quarter of Sec. 16, are ledges of hornblende rock intersected by granite veins, and at one hundred and fifty paces further to the northwest is another ledge of hornblende rock similar to it.

Descending the range again, we continue northwest, and pass one hundred paces beyond the section line; then, turning south, we ascend once more the Iron range, but ere the summit is attained, we find another low ledge of hornblende rock. One hundred paces to the south, or six hundred paces north of the section line, begins some strong magnetic attractions, which continue south for three hundred paces.

September 22. Starting in the afternoon from our camp near the lake, four hundred paces north of the northeast corner of Sec. 19, we went northwesterly to the north line of this section, and then west along the section line. The country is rather flat, and the timber will average from fifty to sixty cords to the acre, one-quarter hard wood. We crossed a small spruce swamp near the corner. The section is only about three-quarters of a mile wide, east and west.

Going north from the northwest corner of Sec. 19, and carefully taking magnetic observations, with the hope of finding some traces of the Iron range, we found nothing practically worthy of notice before reaching the northwest corner of Sec. 18. Going thence southeasterly to the southeast corner, we could detect no magnetic variations. The land in Sec. 18 is slightly rolling, and the timber a mixture of soft and hard wood; which will yield fifty cords per acre, one-half hard wood.

September 23. We broke camp this morning, and I determined to follow the magnetic attractions, as yesterday's work gave no clue as to the continuation of the magnetic range. Starting westward along the shore of the lake, we traced the belt for six hundred paces quite readily, but from this point our sensitive solar compass needles were but little affected. See plate XXVIII. The variation was from 5° east to 2° west, while the dipping needle stood at zero.

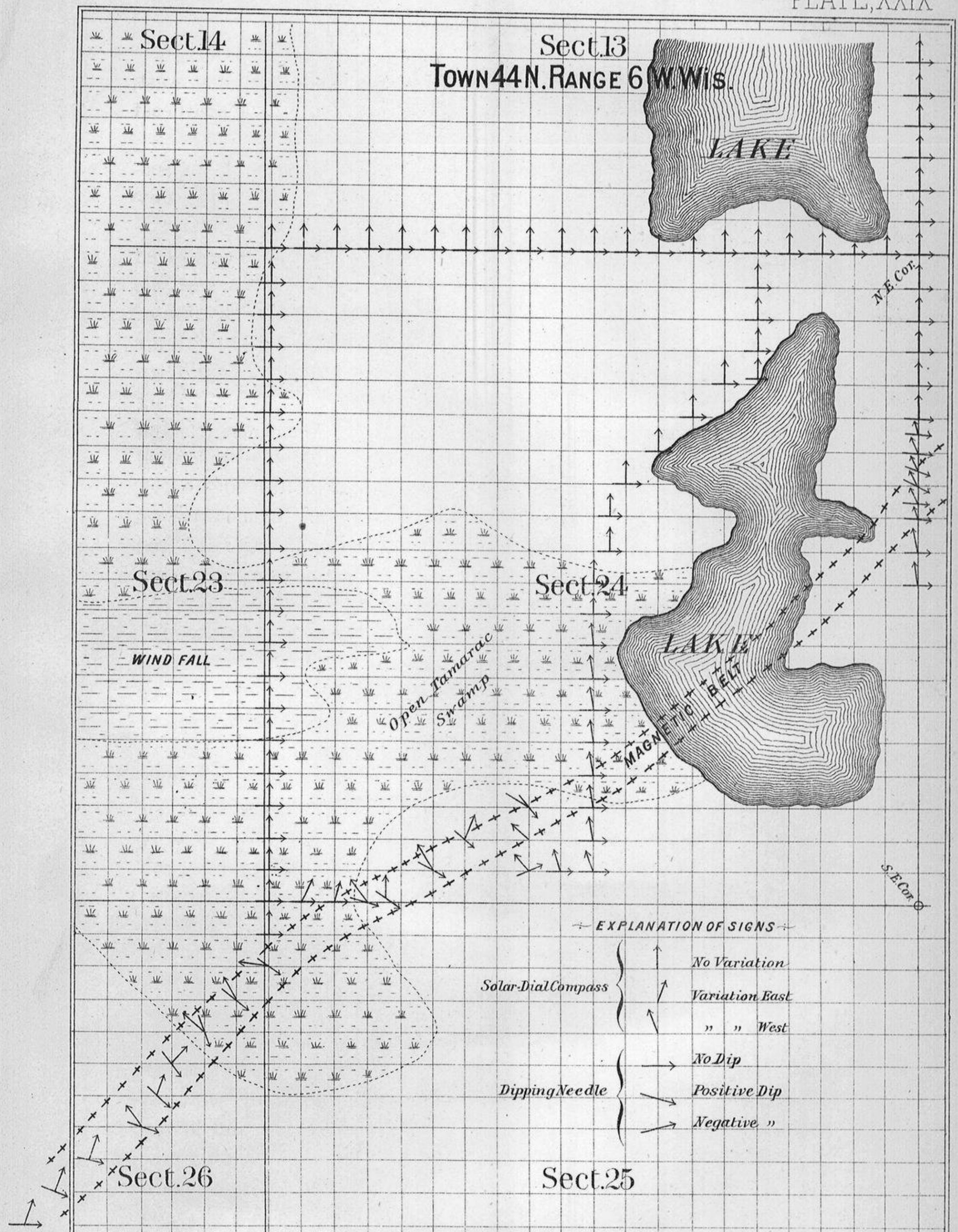
Coming upon a small lake, we passed around its north end, and thence to the northwest corner of the section; here laying aside our packs, we proceeded south, but our needles were not affected for the first four hundred paces. In the next fifty paces, the dipping needle indicated 5° negative dip, which continued the same for the next fifty paces, the solar compass still standing at zero. At five hundred and fifty paces, the solar compass gave a 3° variation westerly, and the dipping needle a positive dip of 5°. This rapidly increased for the next hundred paces, the variation becoming 22° to the west, and the dip 33° positive. Continuing south, the attraction soon ceases, and at eight hundred and fifty paces south of the corner, the dipping needle stands at zero, and the variation is zero.

Having been told that there was iron ore on the north shore of Long lake, we proceeded west along the north line of Sec. 24, T. 44, R. 6 W., hoping thereby to again cross the magnetic belt. At one hundred paces west from the northeast corner of Sec. 24, and one hundred paces north of the line, is the south corner of a small lake the dimensions of which are about one hundred rods east and west, and a half mile north and south, embracing nearly all of the southeast quarter of Sec. 13.

We found no magnetic attractions along the north line of the section, indicating that the range must be somewhere to the south, notwithstanding the reports to the contrary.

Pitching our tents near the northwest corner of Sec. 24, we retraced our steps along the section line to within five hundred paces of the northeast corner of Sec. 24, and then turned south to cross the line of attraction already observed on the east line of the section. Four hundred paces from the line, we came to a lake which is not laid down on the government plats. This lake, as may be seen by consulting plate XXIX, is about three-fourths of a mile in length, north and south, and will average one-third of a mile wide. It is located entirely in the east half of Sec. 24, and occupies, therefore, about one-half of this area. Traveling around on the west side of the lake, we expected at every step to find magnetic attractions. Six hundred paces south from the north line of the section begins some low, wet ground, leading soon into an open tamarac swamp. See plate XXIX. The dipping needle gives in the swamp a negative dip of 5° to 10°, the solar compass indicating only a small westerly variation; but just as we reach the southern limits of the swamp, four hundred paces from the south line of the section, the needle gave a positive dip of 10°, and the solar compass turns to 14° west. Continuing south to within one hundred paces of the south section line, the dip becomes zero, and the west variation also diminishes. Going due west for two hundred paces, the west variation increases to 15°. Turning north for two hundred paces, we find, at three hundred paces north and twelve hundred paces west from the southeast corner of Sec. 24, a variation of 50° west and a dip of 40°. Thence turning west for one hundred paces, the variation changes to five degrees east and the dip becomes zero, showing that this point is west of the magnetic belt, and that the lines of attraction have a southwesterly direction. Proceeding due southwest to the south line of the section, the magnetic attractions continue to remain strong.

Wishing to connect our work with the government survey, we went due west to the corner. The attraction very soon ceased, and at the corner the variation was only 2° east and the dip zero. Going now south for one hundred and fifty paces, the variation becomes again 24° east, and the dip 45°. At fifty paces more the variation changed to 68° west, and the dip became 30°, with quick vibration. Returning north to camp, we passed over a low rise of ground, and, at three hun-



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dred and fifty paces from the southwest corner of Sec. 24, we came to an old windfall, burnt over, and, along this rise of ground, passes the old Marengo Indian trail. The timber of the north half of this section consists of hemlock, birch, spruce, cedar, and balsam fir, and will cut fifty cords per acre, one-fourth hard wood. The timber of the south half is tamarac, etc., the land being mostly swampy. See plate XXIX.

September 23. Last night there was a severe thunder storm, accompanied with high wind, which blew down much standing timber. The reverberations of thunder were remarkably prolonged and loud. We gathered up our camp equipage, and proceeded south to where we had left the line of attraction. Sending our Indian packer on the Marengo trail, to a small lake in the west half of Sec. 26, we proceeded southwest. The magnetic attractions were strong and easily traced. See plates XXIX and XXX. Six hundred paces southwesterly from the northeast corner of Sec. 26, we leave the swamp and come upon higher ground. Arriving at a point six hundred and fifty paces north and one thousand paces west of the southeast corner of Sec. 26, the variation had gradually decreased until it was now only 2° east, and the dip zero. Going southeast, the needles were again strongly affected, and at four hundred and three hundred paces north and seven hundred paces west of the southeast corner of Sec. 26, are some low ledges of banded magnetic schist, which are plainly bedded, and have a strike of S. 50° W., and at one hundred paces southwest of this point the strike is S. 60° W., while the dip of the bedding is 40° to the northwest. The magnetic schist is mixed largely with actinolite and silica. Between these two magnetic belts are ledges of massive diorite, similar to 198.

The timber on the north side of the line of attraction is of a fine quality, and consists of sugar maple, birch, elm, ironwood, linden and fir, and will cut sixty cords per acre, two-thirds hard wood. South of the range, the timber is hemlock, birch and fir.

Proceeding now S. 64° W., we found the variations, at first, chiefly to the east, and then slightly to the west for a short distance, when it changes to the east and then again to the west. See plate XXX. At a point fifteen hundred paces west from the corner, we turned north from the south line. The variations remained to the west, and the dipping needle stood practically at zero, until we reached a distance of six hundred and fifty paces north of the line, where the variations suddenly changed to 30° east, and the dip was 5° positive.

Thinking that the attraction might, possibly, be due to a large boulder, we continued two hundred paces farther to the lake — Trappers — and then along the southeast shore to where our Indian had camped. We found the bottom of the lake sandy and the water clear. Returning after dinner to investigate the matter of the boulder, we found that there was a narrow belt of attraction, having an easterly and westerly direction. Tracing it westward into the lake, we then turned and traced it eastward, on the somewhat crooked line represented on plate XXX, to where we had left it in the forenoon. There were no more outcrops of magnetic schist, but at four hundred paces north and twelve hundred paces west of the S. E. corner of Sec. 26, is a ledge of diorite, similar to those farther east. Again returning to the lake, we camped on the south side of it, just west of the east line of Sec. 27.

September 24. We went westerly, along the south side of the lake, and then along the west side, but not finding any notable attractions, we continued around to the north side, with no better success, and then along the east side to the south again, to where the range passes into the lake; making a raft we endeavored to trace the attractions on the lake, but they were feeble, and as the afternoon was cloudy, preventing the use of the solar compass, we were confined to the dip compass, which was not sufficiently sensitive to be of much aid to us.

We went south on the east line of Sec. 27 to the southeast corner, passing through fine hard wood timber, and then turned west, taking the variation as near as possible from the south line of the section. At six hundred paces on this line, the dipping needle was slightly disturbed, and a gleam of sunshine enabled us to use the solar compass, by which we found a variation of 18° W., which increased to 28° W. at fifty paces further west. This decreased, and at eight hundred paces west it was 5° W.

September 25. We broke camp and proceeded southwest to where we were at work yesterday, and, continuing the same, we reached the northwest corner of a small lake — Cranberry — fifteen hundred paces north and one thousand paces west of the southeast corner of Sec. 34. The shores of the lake are comparatively low and sandy. It lies chiefly in the northeast quarter of Sec. 34, and embraces about one-half of this area. Skirting along the west shore of the lake, we leave the line of magnetic attraction to the east; but proceeding east from the south end of the lake, two hundred paces, and then south and east again across a low cranberry marsh to a rise of land (see plate XXXI), we find the magnetic belt again. The variation at six hundred and fifty paces north and ten hundred and fifty west, is 2° east, and the dip zero. At fifty paces east, the variation is 6° east, and the dip 10°. At twenty paces further the attractions are the same. Still

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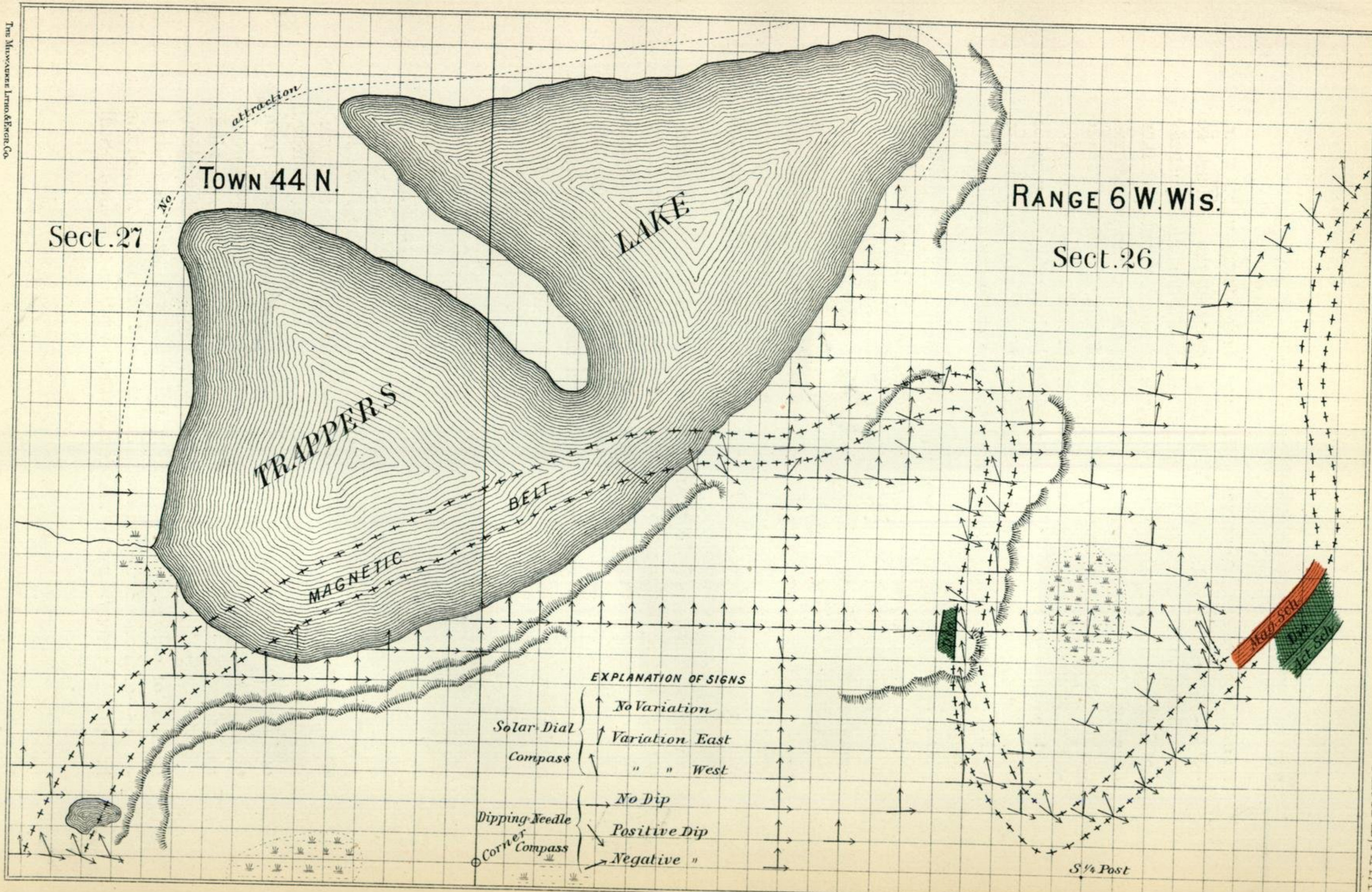


PLATE, XXX

twenty-five paces more, the variation becomes zero, and the dip is 12°; and at fifty paces more, the variation is 8° west, and the dip is 10°.

The back-water of Nemakagon lake, from the dam at its outlet, overflows here, and, through the dead timber to the south, can be seen the open lake not more than thirty rods away. We traveled to the west, around this back-water, and thence southwesterly to a camping place on the north side of Nemakagon lake. This point is located three hundred paces north and thirteen hundred paces west of the southeast corner of Sec. 34. The attraction here is 4° W., and the dip 5° negative. We built a raft and paddled easterly across the narrow bay to a point of land, where the solar compass gave a variation of 4° west, which increased to 12° west. See plate XXXI. Farther east it decreased, and at six hundred paces east-southeast, the variation was 4° west, and the dip needle stood at zero. At the southwest extremity of this point of land, two hundred paces south from where we landed, the variation is 10° west, which decreases to the eastward. This would seem to indicate that the range was making a southwesterly turn.

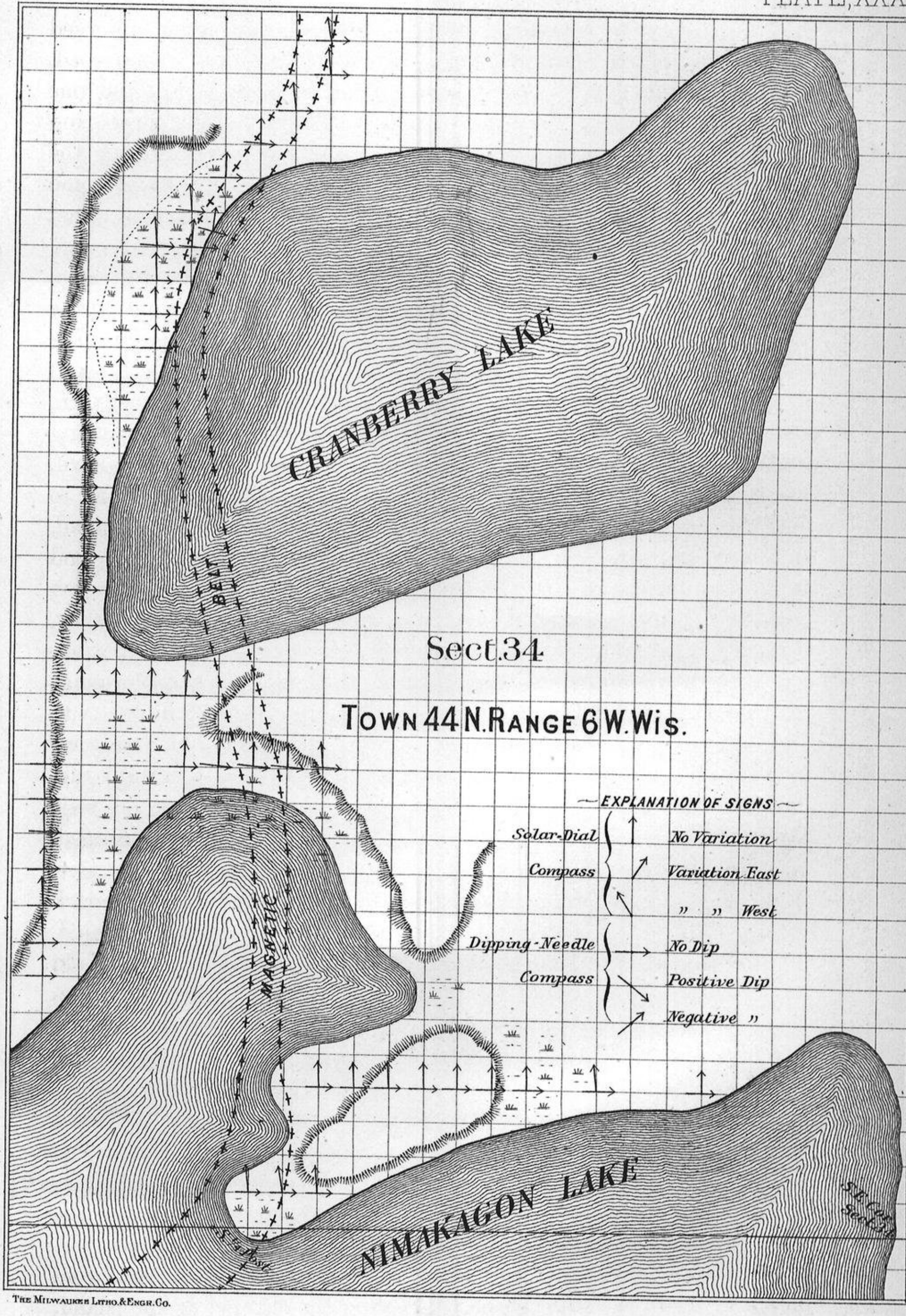
Returning to the spot where we landed, we went easterly, skirting along on the shores of the bay, and thence went northerly, intending to go to the north end of this bay where we were before noon; but we were prevented from reaching there by the back-water. We found, however, no greater variation than already noticed to the south, and the dipping needle did not change from zero.

Again boarding our raft, we paddled nearly due southwest to a sharp point of land — see map — but the attractions were practically nothing. Leaving the raft, we went along the shore to camp, but detected no variation of our needles.

September 26. We returned to our raft and paddled, at first, nearly due south to the south end of an irregularly shaped peninsula, and thence southwesterly to a point on the main shore about five hundred paces north and three hundred paces west of the southeast corner of Sec. 4. On account of back-water we were obliged to go, at first, northwest to near the center of the section, and thence southwesterly for nearly a mile, when our further progress was cut off by the back-water from the dam. We were now compelled to go northerly for about a quarter of a mile in order to get around the back-water, which had overflowed a tamarac swamp. Finally getting around this, we proceeded again to the southwest, and soon struck a trail, which brought us to a dam on the Nemakagon river. This dam is about fifteen feet high, and is located at thirteen hundred paces north and eighteen hundred west from the southeast corner of Sec. 8, T. 43, R. 7 W. South of here a short distance we found the strongest magnetic attraction observed during the day, the variation being 7° west; following a wagon road, we reached Chalmers' camp, fourteen hundred paces north, and one hundred west of the southeast corner of Sec. 7. After procuring some supplies, we returned to the dam, and examined further the magnetic attraction already noted. Constructing a raft out of some loose plank which we found, we paddled and poled up the river. Just above the dam the variation becomes 50° east, but this soon ceases, and our needles for the remainder of the voyage remained at zero. Although there is no perceptible current in the river, owing to the back-water, still the channel can be easily followed by the dead timber which borders it; the general direction of the stream is easterly until it crosses the east line of Sec. 8, when it makes a sharp northeast turn, and we enter the lake at the north end of a narrow bay. Turning south, we rounded a sharp point of land. The sun having gone down, and it being quite dark, we were obliged to hug the shore in order to find the narrow channel between the peninsula and a large island, shown on the government plat — see map. The night was cold, and as our means of propulsion were limited to a couple of limber fish poles and a short piece of a board, our progress was necessarily slow. Our only light came from the feeble twinkling of the few stars not obscured by the clouds, which made the deep shadows from the overhanging trees appear still darker, rendering it a matter of much difficulty to find the narrow passage for which we were in search, but finally we succeeded. Still we were not certain whether it were the right one. Entering the north basin of the lake, our camp fire was nowhere visible, but soon answering shouts responded to our calls. Encouraged, we paddled away and were speedily gratified with the cheering view of our blazing camp fire casting its comforting gleams across the dark waters of the silent lake. Our troubles were now quickly dissipated, and we enjoyed the additional pleasure in finding at camp an old Indian with a birch canoe, the advantages of which our recent experience had taught us to appreciate.

September 27. Having engaged the Indian and his canoe, we proceeded in it to where we had the day before left our first raft, making magnetic observations constantly. We went easterly to the northeast point of the peninsula, but could detect no magnetic attraction. The peninsula is the most elevated land near the lake, and rises at its eastern extremity to one hundred and fifty feet above the surface of the water. It is timbered with good hard wood and scattering pine.

We were hopeful that this was a portion of the range, but were unable to verify the supposition. Crossing the channel to the island,



The Milwaukee Litho. & Engr. Co.

we continued our examination there, but met with no better success. Re-embarking, we proceeded to the north shore of the lake and then coasted along it to camp, but could find no trace of the magnetic belt. The afternoon being cloudy and rainy, rendering it impossible to use the solar compass, we went to pick some cranberries and shoot ducks, of which there were an abundance, and met with excellent success.

September 28. Believing the range to be somewhere to the southwest, we broke camp this morning, and putting our luggage into the canoe with the two Indians and the old trapper's five dogs, Brotherton and myself got on to the plank raft, and, fastening a tow line to the canoe, we set out for the dam. The wind, blowing quite fresh at starting, increased to almost a gale when we were about half way across the lake. Our fair-weather bark was tossed about in a manner that rendered our destination a little uncertain. Brotherton couldn't swim a stroke and therefore took great interest in the craft — a sort of a life lease. The raft was constructed of three planks and, of course, had little superfluous buoyancy to bear the additional weight of the waves by which it was occasionally submerged. Our Indians, for once, seemed to appreciate the danger of the situation and plied their paddles lustily to reach the channel, where the water became smoother. It now beginning to rain and hail, we went ashore, covered up the baggage, and built a fire to dry ourselves, for we had become thoroughly drenched from the rain and the waves, having been some of the time almost under water. Impatient of delay, we cut short our sojourn and again took to our craft to resume observations. The needle, however, remained at zero.

We arrived at the dam about noon, and pitched our camp west of the dam, thirteen hundred paces north and fifteen hundred west from the southeast corner of Sec. 8. After dinner the old Indian, who had always lived in this vicinity, volunteered to take us to some ledges of rock, but like nearly all Indian stories of this kind, his information proved to be of no value, for the ledges turned out to be boulders.

Chalmers' camp was in charge of Mr. Dickson, who had cleared up and planted a couple of acres. He was unable to give the location of his camp.

North of the camp there is a variation of 7° west and a positive dip of 10°. We started out on a wagon road running northwesterly, and took magnetic observations, and came, in about a mile, to an east and west section line, which we followed east to the southeast corner of Sec. 7, T. 43, R. 7 W., and then turned north. The dip compass was but little affected, and the solar compass varied from 2° to 6° west. There seems to be a broad belt of feeble attraction in this locality.

The country is undulating, and the timber fine hard wood with patches of good pine.

September 29. As it rained steadily all day, we remained in camp.

September 30. We took the old wagon road for Greeley's old logging camp. See map. At one side of this road, in the N. W. qr. of the S. W. qr. of Sec. 6, T. 43, R. 7, are some low ledges of greenstone belonging to the Copper series. Greeley's old logging camp, on the south bank of the Nemakagon river, is in the N. E. qr. of Sec. 1, T. 43, R. 7.

We took our course up the river, following the old logging road to the range line, and thence proceeded north across the river. A ledge of greenstone forms the rapids in the river at this point. The rock belongs to the Copper series and contains nodules of delessite and epidote; also small bunches of pyrite and chalcopyrite. Going now up the river on the north side of the stream, brought us to camp; but we found no magnetic attraction. Starting from the west quarter-post of Sec. 8, we proceeded southeast to the south quarter-post of this section, passing over fine hard wood land. From thence we went due south a distance of eight hundred paces, to a small, irregular shaped lake, which is about sixty rods in width at the widest part. Turning northwesterly, we went to the northwest corner of Sec. 17, having found no magnetic attraction.

The timber in Secs. 8 and 17 is excellent hard wood, the land is rolling, some of the ridges are quite steep, but no outcrops could be found on them. Scattered over the surface are frequently seen angular boulders belonging to the Copper series. The soil is a sandy, gravelly loam.

October 1. We started this morning for the small lake near the center of Sec. 17, and then proceeded southeasterly to the southeast corner of 17. Here we turned east and came to Nemakagon lake, near the south quarter-post of Sec. 16.

Proceeding southward along the shore of the lake, to a point six hundred paces south from the north line of Sec. 21 (see map), in order to get around the deep bayous, which are formed by the back-water from the dam in the river, and again changing our course, we went easterly for two miles, to a small stream, crossing the north line of Sec. 23, seven hundred paces east from its northwest corner. We saw no outcrops of rock along the line we had traveled, but in the bed of the creek were many angular boulders. The drift is, apparently, very deep. The general aspect of the country is very similar to that of the Laurentian area. The timber on the south shore of the lake consists, chiefly, of white birch, hemlock, and some pine; and the soil is sandy.

Careful magnetic observations failed to detect any attraction, the needle remaining constantly at the zero point. Judging that the range must pass somewhere near our camp, we returned to near the south quarter-post of Sec. 16, watching closely our compass, but with the same result as before, discovering no variation. Proceeding now northeasterly to the small lake in the central portion of Sec. 17, and thence due north on a line seven hundred paces west from the east line of Sec. 17, and thence west along the north line of this section, we found no magnetic attractions on the lines traversed. Turning north and then northeasterly, we passed through Sec. 8 to the dam, and found as we approached it that the westerly variation began to reappear.

October 2. Proceeding this morning southwesterly from Chalmers' camp, along a logging road, we cross the south line of Sec. 7, about midway between the quarter-post and the southwest quarter-post corner, and pass into the northwest quarter of Sec. 18, and only a short distance further we enter an open spruce swamp.

The logging road takes a more southerly direction, and the magnetic attraction in Sec. 7 continually diminished, until, in Sec. 18, it became practically nothing. Changing our direction to a due southwest course, we left the swamp near the east line of Sec. 13, T. 43, R. 7, but continued our course until, intersecting the north and south center line of Sec. 13, we turned south to the quarter-post, which is near the east margin of a large cedar, tamarac swamp. Going due west from the quarter-post, we find the swamp to extend for nearly a mile in this direction. After leaving it, we passed through the northerly part of an extensive wind-fall, grown over with hazel bushes. It has a west and southwest direction. We found the southwest corner of Sec. 14 situated on the edge of pine barrens, many miles in extent to the westward. We found no magnetic attractions along the lines, but at the corner the solar compass gave a variation of 4° west, and on turning north on the section line, this variation increased, becoming 7° west, at two hundred and fifty paces further north, and also giving a positive dip of 15°. One hundred paces west from this point is Pendleton's camp, now occupied by W. H. Chalmers. Learning of some ledges of rock on the river, at a point about two miles to the west, we concluded to visit the locality, and accordingly proceeded northwesterly in this direction for about one-fourth of a mile, to the main supply road, and thence along this road southwesterly and westerly, making constantly magnetic observations with the solar compass and dipping needle. The country is chiefly pine barrens, with occasional patches of pine, which was cut over a few years ago. The soil is sandy and the surface moderately rolling. We meandered the road as well as we were able, considering the many bends. See map. The solar compass needle varied from 2° to 7° west, and the dipping needle, along the main supply road, did not give a dip exceeding 5°. The waters of the small streams which cross the road are cool and pure as spring water. In the northwest quarter of Sec. 21, T. 43, R. 7, the road crosses the Nemakagon river, on the north bank of which are the ruins of an old logging camp, and northwesterly from the camp are some ledges of diabase, which I think belong to the Copper series.

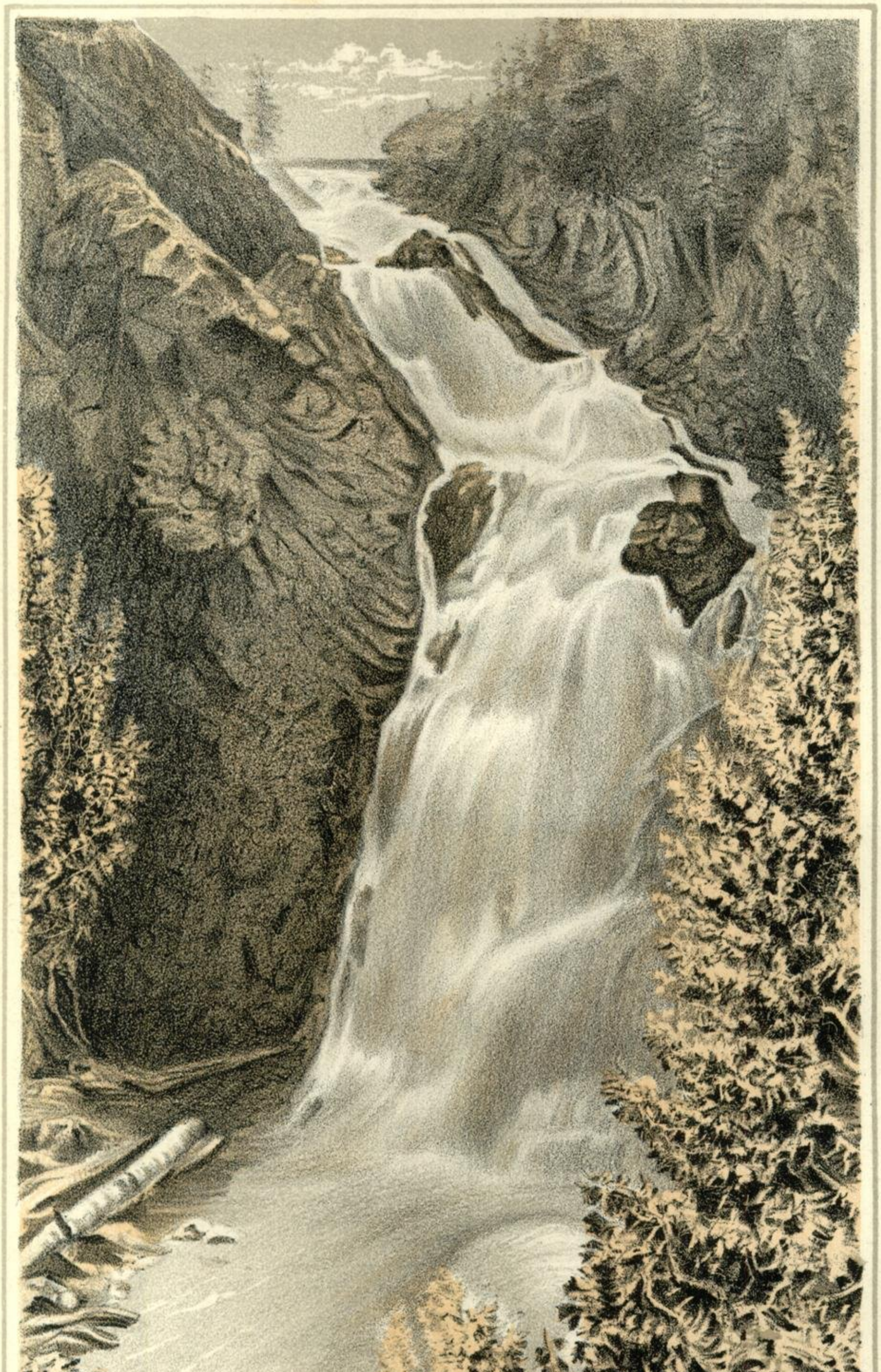
There are no magnetic attractions over these rocks, but on being pulverized, some small particles adhere to the magnet. We returned to the bridge, and crossing to the south side of the river proceeded to where were to be seen some white patches of rock, which proved to be granite. These ledges are low and the bedding planes are much contorted. The average strike is east and west. The color is reddish and light gray, and has a medium grained texture. The three essential minerals, the feldspar, quartz and mica, are plainly visible. The mica (biotite) occurs in black bunches and narrow seams. *Under the microscope*, plain and striated feldspar may be seen; the former, however, is in excess of the latter. The biotite is dark brown and very strongly dichroitic, while the quartz grains are angular and irregular in shape, and contain fluid inclusions, but no salt cubes can be detected. South of this locality, and a little to the east, is a very prominent hill, about three hundred feet high. It now being late, we retraced our steps to the logging camp, and examined, in the northwest quarter of Sec. 22, a high, steep ridge, but found no outcrops upon it, or any magnetic attraction.

October 3. Proceeding this morning to near the center of the N. W. qr. of Sec. 21, and thence going south along an old logging road to near the south line of the section, we turned southeasterly to the high hill already mentioned. Reaching its summit, we followed on its ridge northerly to the low granite ledges above mentioned. The ridge is timbered with hard wood, and the soil is a sandy, gravelly loam. The negative attractions observed along the supply road extend only a short distance to the south.

The country to the north of this range is rolling, resembling in its topography the Laurentian area. We were hopeful of finding outcrops or ledges of rocks among these ranges of hills, but failed. The drift is apparently deep. My impression now is that these granite ledges belong to the Laurentian; and that the Huronian series has so flattened in the dip that the Copper series and Laurentian are brought into direct contact, and the lower Huronian, thereby, covered by the Copper rocks.

What leads me to this conclusion is that the belt of magnetic attractions, after leaving Nemakagon lake, seemed to widen and become less definite in its nature, as if the magnetic force were deep seated. Another fact worthy of mention is that all the float pieces of rock we saw west of the lake belonged to the Copper series.

NOTE. — The question is often asked, "What do you think of the Penokee iron range?" This query, though apparently simple, is not an easy one to answer. Only yesterday (July 8, 1879) I was talking with some parties exploring east of the Penokee Gap, in the interest of the Wisconsin Central Railroad. They were now, after several months' explorations, well satisfied that there was nothing of value in the lower iron belts, but they had confidence of finding the true iron ore belt further to the north; that is, higher up in the iron-bearing series, where it really belongs. I truly believe that good iron ore exists in the Penokee iron range, and that it will eventually be discovered. How soon, will depend somewhat on the amount of attention those attractive and deceptive lower iron ore belts receive from future explorers. If explorers will only profit by the experience of those who have "gone before them," and examine the ground to the north of these worse than worthless lean ore belts, they will, in my opinion, finally meet with success.



LOWER FALL OF BLACK RIVER,
Near Superior, Wis. 160 feet high.

PART V.

GEOLOGY

OF THE

WESTERN

LAKE SUPERIOR DISTRICT.

BY E. T. SWEET.

INTRODUCTION.

The area of the region, here called the Western Lake Superior District, is about 1,500 square miles. This region occupies the extreme northwestern part of the state, and is bounded as follows: On the north by Lake Superior; on the east by the range line between townships 5 and 6 W., to the N. E. corner of T. 48, R. 6 W.; on the southeast by a line passing diagonally across the townships from the N. E. corner of T. 48, R. 6 W., to the S. W. corner of T. 45, R. 9 W.; on the south by the line between townships 44 and 45; on the west by the state line; and on the northwest by the St. Louis river. This is the district which was assigned to me in the spring of 1877, and, while my report will cover much of the country adjacent to this, it is not intended to present anything like a complete presentation of the geology of these additional areas. The country immediately to the south of the district has been included upon the suggestion of Professor Chamberlin, the chief geologist, who has recently requested me to extend the limits of my report sufficiently to cover all of the southward dipping formations. While it gives me great pleasure to comply with this request, so far as my observations have extended, it must be remembered that this area was very carefully surveyed by the late Mr. Moses Strong, and has been quite superficially examined by myself.

A small area, also, outside the district, has been mapped and referred to, consisting of the silicious and chlorite slates, found along the St. Louis river in the vicinity of Thompson, Minnesota. The geological bearing, which, it is assumed, they have upon the subject of the Lake Superior synclinal, is thought to be a sufficient excuse for alluding to them in this report.

In all, no more than two months' time has been devoted to the field-work in the entire district. To one who is accustomed to the Lake Superior forests, it is needless to remark that this limited time has not permitted of a very minute investigation of so large an area as 1,500 square miles. Nevertheless, it is believed that all of the prominent geological features of the district have been obtained except perhaps some of the glacial drift features.

Extra time was given to special localities, and areas, learned from good authority to be entirely covered with drift, were neglected.

To those who, perhaps, have never seen a great unbroken forest, it may be interesting to add that it is impossible to travel at any time of the year, in any considerable portion of the district, except on foot, and that all of my traveling was done in this manner. Provisions enough for two or three weeks, all instruments, camp equipage, and specimens were carried by myself, and by my men. In addition to the ordinary hardships of traveling in an uninhabited region, the Lake Superior country presents the difficulty of exceedingly few roads or trails. The explorer is subject to the incessant annoyances of having to clamber over the trunks of fallen trees, or to grope his way through dense thickets of underbrush, or wade through nearly impassable swamps of cedar. In following streams, or passing from point to point through the forest, even where there are no special examinations to make and consume one's time, it is impracticable to travel at a greater rate than one mile per hour. I have worked hard and made less than six miles per day. When the difficulties accompanying the exploration of the district under consideration are understood, it will be realized that the field work has been accomplished with no slight bodily labor. At certain seasons of the year the region is infested with countless myriads of flies and mosquitoes, which continually attack the explorer at all times of the day and night, rendering existence a misery. "Fly time" lasts from the first of June until about the middle of August.

This report is the outgrowth of two expeditions made into the district for the purpose of doing detailed work; and of one reconnoissance. The first expedition was undertaken in September and October, 1873, under instructions from the late Dr. I. A. Lapham. He directed me to organize a party at Superior City, for the exploration of the Douglas County Copper Range, so far as possible during one month's time. I employed two men; one as cook and packer, and the other as packer, and spent nearly one month in tracing the northern boundary of the range, making sections, visiting the various abandoned mining locations, and collecting specimens. The second expedition occupied portions of April and May, 1877, under authority from Prof. T. C. Chamberlin. For this expedition I employed one man only, as packer, and examined a very much larger area than in 1873. An attempt was made to trace the Douglas County Copper Range into Bayfield county. Localities in Douglas county were revisited, and points previously in doubt settled. Some of the slates along the St. Louis river were hastily examined, and a general survey of the whole district was made. Numerous streams were followed from source to mouth. The main fact established by the expedition is, that Bayfield county and Douglas county, south of the range, are almost entirely covered with vast accumulations of drift.

During the autumn of 1875, I made an extensive reconnoissance of the northern part of the state, in company with Dr. O. W. Wight, then state geologist. From Stillwater, Minnesota, we ascended the St. Croix river to the mouth of the Eau Claire, from which point we traveled across the country to Bayfield, thus traversing a portion of the area under consideration. The notes obtained during this portion of the reconnoissance constitute nearly all of the information which I have obtained in regard to the country to the immediate south of the Western Lake Superior district. They are quite meagre, as a few days only were occupied by the reconnoissance in this part of the state.

Previous geological examination of the district. The only geological examinations ever made in the district previous to those of the present survey, were by members of the corps under Dr. D. D. Owen, in 1847–8. The published results of these examinations are so exceedingly limited that they scarcely deserve mention in this place. One or two pages[1] are taken up by Dr. Norwood in summing up the results of his hasty examination of the Nemadji and Black rivers. Col. Whittlesey somewhere refers to the Aminicon falls in a few sentences. Poplar river is described by Dr. Norwood in three sentences. The Brulé river is several times incidentally referred to by different members of the survey. By far the most elaborate description of the Brulé, with geological observations upon the adjacent country, is by Dr. Owen himself. It was not published in the final report of the survey, but is contained in executive document No. 57, submitted to congress June 21, 1848. Dr. Owen and his assistants labored under the impression that the cupriferous rocks of the Lake Superior country were of more recent age than the accompanying sandstones of the region; an impression easily obtained, and quite natural, if their observations had been limited to the area now embraced in Douglas county, for wherever the formations meet, the sandstones are apparently so badly crushed and tilted that one readily obtains the idea, upon hasty examination, that they have been forced asunder by the eruption of igneous rocks.

Of the arrangement of the report very little need be said. It has been divided into three chapters. In the first chapter, under the sub-

[1] Owen's Geological Survey of Wisconsin, Iowa and Minnesota.

ject of "Surface Features," will be found a pretty concise description of the country, topography, streams, timber, soil, etc. It was thought advisable to make this chapter rather full, from the fact that the district contains very few inhabitants, in reality not a half dozen residing three miles distant from Superior City; it is seldom visited by non-residents, and is an important section of the state, as to which reliable information can very rarely be obtained. The second chapter, upon "Geological Formations," is as brief as consistent with the complete statement of facts, together with a limited discussion of the geological questions to which they seem to point. In the third chapter, under the heading of "Ore Deposits and Mines," will be found a history and description of the abandoned mining locations, with a few hints upon searching for lodes, and other matters of minor importance.

Great difficulty has been met in determining just how far to extend the formations on the accompanying geological map. On the north the line of junction between the red sandstones and the Keweenawan series has been quite accurately made out. To the south of this line, as far as outcrops are concerned, we only know that the Keweenawan rocks extend some one or two miles, although there is no reasonable doubt that, including the south-dipping sandstones, which are clearly Keweenawan, they extend under the vast accumulations of drift many miles to the south. I have included two outline maps in the body of the report, showing the general distribution of the soil, timber, and geological formations.

This report has been prepared under very unfavorable conditions. In the first place, business relations have called me to a locality far distant from the centers of civilization, where much needed works of reference are not accessible; in fact, I have with me but few of the standard works which should be possessed by every student of geology. I especially deplore my inability at this time to make several complete chemical analyses, which I had contemplated reporting in the succeeding pages. Several partial analyses have been made, but with much more labor than would have been experienced in a well equipped laboratory. To these causes must be attributed in part, at least, many of the imperfections which may be found in the report.

It affords me great pleasure to make the following acknowledgments for aid received and information given while in the field, or soon after, in the preparation of my report. I am greatly indebted to Mr. Thomas Clark, Mr. James Barden and the late Mr. Thomas Hogan, with a few other residents of Superior, for favors and information while in Douglas county, and for information afterwards, with-

out which I could not have presented satisfactorily some of the most important features of this report. Mr. Clark aided me for nearly two weeks in the field, in 1873, and to his intimate knowledge of the range and of the locality of outcrops must be accredited much of the accuracy of my work. Mr. Barden furnished me with maps and a history of some of the mining locations. Mr. Thomas Barden, of Ashland, furnished me with maps and assisted me very materially in the spring of 1877. To Mr. Geo. R. Stuntz, of Duluth, the U. S. surveyor who personally subdivided most of the townships in Douglas and Bayfield counties, I am obliged for a vast fund of very accurate information. Mr. Wing, of Bayfield, and Mr. Vaughn, of Ashland, have also assisted me. Mr. Munroe, of Silverton, has aided me very greatly in the drawing of the cuts and plates of the following pages. But I am under more especial obligations to Professor R. D. Irving, under whose personal instruction I first commenced the study of geology, and of the structure of northern Wisconsin. He first advanced the idea of the westward extension of the Lake Superior synclinal, thereby giving me the key to the geology of my entire district, and he also very materially assisted me in the preparation of my report of 1873, upon Douglas county.

E. T. S.

SILVERTON, SAN JUAN CO., COL., *January, 1878.*

GEOLOGY OF WESTERN LAKE SUPERIOR DISTRICT.

CHAPTER I.

SURFACE FEATURES.

TOPOGRAPHY.

Along the shore of Lake Superior, to the westward of the Apostle Islands, and nearly as far as the mouth of the Brulé river, the reddish Lake Superior sandstones rise, at most places, directly from the water's edge to the height of from ten to forty feet. Huge caverns, often supported by columns of sandstone, and presenting various picturesque appearances, have been worn into the rock by the waves of the lake. From the mouth of the Brulé, along the shore to Superior City, only banks of reddish clay are found, usually from five to thirty feet in height. From the lake shore the ascent is gradual for from five to ten miles to the south, when the foot of the "Copper Range" is reached at an altitude of from 100 to 250 feet above the lake.[1]

Above the head of this gently sloping area, the northern face of a range composed of rock, in the western portion of the district, and apparently of drift, in the eastern, suddenly rises to the height of from 300 to 400 feet. The northern escapement, however, is not found in one continuous line running across the country, but is broken up and presents several distinct lines of elevation, all trending nearly E.-N. E. and W.-S. W. The three most prominent ridges are in Douglas county, and, taken together, are known as the "Copper Range." For convenience, I have designated them the Aminicon, Middle River, and Brulé ranges. Along all of them the Keweenawan beds are more or less exposed, the summit often being a bare ridge of rock. The Aminicon Range extends from about the center of T. 46, R. 15 W., to the Aminicon river, in Sec. 29, T. 48, R. 12 W. The

[1] All altitudes in this report are referred to Lake Superior as the base. To obtain the altitude above Lake Michigan, add 20.5 feet; to obtain that above the sea, add 602 feet.

Middle River Range appears to be topographically separated from the others. The distinct line of elevation extends from about Sec. 8, T. 47, R. 12 W., to Sec. 17, T. 48, R. 11 W. On this range the rock exposures are very few in number. The Brulé Range is again distinct from Middle River Range, the two being separated by four or five miles of swampy country, at an altitude of about 275 feet. This range may be said to start from about Sec. 8, T. 47, R. 11 W., and end in the vicinity of Iron river, Sec. 10, T. 48, R. 9 W. The rock exposures are exceedingly limited, and I was unable to find any in Bayfield county. In fact, exposures are rarely met with anywhere, except on the very summits of the ranges, or where rivers break through them. In Bayfield county there is a distinct line of elevation extending from about the point where Iron river leaves township 48 to a short distance north of Siskowit lake, or Sec. 9, T. 50, R. 6 W. From this line, the ascent southward to the dividing ridge is gradual, the divide passing diagonally through townships 45, 46, 47, 48, 49 and 50, ranges 10, 9, 8, 7, 6 and 5 west.

From the summit of the range in Douglas county, the descent is gentle to the south for one or two miles, after which, the general ascent of the country is to the south to about the line connecting the centers of ranges 10, 11, 12, 13, 14 and 15 west, of township 45. Along the two lines indicated is the general course of the "dividing ridge." It is in no sense of the term a ridge, but, in the west, is an extremely level country, almost impenetrable swamps covering a large area both north and south of it. In the eastern part of the district, the general level character of the country is only interrupted by the great number and large size of the "Potash Kettles" accompanying the morainic drift, of which more is to be said hereafter.

The general elevation of the dividing ridge is about 600 feet, obtained at numerous points by barometrical measurement. We therefore find an average descent towards Lake Superior from the dividing ridge of nearly 30 feet to the mile. It is in the swamps and almost innumerable small lakes of this "dividing ridge," that many streams and rivers head, which flow in opposite directions, and finally mingle their waters with the ocean at distant points.

Altitudes. The following table of altitudes is compiled almost entirely from barometrical observations, taken in the spring of 1877. They are given as approximations only, although great confidence is felt that they are very close to the truth, probably in most cases within 20 feet. The instrument used was a very accurate aneroid of English manufacture. I started with it from Bayfield and reached Superior about two weeks after, going to the shore of Lake Superior two or three times while on the route. I then returned to Ashland via the "dividing ridge." All observations were read in inches and hundredths, the place and time being accurately noted. Upon the completion of my field work the reductions of the readings of the mercurial barometer at the U. S. Signal Station of Duluth, for April and May, were kindly sent to me by the observer, Mr. T. S. Collins. Upon making the necessary comparisons with my own observations, I was surprised to find that, when a known altitude could be referred to, I was never more than ten or fifteen feet from the true elevation, and often was within five feet. This comparative accuracy was probably mainly due to the fact that the weather was exceedingly fine, there being no storms, and consequently little or no local fluctuation in the pressure of the atmosphere. The altitudes are all referred to Lake Superior as zero, which is 20.205 feet above Lake Michigan, and 602 feet above the sea.

ELEVATIONS IN THE LAKE SUPERIOR COUNTRY.

T. 50, R. 4 W.	
N. line Sec. 19, 2 m. west of Pike's	393
T. 50, R. 5 W.	
N. E. qr. Sec. 24, at Roath's	547
N. W. qr. Sec. 28	550
T. 50, R. 6 W.	
N. E. qr. Sec. 36, barrens	630
S. part Sec. 23	635
N. W. qr. Sec. 22, head of stream	432
Sec. 21, Siskowit lake	445
N. W. cor. Sec. 13, junction of creeks	189
N. line Sec. 2, Siskowit creek	72
N. W. qr. Sec. 10	210
N. W. qr. Sec. 8	175
S. W. qr. Sec. 19	279
T. 50, R. 7 W.	
S. W. cor. Sec. 24	234
N. and S. line, Cranberry R.	27
N. W. qr. Sec. 20, Cranberry R.	11
W. line Sec. 30, ridge	405
T. 50, R. 8 W.	
N. W. cor. Sec. 25	432
S. W. qr. Sec. 24	427
S. E. qr. Sec. 27, Flag R.	12
Cent. Sec. 33	350
T. 49, R. 4 W.	
Sec. 28, N. W. cor. (?)	180
T. 49, R. 5 W.	
Sec. 16	480
T. 49, R. 6 W.	
Sec. 15, S. W. qr. (?)	670
T. 49, R. 8 W.	
N. E. qr. Sec. Junc. of streams	49
S. line Sec. 11, Flag river	99
E. line Sec. 26, Flag river	193
Cent. Sec. 10	314
S. E. cor. Sec. 8	333
W. qr. post, Sec. 17	335
T. 49, R. 9 W.	
N. E. qr. Sec. 24	270
About cent. Sec. 23	232
S. W. qr. Sec. 23, Iron R.	117
S. line Sec. 15, Iron R.	98
S. W. qr. Sec. 23, stream	126
T. 49, R. 14 W.	
Sec. 36, Road, creek	53
T. 48, R. 5 W.	
Sec. 35 (?), trail	331
T. 48, R. 6 W.	
S. W. (?) Sec 25	387
N. E. (?) Sec. 21	530
N. part Sec. 16	540
Sec. 5, Moose lake	675
Sec. 7, W. part St. Croix road	661
T. 48, R. 7 W.	
Sec 33 (?), St. Croix road, L.	603
Sec. 27, road, burned pines	567
Sec. 23, barrens	634
Sec. 24, barrens	652
Sec. 13, kettles	693
T. 48, R. 9 W.	
N. W. qr. Sec. 2, Iron R.	180
Sec. 11, forks Iron R.	225
S. line Sec. 15, Iron R., crossing of Bayfield and Superior road	270
S. E. cor. Sec. 17	378
½ mile west	468
2½ miles west	402
T. 48, R. 10 W.	
Creek on Sec. 12	376
S. W. Sec. 23, Brulé river	252
About E. qr. post, Sec. 23	446
Near north qr. post of Sec. 23, bare knob of diabase	558
N. W. qr. Sec. 27, main shaft Percival Mine	450
E. Sec. 29, creek	432

T. 48, R. 11 W.

E. qr. post Sec. 36	538
S. E. cor. Sec. 35	547
S. W. cor. Sec. 35	475
S. qr. post Sec. 34	440
Creek near same	424
S. E. qr. Sec. 33, trail	358
S. W. qr. Sec. 32	321
S. line Sec. 31, Poplar R.	265
N. line Sec. 31, creek	176
Cent. Sec. 19, Poplar R.	95
S. line Sec. 18, Poplar R.	51
S. line Sec. 18, Middle R.	50
Sec. 18, ridge between Poplar and Middle R's	111

T. 48, R. 12 W.

N. E. cor. Sec. 24, river	99
¼ mile S. Junc. sandstone and Copper Rocks, river	130
¼ mile S. Junc. sandstone and Copper Rocks, top of ledge	184
Sec. 25, creek	146
Qr. post, S. line Sec. 35, river	243
1 mile west, creek	301
S. line Sec. 33, qr. post	329
S. line Sec. 32, Aminicon river	261
N. E. qr. Sec. 29, Junc. sandstone and Cupriferous strata, top	190

T. 48, R. 13 W.

S. line Sec. 36, top of range	396
S. line Sec. 35, creek	261
S. W. qr. Sec. 35, turn in road to Superior	234
Road to Superior, 8th mile post	153
Road to Superior, 7th mile post	90
Road to Superior, 6th mile post	73
Road to Superior, 5th mile post	56
Road to Superior, 4th mile post	53
Road to Superior, 3d mile post	44
N. W. qr. Sec. 5, Bluff creek	9
Sec. 32, bank Nemadji river	18
S. W. qr. Sec. 29, river	0

T. 48, R. 14 W.

N. W. qr. Sec. 11	68
Sec. 11, river at Wright's	5
N. part Sec. 14	64
S. E. qr. Sec. 23	81
N. E. qr. Sec. 26	95

T. 48, R. 15 W.

About cent. Sec. 32	275

T. 48, R. 16 W. Minn.

Near cent. Sec. 11, river at Conglomerate, near foot of rapids	9
S. E. qr. Sec. 10, R. R	238
S. W. qr. Sec. 5, R. R., Thompson.	419
State quarries at Thompson	459
N. E. qr. Sec. 6, river	467

T. 47, R. 5 W.

Sec. 11, S. branch Fish creek	7
Sec. 9, W. branch Fish creek	7
Cent. Sec. 10	126
Sec. 5, creek	45
N. W. qr. (?) Sec. 6	212

T. 47, R. 7 W.

N. line Sec. 4 (?)	594
S. line Sec. 5, lake	510

T. 47, R. 7 W.—(continued).

N. W. qr. (?) Sec. 8	555
N. W. qr. (?) Sec. 8, lake	501
Sec. 7, lake	510

T. 47, R. 8 W.

Sec. 13 (?), lakes	499
Sec. 13 (?), top of bank	559
Sec. 14 (?), "kettles"	627
Sec. 14 (?), bottom of	540–570
Sec. 14 (?), barrens	520
Sec. 15, barrens	590
Sec. 21 (?), Spider lake	526
Sec. 21, other lakes	520
Lake one-quarter mile S. W. Spider lake	578

T. 47, R. 9 W.

N. E. cor. (?) Sec. 36	625
N. E. qr. Sec. 33, lake	595
S. W. qr. Sec. 30	560

T. 47, R. 10 W.

N. W. cor. N. E. qr. Sec. 26, barrens	541
Sec. 27, junction of rivers	365
Sec. 23, forks of creek	397
S. E. cor. Sec. 22	514
S. W. qr. Sec. 23, creek	370
S. W. qr. Sec. 23, hill	540
S. W. qr. N. W. qr. Sec. 23, Brulé,	347
Sec. 11, Brulé river	295
Sec. 29, Nebagamain river	402
S. W. cor. Sec. 27	513

T. 47, R. 13 W.

E. hf. Sec. 2, Edwards' mine	275
N. E. qr. Sec. 8, Fond du Lac mine,	340
W. qr. post, Sec. 18	432
N. W. qr. Sec. 20, river	368
Cent. Sec. 16, river	341
S. line Sec. 14, river	430
S. E. qr. Sec. 11, road	438
Sec. 36 (?), St. Croix and Superior road, 15th M. P	531

T. 47, R. 14 W.

N. W. qr. Sec. 1	153
N. W. qr. Sec. 14, foot of Copper range	202
S. W. qr. Sec. 14, Nickel loc.	364
S. E. cor. Sec. 15, Copper Creek mine	281
S. E. qr. Sec. 15, creek, junction of Cuprif. series and sandstone	216
S. E. qr. Sec. 15, top of sandstone,	296
N. line Sec. 15, creek	189
S. W. qr. Sec. 15, Cuprif. strata	400
S. E. cor. Sec. 21, head Black River Falls	387
S. E. qr. Sec. 21, river, one-quarter mile below head of falls	189
Foot of falls	225
Top of sandstone	365
W. qr. post Sec. 12, exposures	432

T. 46, R. 10 W.

Secs. 33, 34, 26, 27, 22, 23, 13, 14, 11 and 12, level barrens or prairie,	567
Sec. 21, Brulé, at Gheen's	396
Sec. 16, barrens	470
N. E. qr. Sec. 3, river	388

T. 46, R. 13 W.	
N. line Sec. 1, St. Croix and Superior road, 16th mile post	576
S. line Sec. 1, road, 17th mile post,	592
Road, 18th mile post	585
Road, 19th mile post	580
Road, 20th mile post	589
Road, 21st mile post	594
T. 45, R. 10 W.	
Sec. 30	481
N. line Sec. 20	522
N. line Sec. 17	531
Secs. 8 and 5	560
T. 45, R. 11 W.	
Head of St. Croix and Brulé rivers, about	425
T. 45, R. 13 W.	
Sec. 2, St. Croix and Superior road, 22d mile post	590
T. 45, R. 13 W.—(continued).	
Road, 23d mile post	600
S. E. qr. Sec. 14, Moose river, road,	590
Sec. 26, dam	576
Sec. 35, road	594
T. 44, R. 11 W.	
Sec. 1	459
Sec. 14, Ox lake	397
Sec. 21, barrens	477
T. 44, R. 13 W.	
Sec. 2, creek	442
Sec. 23, Norway Camp, river	355
E. line Sec. 36, Chase's dam	360
T. 43, R. 11 W.	
N. W. qr. Sec. 6, Amrick, river	366
T. 43, R. 12 W.	
Sec. 2, barrens	470
Sec. 6, barrens	432

TOPOGRAPHICAL RELATIONS.

The topographical features of this district, like those of all other regions, depend, to a great extent, upon the underlying geological formations. The general elevations were doubtless well defined at the close of the Keweenawan Period, before the Silurian seas had commenced the deposition of the great sandstone formation.

In the western portion of the district, the Keweenawan strata lie at, or near, the surface, and the prominent line of elevation extending across Douglas county, distant from Lake Superior six to ten miles only, is formed by the northern edge of the southward-dipping Keweenawan rocks. To what extent these rocks affect the general altitude of the district, and the Bayfield peninsula, it is impossible to state, on account of the vast accumulation of drift in that region. It is, however, highly probable that they form the nucleus of the peninsula and of the great ridge extending to the southwest from it.

The immediate surface contours have been so remarkably modified by the drift, and by agencies which have been at work in post-glacial times, that all local surface reliefs are of comparatively modern origin. A great kettle range extends for many miles southwest from the Bayfield peninsula, causing a very rough and uneven country. The "kettles" or "pot holes" are, in localities, very numerous, and often from 50 to 150 feet deep. It is often necessary in traveling amongst them, to very nearly describe a series of semi-circles. Another cause, producing a marked feature of the surface, is the rapid descent of all the streams flowing north, thereby allowing them to excavate deep and narrow valleys through the soft materials of the drift. Near the lake these valleys are usually from 100 to 250 feet deep, and often not more than one-half mile across. Terraces are sometimes found along the valleys, as will be hereafter shown.

HYDROGRAPHIC FEATURES.

Lakes. The western end of *Lake Superior*, the largest of known fresh water bodies, lies directly to the north of Douglas and Bayfield counties. Whatever may be true of the other great lakes of North America, it does not owe its origin entirely to glacial action. It has long since been shown that the main portion of the lake lies in the trough of a synclinal, which probably curves somewhat more than does the lake, from northeast to southwest. It was first shown by Professor Irving, and afterwards more completely demonstrated by observations in Douglas and Burnett counties, that the western end of the synclinal extends southwesterly into Wisconsin between the Bayfield and Keweenaw peninsulas. It is as yet an open question whether or not the western end of the lake, which lies north of Bayfield and Douglas counties, is entirely due to glacial action. The known facts at present bearing upon the question would seem to indicate that it is. We know that the region has been the theater of some of the most powerful glacial manifestations in all of North America. The Apostle Islands seem to owe their origin to glacial action, and there is no doubt that the red sandstones now found at the base of all the islands, and on the shore in Bayfield county, at one time extended much farther to the north. They were doubtless removed by the glaciers.

In Minnesota, all that we know of the north shore of Lake Superior is, that along it there are in many places high cliffs of trappean rocks, and back of them, at some distance, slates, magnetic schists, and quartzose rocks. The mountains at Duluth consist in the main of a coarse gabbro, in many respects like that at Bladder lake, Wisconsin. If the Minnesota shore strata are similar to, and of the same age, as the Douglas county rocks, it may be just possible that the western end of the lake also lies in a synclinal, the Douglas county range representing the axis of a great fold. This idea is thrown out as a suggestion only.

Fluctuations in the level of Lake Superior. In the past, as will be shown in another chapter of this report, the lake has been subject to great fluctuations of level. The present annual variation in the altitude of the surface is quite considerable, but I have not any exact figures at hand. The following historical incident, however, will illustrate the fact:

At an early day in the history of Wisconsin territory, a treaty was made with the Indians inhabiting the country in the vicinity of the western end of Lake Superior, for the cession to the government of a large tract of land lying east of a line running directly south from the foot of the first rapid found in ascending the St. Louis river, to the St. Croix river. This line was run by Mr. George Stuntz, I think, in 1847. For the purpose of finding the rapid, he ascended the river from the bay in a canoe, and when several miles east of Fond du Lac, was told to commence, by the chief who accompanied him, as the Indians had a distinct remembrance of rapids being at that point. As Mr. Stuntz could discover nothing of the kind, he, of course, continued the ascent until he found them, one mile above Fond du Lac. Owing to exceedingly high water in Lake Superior that season, Wisconsin obtained an extra strip of country several miles in width. Mr. Stuntz has informed me that he himself has since seen rapids, in seasons of very low water in the lake, even below where they were said to occur by the Indians.

The water of Lake Superior is always cold. In the body of the lake it never rises above the temperature of 46° Fahr. As the waters which flow into the lake are gathered almost entirely from Archæan areas, the rocks of which are, to a very slight extent only, susceptible to chemical action, it is found to be of great purity. In confirmation of this, I have only to state that in the several chemical laboratories of Marquette, Michigan, lake water is used entirely in lieu of distilled water.

Of the large number of *Interior Lakes*, in Douglas and Bayfield counties, by far the greatest proportion of them lie in the immediate vicinity of the "Kettle Range," and are entirely without visible inlet or outlet. They are usually quite small, averaging from one to two acres in extent. Instances, however, are known in which they are several miles in extent, notably in T. 47, R. 8 W., and T. 45, Rs. 9 and 10 W. The small lakes generally have steep and high banks, and, in places where they are numerous, appear to be of nearly the same altitude. Some of them are found on the very summit of the dividing ridge.

The lakes with an outlet are generally found on the highest portions of the district, and are the sources of the various streams flowing both north and south. Examples of these are the Upper St. Croix lake, Nebagamain lake, and Aminicon lake. They are surrounded by dense swamps of tamarac and cedar. The streams themselves, near their sources, are often greatly expanded in width, and really are nothing but a series of small lakes. This is especially the case with the upper Brulé, St. Croix, and Aminicon rivers. These expansions, or lakes, are generally bordered by swamps.

Drainage. The drainage planes of the district under discussion, if the inconsiderable area which drains into Chequamegon Bay be omitted, may be said to be no more than two; a short, steep slope to the north, and one very slightly inclined to the south. Most of the streams flowing north pursue a remarkably straight course. Where there is an apparent exception to this rule, as is the case with the Lower Nemadji, it will be found that the stream flows through an alluvial bottom and has a very slight fall. Many of the small streams, which have a general straight course, if followed, will often be found to meander from side to side of the valley, compelling the traveler to journey two miles in order to gain a distance of one. This is invariably the case where the current is slow or sluggish.

A noticeable feature in the drainage of this district, common to all regions of tilted rocks, is that the larger streams prefer to follow the strike of the strata. One has only to glance at the map, and notice the St. Louis below Thompson, the Nemadji, and the Upper St. Croix, to arrive at a knowledge of the strike. The White and Marengo rivers, in Ashland county, exemplify the same principle.

Another salient feature in the hydrography of the district is the entire absence of streams on the dividing ridge in T.'s 45, 46, 47, 48 and 49, R.'s 10, 9, 8, 7 and 6, respectively, a region nearly 40 miles in length and from six to ten miles in width. It is nearly coëxtensive with the barrens and Kettle Range of Bayfield county. The absence of streams is probably due to the fact that the soil, to a great depth, consists of sand and fine gravel, thereby allowing the water to percolate directly into the earth from the surface. Nearly all of the rivers which head around the margin of this high streamless area have, at or near their sources, numerous, and often large springs of clear, cold water. Near the head of the Brulé, hundreds of these may be seen boiling up from the bottoms of the small lakes already mentioned. They also are found at the head of Iron, Flag, and other rivers. The origin of the springs can be readily traced to the streamless area. The water that falls upon the surface easily descends until it meets an obstruction, in the shape of a clay bed, in the drift, or the underlying solid rocks, which it then follows until an outlet is found.

In hydrographic features, the southwestern part of Douglas county is, in many respects, the exact opposite of those of the region just described. Small streams are numerous, the country is quite level, and wet swamp lands, almost impassable, predominate. Altogether, it is an entirely different looking country.

Rivers and Creeks. The streams which flow into Lake Superior are nearly all of small size. With very few exceptions they are short, straight and swift, containing many falls, cascades, chutes and rapids.

The Saint Louis river forms the boundary between the states of Wisconsin and Minnesota from one mile above the village of Fond du Lac to the Bay of Superior, a distance of about nineteen miles. It is said to be the second in size of all streams flowing into the lake. The current is gentle, and the channel deep for a long distance above Knife Falls, in the western part of Sec. 14, T. 49, R. 17 W. Below the falls to Thompson, a distance of five miles, the stream breaks over the edges of tilted slates, nearly at right angles to their strike. At Thompson the course of the river changes from south to nearly east, and follows approximately the strike of the siliceous and chloritic slates, a distance of seven or eight miles. Along this portion of the stream and for several miles above Thompson, the scenery is wild and grand in the extreme. Cañons, falls, and rapids succeed each other with remarkable rapidity. In high water the rapids in some places suggest a quite favorable comparison with those of the Niagara river above the falls.

From the northwest corner of Wisconsin, near Fond du Lac, the current is slow, the river broad in places, and of sufficient depth to admit of navigation by the smaller class of vessels plying upon Lake Superior. Numerous islands occur in the stream, some of which are heavily timbered. Rich alluvial bottoms extend into the country from the south side of the stream for several miles. On the north side, from Fond du Lac to Oneota, at varying distances from the river, there are horizontal red sandstones rising in hills to the height of over 250 feet above the lake. At, and north of Duluth, high hills are found, made up of from very coarse to fine-grained rocks, which I refer to the Keweenawan system. In Wisconsin, the only rocks exposed in the bank of the stream are red sandstones in the immediate northwest corner of the state.

Three small streams enter the St. Louis river from Wisconsin, the Pokegama, Little Pokegama, and Lord's creek. They all flow parallel to the Nemadji, but make an abrupt turn and enter the St. Louis. The Pokegama, for a distance of 20 miles, flows parallel to and within two miles of the Nemadji river, and when within one-half mile of that stream makes a sharp bend and enters the St. Louis river through Pokegama bay.

The Nemadji, or Left Hand river, gathers its waters from numerous small streams in the eastern part of Carlton county, Minnesota, and from others in Douglas county, Wisconsin. The main stream enters Douglas county nine miles south from Fond du Lac, flows a northeasterly course, and reaches the bay of Superior through "Lowertown," opposite the "Entry" from the lake. The mouth of the river is 165 feet wide and of sufficient depth to allow vessels of large size to ascend nearly a mile. The current of the stream throughout its whole course is slow, there being no rapids or falls except very inconsiderable ones on the N. E. quarter, Sec. 27, T. 48, R. 14 W., formed by a low ledge of sandstone. These rapids can easily be ascended with a canoe or rowboat. For about 15 miles farther up, the stream has a width of from twenty to thirty yards, and a depth of from three to ten feet. Banks of red marly clay arise from the river to the height of five or ten feet. To the north the country is low and level; on the south rolling and hilly, until the foot of the "Copper Range" is reached.

The Nemadji (pronounced by the Indians Ne-muj-i-ti-gue-ag) has two important tributaries entering from the south, Black river and Copper creek. Both cross the Aminicon range, passing it in falls and rapids, one and one-half miles apart.

Black river has its source in a small lake lying partially in Minnesota and partially in Wisconsin. It flows a northerly course, and enters the Nemadji eight miles south of Superior City. For a great portion of its length it passes through tamarac and cedar swamps, containing much fallen and decaying timber. This would readily be suspected from the character of the water, for although it contains no sediment, it is, especially in the fall of the year, of nearly inky blackness, and has a slight astringent taste. This is doubtless due to the presence of organic matter, derived from fallen leaves and timber.

From three to five miles south of the Copper Range, Black river is a stream ten or twelve yards in width, and from one to three feet deep. The current is slow, and the channel contains numerous boulders of sandstone, as well as of Keweenawan eruptive rocks. The valley is from fifty yards to one-fourth mile wide, with clay banks upon either side from twenty to fifty feet high. On approaching the range the valley becomes very narrow and the boulders much more numerous. On the southeast quarter of Sec. 28, T. 47, R. 14 W., is the most southern exposure of the Keweenawan strata noticed along the stream. Three hundred feet below here, one of the hard layers of this series crosses the river, trending northeast and southwest. Over it, the water descends in a perpendicular fall of thirty-one feet. Dr. Norwood[1] thus described this fall thirty years ago, and I can give no more faithful description now. "The river," said he, "is about forty feet wide, and falls into a circular basin, about sixty feet in diameter; a large mass of rock on the brink of the precipice, midway the river, divides the water into two chutes, and adds greatly to the picturesque appearance of the fall." By the windings of the stream the next mile and a half of the river is made up of low falls and rapids, with short intervening spaces of smooth water.

In following down the river the sound from the upper fall can still be distinctly heard, when the dull roar from the lower falls is first discerned. These are on the southeast quarter of Sec. 21, T. 47, R. 14 W. The descent of the river here, in a horizontal distance of not more than fifty yards, is 160 feet. This includes the rapids at the head of the falls, the great chute of over 140 feet down an inclination of about 80°, and a low fall of fifty or sixty feet from the foot of the chute. Plate XXXII is an excellent representation of the falls, reproduced from a photograph. As there had been many widely varying estimates of the height of the falls, and, moreover, as upon my first visit to the locality I had a very inaccurate aneroid, I caused a line of levels to be run by Mr. Clark, of Superior, for the purpose of accurately obtaining their altitude. He found it to be, between the points already mentioned, a few tenths over 160 feet.

From the foot of the falls the river passes for nearly a mile through a gorge or cañon from 100 to 170 feet deep. The sandstone walls of the lower cañon soon become less elevated above the stream, but the current is rapid, the valley narrow, and the clay-banks high to the Nemadji river. The elevation at the head of the falls is 387 feet above Lake Superior, at their foot, 227 feet, and at the head of the "Upper Fall," over 500 feet. This leaves approximately 300 feet descent from the head of the Upper Falls to the foot of the Lower Falls, a distance in a direct line of less than three-fourths of a mile.

Copper creek is a small stream formed by the junction of two branches, one and one-half miles southeast from Black river falls. Its course is rapid for the entire length, which is only five or six miles. On the south branch or fork, about one hundred yards above its junction with the east fork, there is a beautiful fall of nearly twenty feet, formed by two perpendicular cascades, which are separated by only a few feet of rock, the lower one dropping into an oval basin about twenty feet across. The water of the stream is clear, cold and transparent, and abounds with brook trout. For the distance of one-half mile below the fall, the creek passes, in a series of rapids, through a cañon worn first in the eruptive Keweenawan rocks, and afterwards in horizontal sandstone, the nearly vertical walls of which are from twenty to one hundred feet in height.

Bluff and Bear creeks are two small streams, having their sources on the north slope of the Copper Range, near the "Wisconsin Mine." Both pass through fertile meadows in the vicinity of Superior City, and enter the Bay of Allouez two and three miles, respectively, southeast from the mouth of the Nemadji river.

[1] Owen's Geological Survey of Wisconsin, Iowa and Minnesota.

The rivers and streams already mentioned empty into the Bay of Superior and the Bay of Allouez, and naturally seek Lake Superior through the "entry" between Wisconsin and Minnesota Points. However, a large proportion of the water flowing into Superior Bay does not now find its natural outlet, for the Duluth authorities have caused a canal to be cut across the northern end of Minnesota Point, for the purpose of allowing vessels to enter the "Inner Harbor" of the Bay of Superior directly from the lake. This canal has a width of 250, and a depth of 16 feet. As a strong current is continually passing through it into the lake, from the bay, it materially injures the harbor at Superior, seven miles down the bay, by directly lowering the water in the whole bay, and incidentally causing a filling up of the old channel through Superior harbor with a silt of fine sand and alluvium, brought down from the high lands by the streams. The deposition of the silt, etc., is very rapid indeed, and is caused by the greatly diminished velocity of the current in the old channel. I think it perfectly safe to predict that, if the waters of the bay are allowed to discharge at the present rate through the canal, it will eventually cause an entire closing up of the "entry," if not the filling up of the whole lower portion of the bay.

Mr. W. H. Newton was appointed by Governor Washburn, in the fall of 1872, an agent to make a special survey of Superior harbor. In his report he says: "Forty-three one-hundredths of the entire water flowing into Superior Bay * * * is directed to the Duluth canal." In summing up the results of his survey, Mr. Newton says: "The survey shows, 1st. A lowering of the water in the bay below any recorded mean year's elevation of nearly one foot. 2d. The bottom of the bay has been lowered a mean depth of 1 33-100 feet. The main channel has decreased in depth towards the entry, and increased in depth towards Conner's Point. The whole surface of the bottom has materially changed, and now there is much deeper water from Conner's Point to the Duluth canal than in 1861. 3d. A well defined change in the shore, indicating an abrasion below the surface of the water on Minnesota Point on the lake side, that, if continued, will sooner or later make a breach in the narrow portions of the point."

The Aminicon, or Spawn river, rises at Aminicon lake, five miles southeast of Black River Falls, flows a northerly course, and enters the lake nine miles east of Superior. Upon the upper waters of the stream there are several tracts of fine pine forest, as well as numerous swamps of cedar, spruce and tamarac. In descending the stream, the first rapids found, except very inconsiderable ones, are on Sec. 5, T. 47, R. 12 W., where porphyritic rocks were observed in situ. Above here, for six or eight miles, the stream has an average width of fifty feet, and the current is tolerably smooth, there being but few boulders in the stream. From the head of the rapids just indicated, the water dashes through chutes and down cliffs for a distance of nearly three miles to the northern part of Sec. 29, where there is a perpendicular fall of about 40 feet just above the junction of the Keweenawan eruptive rocks and the Lake Superior sandstone. From one-fourth mile above the fall to its head, the descent is about 100 feet. The stream divides a short distance above the sandstone, so there are really two falls; the branches however, soon unite, having formed a small island, one hundred or one hundred and twenty yards in diameter. From the fall the stream passes for a short distance through a gorge with sandstone walls, and then emerges into a narrow valley with clay banks. The descent is gradual from the falls to Lake Superior.

Middle river has been very little explored. It has its source in the great swamps to the south of the Copper Range, through which it flows a northeasterly course. Exposures were observed only on the south line of Sec. 35, T. 48, R. 12 W., and on Sec. 24 of the same township. At the latter point is the junction of the sandstones with the Keweenawan rocks. The exposures are on the left side of the river only. There are no rapids or falls which might not easily be descended during high water with a canoe, although the current is swift, and boulders, in places, numerous.

Poplar river, six or eight miles from its mouth, is a stream fifteen or twenty yards across, and is about the size of Middle river. The stream was carefully followed from Sec. 6, T. 47, R. 11 W., a distance of eight or nine miles to the north, and no rocks in place were found. It is a very rapid stream, and contains numerous boulders in its channel. The fallen timber and dense underbrush along its banks form a perfect jungle.

The Brule river is the largest and longest stream wholly within the district. The river has been very accurately described by Dr. Owen, as heretofore stated. It was also described by Mr. Frank Ives, whose manuscript report, submitted to Dr. Lapham in 1874, is at present in my possession. Facts have been taken from both reports, in order to complete the description, as I have followed the stream but about half its length. The head of the Brulé is less than two miles from the Upper St. Croix lake. Several small spring branches unite with the main channel in the northern part of T. 45, R. 11 W., and the exceedingly sluggish stream winds through dense cedar, tamarac and alder swamps, for a distance of eight or ten miles, to the dalles of the Brulé on Sec. 15, T. 46, R. 10 W. About four or five miles above the dalles on Sec. 30, commence the Upper Spring lakes. These lakes extend to within a mile of the dalles, and are usually merely former channels of the river. There are somewhat more than a dozen of them, each covering from three acres to a quarter of an acre. They are usually parallel to, and on the east side of, the main channel. They are not often more than five or six feet deep, but the water is very clear, and in the bottom of most may be seen jets of sand and fine gravel continually boiling up, varying in size from an inch to five or even ten feet in diameter. In passing over the surface of some of the larger lakes in a canoe, from fifty to a hundred of these springs may be counted. In these lakes are the breeding grounds of the vast numbers of brook trout that inhabit the upper waters of the Brulé. I have seen them, upon a clear day, in these lakes, as thick as minnows in a common pond. The bottom of the stream above these lakes, and of the much larger lakes immediately below them, contain a deep, loose black mud, filled with insects and worms, the favorite food of the trout. It has been aptly said that this is the angler's paradise. One may capture in a short time all that he can carry. Joseph Gheen, a half-breed Indian, has recently built a cabin upon Sec. 21, near the lakes, from which point he takes the fish during the winter months to Duluth and Ashland. About a mile below the Spring lakes, swift rapids are found about two hundred yards in length, and near the termination the river is only seven or eight yards wide. The fall of the river here is about fifteen feet, and the place is known as the Dalles of the Brulé. The banks are of clay and boulders only, and seven or eight feet high.

At the foot of these rapids is the third Pucwagawong (Chippewa Indian — a place where reeds or flags grow) or Flag lake. It is only 250 yards in length and perhaps 150 in width. From the foot of the third to the head of the second Flag lake there are rapids of not more than a hundred yards in length. The latter lake is a mile in length and from two to four hundred yards in width, with a depth of three or four feet. The bottom is very muddy, and it is said that during the summer, reeds, grasses and moss form an almost complete mat over the surface of the water. Descending a rapid of 150 yards in length from the second Flag lake, the first Pucwagawong lake is entered, of about the same size as the second, except that it is nearly twice as deep. Cedar swamps surround these lakes, and the banks are lined with boulders, which are also often seen in the lakes projecting above the surface of the water. From the foot of the first Flag lake, about the north line of Sec. 3, T. 45, R. 10 W., there are a number of rapids separated by short intervening bodies of slow water, to Sec. 23, T. 47, R. 10 W. Just above the foot of these "upper rapids," the Brulé receives its most important tributary, in the northern part of Sec. 27. The Nebagamain is the outlet of a lake by the same name. It is a small, swift stream not over fifteen or twenty feet across. The valley is narrow, and from 75 to 150 feet deep. Numerous boulders are seen in the banks but no rock in place.

From the foot of the upper rapids there is slack water for ten or twelve miles by the river, to the head of the lower rapids, near the south line of Sec. 26, T. 48, R. 10 W. From here the river may be said to be one continuous rapid, to within one and a half miles of Lake Superior. At first, for about three miles, to the south line of Sec. 15, the rapids are over Keweenawan eruptive rocks, and afterwards over sandstone. The fall from the first sandstone in Sec. 15 to the lake is about 200 feet. There are upwards of one hundred falls and rapids from here to the lake, but none of them have a perpendicular descent of more than four or five feet. At the head of each the water, from a comparatively quiet pool, leaps over the escarpment and glides quietly along over the smooth, clean sandstone to the next stair, falling in some instances over twenty or more such steps before it reaches the slack water at the head of the next fall.

The Brulé has no distinct "bottom-lands" from its source to its mouth. The stream follows a valley of its own excavation, from one hundred to two hundred feet deep, its entire length. From its head, to the head of the upper rapids, this valley is in places two or three miles broad, and is now occupied by swamps thickly grown up with white cedar, tamarac and alder. Below the upper rapids the valley is quite narrow, the clay and gravel banks, like escarpments of rocks, form bold and high shores, retreating a few feet, or rods, here and there at a bend or where a dry ravine extends into the uplands. Nor has the river more than a single important tributary. It drains, for so long and large a stream, an exceedingly limited area. The great springs adjacent to the barrens, and near its source, provide its main supply of water.

Iron river has many branches, nearly all of which originate along the base of the northwestern flank of the high land. There are many small springs at the heads of these streams, and the valleys are all deep and narrow. Occasionally there are swamps of a few acres in extent, along the larger branches, but usually the high lands come up on either side within a few rods of the stream. In sections 22 and 23, T. 49, R. 9. W., the main branches of Iron river are only from one-eighth to one-fourth mile from the main stream, and yet are separated from it by ridges from 75 to 125 feet in height. From the source to the mouth of Iron river, is almost one continuous rapid. There are no falls until within two or three miles of the lake, when red sandstone, the first rock *in situ*, is found. In many places the channel is badly blocked up with fallen timber.

Flag river also heads along the flank of the moraine. Its valley is deep but somewhat wider and more swampy than that of Iron river. There are no rock exposures along this stream.

Cranberry river is about twenty-five feet wide for a distance of three or four miles above its mouth. The current of the lower part of the stream is gentle, and the valley is broad. The small branches of the river are swift flowing streams, the largest of them having a fall of between 200 and 300 feet, in a distance of only two or three miles.

Siskowit creek is a small stream, heading at Siskowit lake and in the swamps of the vicinity, in T. 50, R. 6 W. It flows through a deep and narrow valley, heavily timbered to the water's edge. There are falls and rapids over the red sandstone from about three miles above Siskowit bay.

The rivers and streams already mentioned flow into Lake Superior. They are generally small, short and swift, and each has cut a tolerably straight and deep valley through the drift from its source to its mouth. They all pass through portions of the dense forest, which everywhere borders the south shore of Lake Superior.

St. Croix river heads in the Upper St. Croix lake, in T. 45, Rs. 11 and 12 W., and is tributary to the Mississippi. For the first few miles of its course, it is a rather rapid stream, the channel containing numerous boulders of granite, gneiss and Keweenawan eruptive rocks. From the mouth of Ox creek to Chase's dam, in Sec. 36, T. 44, R.

11 W., the current is very sluggish and quite deep, passing over a loose blackish sediment, and winding through a long swamp of cedar and tamarac. The limits of the swamp are usually less than a mile on either side of the channel, and in consequence of fires and the rise of water caused by Chase's dam, the former tamarac and cedar trees now stand as bare and blackened poles. From Chase's dam for something over twenty miles, the river very nearly follows the strike of the southward dipping reddish Keweenawan sandstones, which frequently crop out along the banks, and in the channel, forming swift and dangerous rapids.

It is only necessary to mention two of the tributaries of the St. Croix, the *Eau Claire* and *Moose rivers*. The *Eau Claire* is a small and gently flowing stream, issuing from the Eau Claire lakes. It has no tributaries, but passes from the lower lake, a distance of almost twelve miles, across the barrens to the St. Croix river.

Moose river heads upon the dividing ridge, in T. 45, Rs. 12 and 13 W., and flows directly south to the St. Croix. The upper portion of the river, and its branches, flow through swampy bottoms, in the immediate vicinity of great pine forests. The lower portion of the stream is very rapid, passing over the upturned edges of the southward inclining Keweenawan strata. Along this portion of the stream the barrens come up close on the east side.

Climate. The climate of the Lake Superior country is somewhat rigorous during the winter, and quite cool during the greater part of summer. In the vicinity of the lake shore, however, it is by no means so subject to sudden and great extremes of temperature as the inland district, several degrees to the south. For at least fifteen or twenty miles south of the shore, the temperature is considerably modified by the proximity of the vast body of water in Lake Superior. The cold winds of winter, in their long passage across the lake, which never freezes, are very sensibly warmed, and to some extent transfer their warmth to the country over which they pass. During the warm days of summer a cool breeze usually springs up from the lake towards evening, and the nights are always cool. Thus the great lake, although, of course, to a much less extent, has an oceanic effect in equalizing the temperature in its vicinity. A thermometer was kept for nearly a year at the head of the Brulé by Mr. Ives, and from him I learn that the mercury at that locality usually descends ten or fifteen degrees lower in winter, and rises about that much higher in summer, than at the United States signal station of Duluth, upon the shore of the lake. A study of all the meteorological observations which have been taken at Bay City (Ashland), Bayfield, Superior and Duluth, and at present (1874) accessible to me, shows a mean annual temperature at the lake shore of about 38° Fahrenheit. The spring months show a mean temperature of 34°; summer, 62°; autumn, 40°; and winter, about 15°. The prevailing winds in spring and summer are from the northeast; in autumn and winter from the southwest. The annual rain fall and melted snow is about thirty-seven inches. Winter sets in about the last of October, and continues cold and usually clear until the first of

April, in ordinary seasons. In 1873 we had freezing nights in the early part of September, on the Copper Range, and a heavy snow storm upon the third of October. The snow usually lies from three to four feet deep in the forest all winter. In 1877, the snow was nearly gone on the 10th of April, and all gone by the first of May, although ice was found in the swamps two or three weeks later. Maple buds were considerably expanded April 25th, and a week later the first flower *(Ranunculus)* was noticed in the barrens. It may be stated, however, in this connection, that the spring of 1877, in this district, was about a month earlier than usual.

On the south slope, in the vicinity of the Upper St. Croix, the seasons are generally two or three weeks earlier than on the north slope. This is partially due to the more sandy character of the soil. Strawberries ripen on the south slope about the first of August; along the north slope and on the Apostle Islands, from the middle to the last of August. Very little in the line of agriculture has been accomplished in this district, but enough has been done to demonstrate the adaptability of the staple cereals, wheat, oats, rye and barley, to the climate. Winter wheat especially thrives, as it is effectually protected from the frosts of the winter by a deep but light coating of snow. In the few trials as yet made with this grain, from forty to sixty bushels to the acre have been realized. The climate and soil appear to be well adapted to the growth of the potato. Large crops of the finest potatoes that I have ever tasted are raised at Superior City. There are but three or four farmers living in the district, and not more than 300 or 500 acres have been cleared for agricultural purposes in Douglas and Bayfield counties, having an area of upwards of 3,000 square miles.

Soil. Within the limits of this district there may be distinguished four classes of soils. With one exception they owe their origin entirely to the drift, and mainly to the reärrangement of the drift since its deposition. It is not intended to attempt a critical description of the soils, nor to give the exact areas occupied by each, only to notice them in a general way, and to approximately place them. There is perhaps no area of equal extent in the state characterized by as radically different soils as this. While they often imperceptibly grade into each other, the main areas of the various soils can usually be recognized by a glance at the various classes of vegetation which they support. A good soil map of northern Wisconsin would very accurately show the distribution of timber, as may be noticed from an inspection of the accompanying outline map.

Class I. The red marly clay soil. This soil has been so excellently described by Professor Chamberlin, on page 193 of the second volume of the Geology of Wisconsin,

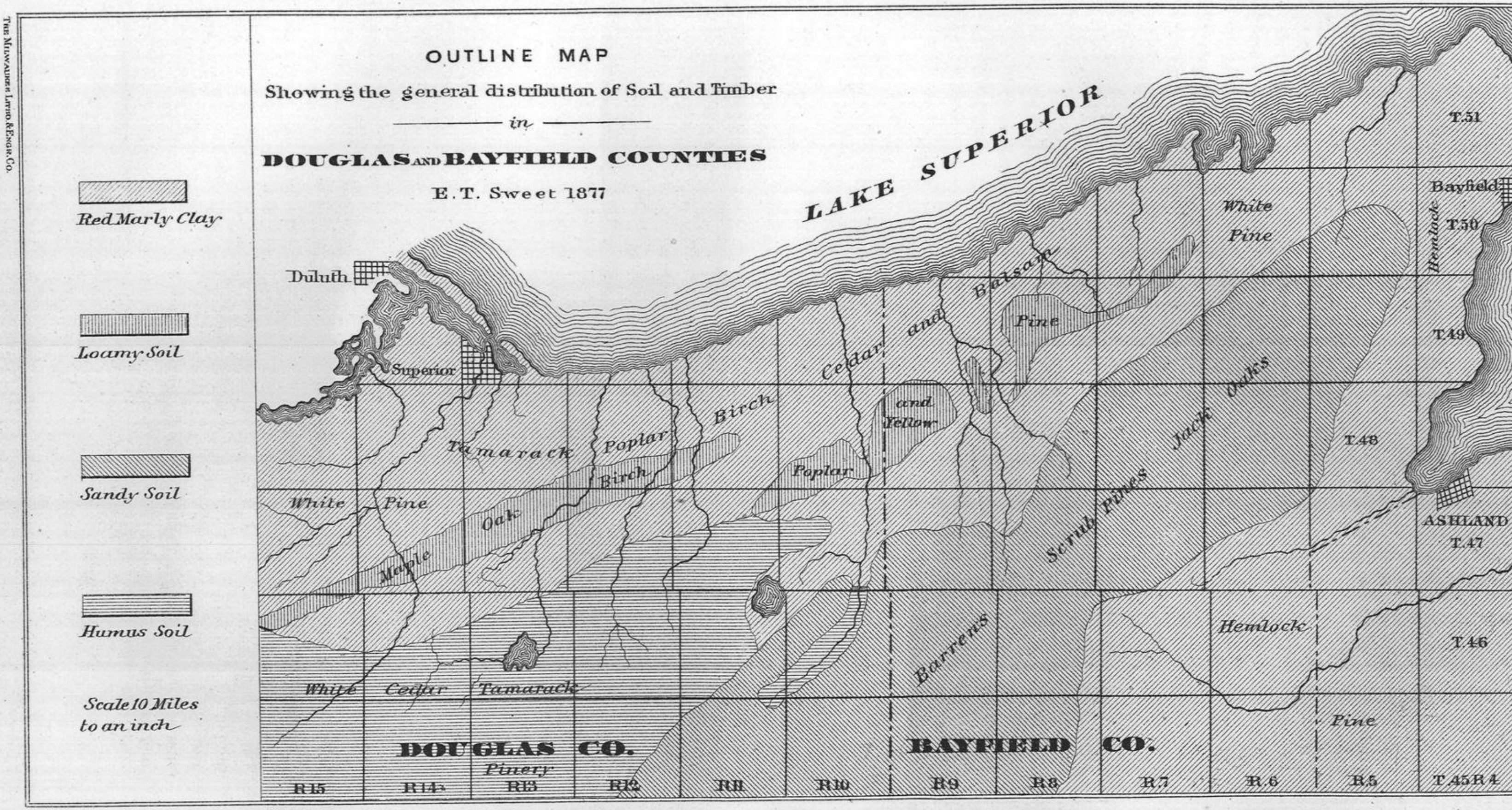


PLATE XXXIII.

that it requires but a brief notice in this connection. It is the predominant, and almost exclusive soil on the north slope of the district. It is usually covered with a very slight coating of humus or vegetable mould, which is frequently so light that a slight scraping with the foot exposes the surface of the red clay, which, interstratified with layers of fine sand, is many feet in depth. The physical properties of this clay, so far as I have observed, are the same, whether taken from the surface, or several feet below it. Where it is unmixed with sand, it is very tenacious, and is exceedingly retentive of moisture, making a "heavy, cold" soil. As a general rule, it contains too little sand, in the Lake Superior country, to give it the most desirable drainage and "lightness" for agricultural purposes in this latitute. It however appears to be an excellent grass soil. In the eastern part of the district it is heavily timbered with hemlock and pine, and in the western portion with scrub pines, poplar, birch, balsam and spruce. An analysis of this class of soil, from near Ashland, will be found below. It is typical of the red clays, and was made for the survey by Mr. T. E. Bowman.

Class II. Loamy soil. This soil is found on the summit of the Copper Range and a short distance to the south of it. It is also found on the high ridges to the east of the range, and at places along some of the river valleys. It contains more sand and much more decomposed vegetable matter than the marly clay soil, and is in every way its superior. On the Copper Range it mainly owes its origin to the decomposition or wearing down of the Keweenawan eruptive rocks, while at other places the clay has been partially washed from the sand, often to the depth of several feet. When it is found in the vicinity of the large streams, it often has many of the characteristics of an alluvial soil. The loamy soils are timbered with a medium growth of poplar, maple, birch, oak and balsam. Below is given an analysis of this soil, found in Mr. Ives' manuscript report.

Class III. Sandy soil. The area occupied by this soil is known as the "Barrens" of Bayfield and Douglas counties. It is nearly coëxtensive, as far as this district is concerned, with the great moraine and Kettle range, extending to the southwest from the Bayfield peninsula. This soil is made up, to a great depth, of light colored, rounded grains of quartz, frequently mixed with fine gravel. There are exceedingly few boulders scattered over the country occupied by this soil. It owes its origin, of course, to the drift. This soil is of the poorest quality. It sustains but a scant growth of stunted scrub pines. It contains no vegetable mould, and only here and there bears a tuft of grass. Fires have passed over the "Barrens" recently, during very dry seasons, and destroyed in many places the little timber that formerly existed on the soil. Now there are areas of eight or ten miles in length, notably along the east bank of the upper Brulé, upon which there are no trees or shrubs, and very little vegetation of any kind. These treeless areas contain no streams, and very few lakes, while the remainder of the sandy district, although showing no streams, has an abundance of small lakes. I think, however, that the scant vegetation of the "Barrens" is not mainly due to a lack of water — for the trees are no larger about the lakes than elsewhere — but to an insufficient supply of proper plant food in the soil.

Class IV. Humus soil. Following the example of Professor Chamberlin,[1] I include under this head only the swamp soils, or those which are composed largely of decomposed vegetable matter. Nearly the whole of the southwestern part of the district is occupied by the humus soil. This soil varies in depth from one to even ten or twenty feet, and is usually underlaid by the red marly clays. It is made up of a small proportion of earthy matter associated with decomposed vegetable substance which has resulted from the decay of fallen trees, twigs and leaves, and also from the accumulation of moss with which the surface of the swamps is heavily coated. In some places, *e. g.*, south of Superior City, for a distances of five or six miles, the surface of the coun-

[1] Geology of Wisconsin, Vol. II, p. 195.

try partakes somewhat of the characters of a swamp. The vegetation belongs to the swampy class, and the soil is covered with humus and moss several inches deep, underlaid by red clay. Some parts of these semi-swamps are true small swamps, but in general, these large areas have rather a marly clay, than a humus soil. These semi-swamp lands are often among the best in the district for agricultural purposes. On the typical humus soils there is always a dense growth of white cedar, tamarac and spruce.

The following analyses are introduced simply to show the general composition of the above mentioned soils. Nos. 1 and 2 are by Mr. T. E. Bowman; they were made simply as clay, not as soil analyses. Nos. 3 and 4 are from Mr. Ives' manuscript report:

Soil Analyses.	1. Red Clay from Ashland.	2. Siliceous Red Clay from Ashland.	3. Loamy Soil from Douglas County.	4. Sandy Soil from Barrens, Douglas County.
Organic matter	......	....	9.60	.80
Silica	48.74	57.60	[1]80.36	*94.08
Alumina	34.72	25.85	2.90	.74
Per-oxide of iron	4.40	4.11	.90	1.00
Calcium carbonate	4.31	6.40	1.01	1.15
Magnesium carbonate	4.01	3.53	.86	.26
Moisture and water	4.09	2.57	3.15	.37
Total	100.27	100.06	98.78	98.40

Timber. The great forest, of which the Western Lake Superior district is but a small part, occupies the northern half of Wisconsin, nearly the whole of Michigan, the northern part of Minnesota, covering the country far to the east and west of these states, and stretching away to the north for an unknown distance into the British possessions. In Wisconsin and Michigan, the forest is exceedingly dense, and in the forests of these states there are at present the most considerable lumbering districts of the world. The pine lumber annually manufactured in Wisconsin alone exceeds one thousand millions of feet. In 1875 it was 1,097,443,681 feet.[2] Notwithstanding this vast annual yield, there is sufficient pine lumber in Wisconsin to supply the demand for many years, if the tracts of pine still uncut shall be efficiently protected from the ravages of fire. It is perfectly safe to state that in Wisconsin more pine lumber is yearly destroyed by fire than is felled by the woodman's axe. The fires usually originate during the dry season, through the carelessness of explorers in leaving their camp fires. Sometimes they start from a fire set to burn off the dead grass from an acre or two of some of the "hay meadows" in the district. The dry tops of the pine trees, which are allowed to remain where they fall by the lumbermen, greatly assist the spreading and destructiveness of the fires. Trees left standing among the fallen tops of others are always killed by the fires, and in the course of a year, become decayed and worm-eaten, and totally unfit for lumber. During the past two or three years, which have been unusually dry, extensive fires have swept over northern Wisconsin and devastated several thousand square miles of territory, and destroyed many thousand acres of most

[1] Insoluble silicates.

[2] See "State of Wisconsin," a pamphlet published for distribution at the Centennial Exhibition, p. 11.

excellent pine. By the term "pinery," or "pine lands," must not be understood a tract *exclusively* occupied by pines; indeed, areas upon which pine, suitable for lumber, is the prevailing timber, are the exception rather than the rule in northern Wisconsin. If a tract of several hundred acres occurs in the vicinity of a stream, by which the logs may be conveniently floated down to the saw mills, sometimes a hundred or more miles distant, and has an average of one or two trees of two or three feet in diameter per acre, it is classed as "pine land." Of course there are small areas of over a hundred fine lumber pine trees to the acre, but such areas are not of frequent occurrence.

In the Western Lake Superior district, we find all the classes of timber represented which are found in the above-mentioned great northern forest. The accompanying plate, which is an outline soil and timber map, will show at a glance the general distribution of the timber. It is not intended to present the details of the forestry of the district. The plate is upon too small a scale to represent small areas. Only the prevailing timber upon important areas is designated. In the eastern part of the district, hemlock is the prevailing growth, although there are small areas of valuable pine lands; and also localities upon which sugar maple is the predominating timber. The hemlock trees are usually from one to three feet in diameter, and stand quite close together. Red pine, birch, white cedar and aspen, are often found scattered among the larger hemlocks. As yet there have been very feeble attempts made to utilize either the hemlock bark or timber. It is well known that hemlock bark is regarded as inferior to none for tanning purposes. But a very few cords have been shipped down the lakes to the tanneries from Bayfield and Ashland counties, where it is found in almost inexhaustible quantities. In the opinion of the writer, a manufactory established at Ashland or Bayfield, for the purpose of producing the "extract of hemlock bark," to be shipped and used in tanning leather, would be a valuable investment.

Along the lake shore in Douglas county and extending into Bayfield county, and reaching back as far as the Copper Range, there is a very dense growth of small trees consisting of about equal numbers of poplar, birch, cedar and balsam. These trees are ordinarily less than a foot in diameter, and from twenty to eighty feet in height. In this area, large white pines are frequently found, as are also the red or Norway pines, and sometimes elm, basswood, spruce and tamarac. The underbrush and vast numbers of fallen trunks of trees, make traveling in this area extremely arduous.

On the Copper Range, and on the high ridges to the east and south of it, the prevailing growth is sugar maple, black oak, birch, poplar and yellow pine. These trees are generally less than eighteen inches in diameter and are not nearly so close together as those farther north, just mentioned. Scattered among them occur cedar, tamarac, balsam and white pine trees. To the south and southwest of the Copper Range there is a large tract of country occupied mainly by dense swamps of cedar and tamarac. The trees are small, generally being from six to ten inches in diameter, and often so close together that it is with great difficulty that a person can pass between them. In the swamps, and associated with the cedar and tamarac, are often found balsam and spruce. Between the swamps there are frequently narrow ridges of drift upon which grow pine, birch and poplar. Several small areas of pine have been indicated upon the accompanying plate, but it must not be understood that pine in each case is the prevalent growth; only that these areas contain valuable pine lands. North of Siskowit lake, there is some very fine pine. Excellent white pine is also found upon the head waters of the Nemadji river and on the upper waters of Moose river. Along the banks of the Upper Brulé there are narrow belts of beautiful red or Norway pine. They stand on the high sandy banks of the river unassociated with other trees. They are from one to two feet in diameter, and often are perfectly straight, and without a limb for from fifty to eighty feet from the ground. These "Norways" would make very superior spar timber.

The "barrens" have a timber growth exclusively their own. The trees are either scrub pines, or black-jack oaks, averaging in diameter about three or four inches and in height not over fifteen feet. In some places, as on the sand hills of the barrens, the trees are at considerable distances from each other, and in other places the little scrub pines, not over two inches in diameter, are so close together as to constitute a nearly impenetrable thicket. On the sides of the barrens, and in low places, quite large groves of Norway pines are frequently found.

The following list comprises all of the trees and shrubs that I have noticed in the Western Lake Superior district. Those marked with an asterisk are scarce and were rarely observed. A complete catalogue of the trees and shrubs is not contemplated.

LIST OF TREES AND SHRUBS NOTICED IN THE DISTRICT:

Common Name.	Scientific Name.	Locality where Observed.
Basswood*	*Tilia Americana*	Copper Range, Douglas Co.
Sugar Maple	*Acer Saccharinum*	Copper Range, Douglas Co.
Red Maple	*Acer rubrum*	Southwest of Siskowit lake.
Mountain Ash*	*Pyrus Americana*	Flag river.
Bunch Berry*	*Cornus canadensis*	Cranberry river.
Kinnikinnik	*Cornus sericea*	Swamps, Douglas county.
Red-osier (Kinnikinnik)	*Cornus stolonifera*	Swamps, Douglas county.
High-bush Cranberry*	*Viburnum opulus*	Wisconsin mine.
Common Cranberry*	*Vaccinium Macrocarpon*	Swamps, Aminicon river.
Blueberry	*Vaccinium Pennsylvanicum*	Barrens (very common).
Blueberry (Huckleberry)	*Vaccinium canadense*	Swamps, Moose lake.
Huckleberry*	*Vaccinium corymbosum*	Moose lake.
Black Ash*	*Fraxinus Sambucifolia*	Head of Aminicon river.
Moose-wood	*Dirca palustris*	Copper Range.
Crowberry*	*Empetrum nigrum*	Siskowit lake.
Elm	*Ulums Americana*	Poplar river.
Burr-oak*	*Quercus macrocarpa*	Copper Range.
Jack-oak (Scrub-oak)	*Quercus nigra*	Barrens.
Black Oak	*Quercus tinctoria*	Copper Range.
Hazle-nut	*Corylus Americana*	River banks and bottoms.
Iron-wood*	*Ostrya Virginica*	Copper R., banks of streams.
White Birch	*Betula alba*	With heml'ks, n'r Bayfield.
Canoe Birch	*Betula papyracea*	South of Copper Range.
Yellow Birch	*Betula excelsa*	Copper Range, and south.
Black Alder	*Alnus incana*	Head of most streams.
Hoary Willow*	*Salix candida*	Mouth of Flag river.
American Aspen, (Poplar)	*Populus tremuloides*	Common everywhere.
Large-toothed Poplar	*Populus grandidentata*	Common everywhere.
Balm of Gilead*	*Populus candicans*	Aminicon river.
Scrub Pine	*Pinus banksiana*	Barrens, common.
Red Pine (Norway)	*Pinus resinosa*	Upper Brulé, common.
Yellow Pine	*Pinus mitis*	Copper Range.
White Pine	*Pinus strobus*	Head Moose river, common.
Balsam	*Abies balsamea*	Common everywhere.
Black Spruce	*Abies nigra*	Siskowit lake, swamps.
White Spruce	*Abies alba*	Swamps, south of Copper R.
Hemlock	*Abies canadensis*	Eastern Bayfield county.
Tamarac	*Larix Americana*	Swamps, common.
Cedar (Arbor Vitæ)	*Thuja accidentalis*	Swamps, common.
Ground Hemlock	*Taxus canadensis*	Eastern Bayfield county.

Game. There is very little wild game in the district. In places the Virginia deer are quite plenty. Moose are also occasionally found. There are also a very few gray wolves, lynxes, wolverines and brown bears. Porcupines, woodchucks and red squirrels are quite frequently seen. The fur-bearing animals, as the beaver, otter, mink, fisher, and marten, although found in the district, are very rare indeed. The only game birds that are found in the district are the ruffled grouse or partridge, which is quite abundant, the spruce partridge, which is rather rare, and the pigeon, which is very seldom seen. Birds of all kinds are scarce in the Lake Superior country; indeed a person may sometimes in the spring or autumn travel for a day through the forest without meeting a half dozen birds. The following list comprises all that have come under my observation in the district: Ruffled grouse, spruce partridge, pigeon, robin, hermit thrush, black wood cock, black backed woodpecker, sap sucker, high holder, red winged blackbird, purple grackle, snow bird, yellow throated vireo, horned owl, screech owl, blue jay, mallard, wood duck, teal, fish duck, red breasted merganser, hooded merganser, chipping sparrow, pine finch, red crossbill, common crow, raven, sparrow hawk, and the red tailed hawk.

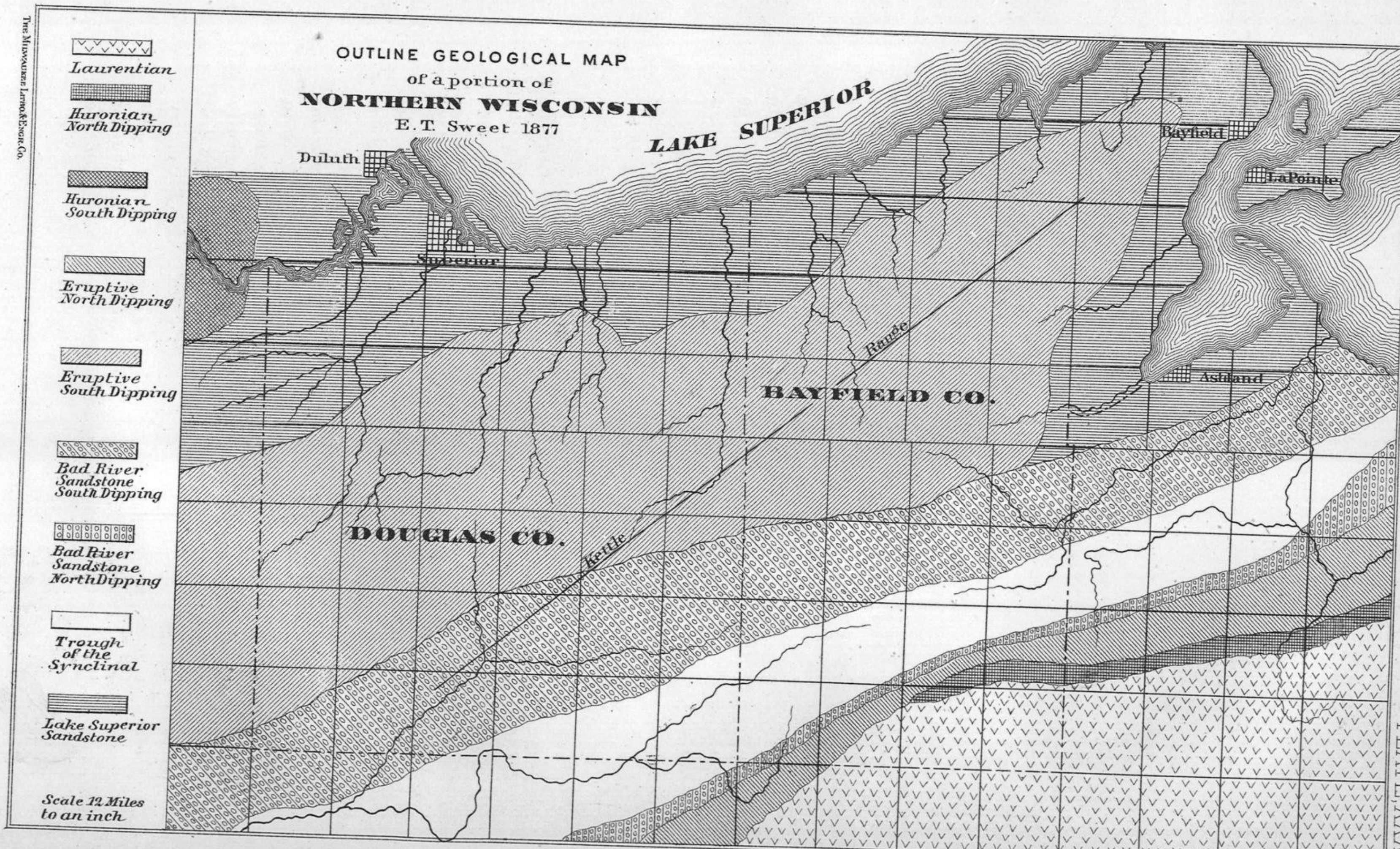
CHAPTER II.

GEOLOGICAL FORMATIONS.

GENERAL GEOLOGICAL STRUCTURE OF THE DISTRICT.

The geology of the southern shore of Lake Superior has been for many years a fertile theme, upon which numerous warm discussions and earnest controversies have taken place among geologists. The main points of difference of opinion have been in regard to the age of the several geological formations found upon or in the immediate vicinity of the south shore of the lake. The results recently obtained in northern Wisconsin, taken in connection with those previously reached by Brooks and Pumpelly in northern Michigan, add much to our knowledge, however, and give us nearly as complete a knowledge in regard to the structure of northern Wisconsin as is had of any other portion of the state.

The principal results of the geological researches in the above mentioned districts are discussed at some length in Part I of this volume. The following is a brief summary statement of the main points bearing upon the geology of our district: The whole northern portion of Wisconsin, to within fifteen or twenty miles of Lake Superior, on the northeast, and say fifty or sixty towards the northwest, is occupied by highly crystalline granite, gneissic and chloritic rocks, which have been referred to the *Laurentian* formation. These rocks have commonly a strike of but a few degrees north of east, and a high dip either to the north or south. Unconformably overlying them on the north are found the *Huronian* strata, consisting of silicious marbles, quartzites, silicious schists, containing magnetite and specular iron ores, black slates and diorites, etc., in all, some 13,000 feet thick, and dipping constantly to the north. Overlying the Huronian strata in Ashland county is the *Keweenawan* system, having a thickness measured by miles, and consisting of a great variety of rocks lithologically distinct, among which may be mentioned diabase, felsitic porphyry, melaphyr, conglomerate, sandstone and shale. The belt of country occupied by these rocks is locally known as the Ashland County Copper Range. It is a westward prolongation of the great Mineral Range of Keweenaw Point, upon which the most noted copper mines of the



OUTLINE GEOLOGICAL MAP
of a portion of
NORTHERN WISCONSIN
E. T. Sweet 1877
LAKE SUPERIOR
Duluth
Superior
Bayfield
LaPointe
Ashland
BAYFIELD CO.
DOUGLAS CO.
Kettle
Range
Laurentian
Huronian North Dipping
Huronian South Dipping
Eruptive North Dipping
Eruptive South Dipping
Bad River Sandstone South Dipping
Bad River Sandstone North Dipping
Trough of the Synclinal
Lake Superior Sandstone
Scale 12 Miles to an inch
The Milwaukee Litho. & Engr. Co.

PLATE XXXIV.

world are worked. This range enters the state of Wisconsin in the extreme northeast corner, extends in a southwesterly direction entirely across the state, and enters Minnesota in a broad belt, between the mouth of Kettle river and Taylor's falls, although in this region it is mainly covered by the rocks of later formations. Along the course of this belt the rocks dip constantly to the north, the angle of dip decreasing and the surface width increasing as the formation is traced westward. These northward-dipping rocks seem to form the southern side of a synclinal, of which the southward-dipping beds of our district form the northern side. The northward-dipping beds lie wholly without the region now under consideration, and will be found described in other portions of this volume. We may then pass at once to the consideration of the southward-dipping beds which underlie the whole of our district, even those portions where the horizontal sandstone is now the surface rock.

In northern Wisconsin there are no southward-dipping rocks which can be referred to the Huronian. In Minnesota, however, along the St. Louis river, and approaching within two or three miles of the northwest corner of Wisconsin, there are strata, which, although at present not absolutely known to be Huronian, may, with very little doubt, be referred to that formation. Lithological characters alone, were they to be entirely depended upon, would assign the formation at once to the Huronian. It is made up principally of chloritic and silicious slates, which occasionally grade into heavily bedded quartzite. The slates are found along the St. Louis river from Knife falls to Greeley, a distance of ten or twelve miles. The general strike is about N. 85° E. (magnetic), and the dip, although somewhat variable, about 40° to the south. As but a very short time was spent in examining these slates, their junction with the Keweenawan rocks was not found, but they apparently underlie the latter, which are found at some distance to the south of them. Moreover, dykes are found, at various localities, especially along the Dalles of the St. Louis, at Thompson and at the "Junction," which cut through the beds of slate and silicious schist, and consist of a very coarse-grained gabbro, similar to that lying at the base of the Keweenawan, in Ashland county, and largely exposed at Bladder lake. These dykes are probably simply veins or small branches which were thrust into, or up through, the slates, from the main eruptive mass, and are of contemporaneous origin with the Keweenawan gabbro. Further facts in regard to the slates of the St. Louis river will be found on a subsequent page.

Undoubted Keweenawan rocks are found in Douglas county, twelve or fifteen miles southeast from the eastern end of the St. Louis slates.

They extend entirely across the county, outcropping in a more or less broken line, and forming the well known Douglas county "Copper Range." The trend and dip of this formation, although occasionally quite indistinct, are nevertheless, as shown by a great number of perfectly reliable observations, nearly uniform. The general strike is about N. 60° E. (magnetic), and the dip 36° to the south. The dip appears to be a little greater at the eastern than the western end of the range. It will be observed that the dip and strike do not differ materially from those of the above mentioned slates. Owing to the vast deposits of drift in this vicinity, the croppings of the formation can not be traced at most more than three or four miles in a north and south direction, anywhere along the entire length of the range, which is about thirty miles. Southward from the Copper Range for a distance of nearly twenty miles, the drift effectually conceals all underlying strata from view. On Moose river, in the northern part of township 44, Keweenawan rocks again make their appearance, and are overlaid by conglomerates and sandstone, all dipping about 18° in a southward direction, and trending N. 55° E. On the St. Croix river, in townships 42, 43 and 44, there is a bed of reddish sandstone, which directly overlies the above mentioned conglomerates and Keweenawan strata. The entire thickness of conglomerates and sandstones is about 9,000 feet. The dip of the sandstones is about 14° to the southward, the strike being N. 65° E. (mg). These sandstones crop out in Minnesota on Kettle river, six miles above the falls of that stream.[1] In Wisconsin, they are found thirty-two miles north of east from the St. Croix river, in Bayfield county, on the upper waters of White river,[2] again on White river, six miles south of Ashland, and on Bad river at Leihy's falls, in the southern part of township 47. On White river, near Ashland, the exposed thickness is but a few hundred feet, and the dip 25° southward. On Bad river, the exposed bed shows a thickness of 2,000 feet, and dips 38° in a southerly direction. The dip, then, of the southward inclining strata, like that of the northward dipping formations in northern Wisconsin, *decreases in following the strike from east to west.* The decrease, however, is not so great on the north as on the south. This not only is proven from actual observation, but is in entire accordance with and explains the relative widths of the belts in northwestern Wisconsin, occupied by the northward and southward dipping formations.

Lying between the Douglas county Copper Range and Lake Superior and skirting the lake shore nearly as far as Ashland, lying at the

[1] See Owen's Geol. Survey of Wisconsin, Iowa and Minnesota.

[2] Owen, in an old executive document.

base of the Apostle Islands, are the horizontal reddish sandstones, known as the *Lake Superior sandstone.* These occupy a narrow belt in the vicinity of the lake shore, are found in contact with, and are unconformable to, the cupriferous series of Douglas county, and the slates of the St. Louis river. On account of the drift they are seldom or never seen, except along a few of the streams, or on the lake shore. After the laying down of these sandstones, which were formed, certainly at latest, during the early commencement of the Silurian, they are not positively known to have been covered by later deposits until the period of the glacial drift. They were therefore subject, with the previous formations, for a very long space of time, to eroding influences.

During the period of the *Glacial Drift* this district was subjected to powerful glacial action. The deposits of clay, sand, gravel and boulders have a thickness of several hundred feet, and cover almost the entire country. There are also evidences of the former existence of great streams of water flowing from the melting or retreating glacier. Much additional information will be found upon this, and other points above referred to, under the proper subjects, in the succeeding pages of this report. A reference to Plate XXXIV of this volume will give a clear idea of the general geological structure of the district. A glance at the following table will readily serve to convey a definite impression in regard to the order of the geological formations of the Western Lake Superior district:

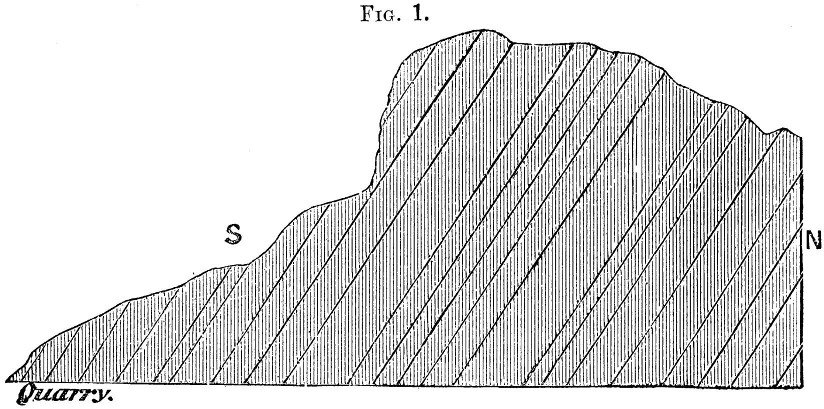
QUATERNARY.	*Recent.*	— River, lake and swamp deposits.
	Champlain.	— Stratified, red marly clay, and sands.
	Glacial.	— Boulders, gravel, sand and clay, 200 to 500 feet.
LOWER SILURIAN.	*Probably Potsdam.*	Lake Superior red sandstone, having a known thickness of 400 to 600 feet, and probably much greater.
ARCHÆAN.	*Keweenaw, or Copper-Bearing Series.*	Detrital strata, consisting of conglomerates, breccias, sandstones and shales, mainly overlying melaphyr, etc., having a south dip and maximum thickness of 9,000 feet.
		Eruptive strata — consisting of melaphyr, diabase, porphyry, gabbro, etc., having a south dip, and apparent maximum thickness of over 36,000 feet.
	Huronian.	Quartzites, silicious and chloritic slates. Along the St. Louis river, many thousand feet thick.

The Huronian Slates of the St. Louis River. These slates, although without my district, and indeed beyond the limits of Wisconsin, are nevertheless so close to it, and so intimately connected geologically with the adjacent Wisconsin formations, that a complete understanding of the relations of the latter seems to require at least a hasty description. These slates are referred to the Huronian for several reasons, among which are the following: They apparently occupy the same stratigraphical relations to the Keweenawan formation as the undoubted Huronian in Ashland county; that is, they underlie it. There are numerous dykes near the slate quarries at Thompson, and particularly at the junction, of from ten to one hundred feet in width, which cut the slates, and consist of precisely the same rock as that found at the base of the Copper-bearing Series in Ashland county. I regard these dykes as small branches, or ramifications, from the main mass of Keweenawan gabbro. If such is the case, they of course not only show the slates to be more ancient, but go far towards proving the eruptive origin of the Keweenawan massive rocks. The slates are certainly older than the Lake Superior red sandstones, for half a mile below Greeley, conglomerate and red sandstone unconformably overlie them. Finally, their lithological characters are typically Huronian. No considerable thickness of silicious slates and quartzites is known in the region of the great lakes, which is referable to either the Laurentian or Keweenawan. There is very little danger of error, then, in assigning them to the Huronian.

Local details. At a small town, called Junction, on Sections 1 and 12, T. 48, R. 17 W., the Huronian rocks are very largely exposed. Some of the layers are harder than others, and have resisted eroding influences much better, so that well defined ridges have been left from fifty to two hundred feet in width and often a mile or more in length. These ridges are nearly vertical on the north, but slope off with the general dip of the layers to the south. The rock at this place consists largely of chloritic schist, which frequently passes into a chloro-siliceous slate; although the slaty structure is not so well marked here as a couple of miles to the east. Veins of quartz, from a few inches to several feet in thickness, are found occasionally traversing the strata. The dykes of gabbro, above referred to, are mainly transverse to the bedding of the slates, and are nearly vertical. Their only effect on the slates seems to have been a slightly increased degree of contortion in the vicinity of the dykes. All of the slates, in fact, are much more contorted at this locality than at Thompson. The surface rock in the dykes is always considerably decomposed, and it is very difficult to obtain an unaltered specimen. Weathering changes the rock from a dark greenish black, coarse grained mass, to a brownish yellow, clayey material, which when dry crumbles readily. The slates weather rather light-colored. The strike of the formation here is N. 85° E., and the dip from 35° to 40° to the south. The layers are from one to five feet in thickness, but each layer is cut by a great number of fine joints into thin plates of slate. These joints, which form the plates of slate, always have the same strike as the formation, and so far as observed make an angle with the upper surface of the layers of from 32° to 36°. At the Junction the dip of the joints is from 69° to 76° S. The following section, taken at one of the slate quarries near Thompson, will explain the system of bedding and jointing of all the St. Louis slates.

At Thompson there are many hundred acres of the Huronian strata entirely exposed. As at the Junction, ridges, owing to unequal weathering, are of frequent occurrence. Dykes of gabbro are also often seen traversing the strata. A quarter of a mile northeast from the depot, two slate quarries have been quite extensively worked. The section below was taken at the western end of the largest quarry. Here the strike is N. 85° E., and dip 58° S. The dip of the slaty joints is 88° N. At one of the quarries, about 300 feet of the bed has been worked, and at the other not over 75 feet. The slate here shows less contortion than that observed at any other place along the St. Louis, but it is nevertheless considerably warped, so much so as to render it unfit for anything except roofing slate, and that would have to be selected with care. It was owing to this

FIG. 1.



SECTION AT ONE OF THE THOMPSON, MINNESOTA, SLATE QUARRIES.

Layers of rock from 4 inches to 6 feet thick. Plates of slate from 1-16 to 1-4 inch in thickness.

fact that the quarries were several years ago abandoned. Some of the most siliceous slates contain a considerable number of disseminated crystals of iron pyrites. The slates obtained at these quarries are quite dark colored and of medium hardness. A short distance both north and south of the quarries there are beds composed of lighter colored and more siliceous layers, which show the transverse slaty cleavage somewhat imperfectly. These beds are mainly quartzite. At the rapids, near the center of Sec. 31, T. 49, R. 16 W., which was as far as I could ascend the stream, the beds are exposed in heavy layers, having the same strike, dip and jointage as at the quarries.

The dalles of the St. Louis commence one-eighth mile above the railroad bridge at Thompson. Just above the bridge, two small islands cut the stream into three channels during high water, which unite nearly under the bridge. At the bridge the cañon is only 33 feet wide, and the walls are fully 75 feet high. On these cliffs there are potholes and evidences of former channels, which prove that the gorge has been entirely excavated by the eroding action of running water. The rock here is lighter colored and more talcose than at the quarries, in consequence of which, of course, it is somewhat softer. It, however, preserves the same bedding and jointage as before. About one-half mile below Thompson, at the first rapids, the strike remains N. 85° E., but the dip is only 48° S., and the slaty joints dip 80° S. Several exposures below this do not show any unusual petrographical structure or stratigraphical characters.

Near the center of Sec. 11, T. 48, R. 16 W., not quite two miles from the northwest corner of the state of Wisconsin, conglomerates begin to overlie the slates.

The very round pebbles of the first exposure of conglomerate seen in descending the stream, are principally white quartz, from one-eighth to three inches in diameter, and the matrix iron pyrites with a little red sand. The bed of conglomerate dips 8°, S. 15° E. Fifteen or twenty rods below these conglomerates, there is another ledge of nearly horizontal conglomerate, made up of quartz and greenish slate pebbles, cemented mainly by sand, and abutting against greenish chloritic slates. The slates trend nearly east and west and dip about 40° S. Several small veins of white quartz traverse the slates just above the junction of the slates and conglomerate. There is no doubt that this conglomerate and all overlying the slates, was formed from the wearing down of the Huronian strata. The quartz pebbles came from the veins of that mineral, cutting the slates; the slate pebbles from the slate, and the greenish part of the matrix from the chloritic slates. Nearly two hundred feet from the junction of slate and conglomerate, there is an exposure in the bank of the river at a height of twenty feet, of a dome-like protrusion of slate five feet high, covered by nearly horizontal conglomerate, similar to that above mentioned. On the opposite, or south side of the stream, the conglomerate is overlaid by twenty or thirty feet of Lake Superior red sandstone. The conglomerate grades upward into the sandstone. On the north side of the stream, an eighth of a mile below this, at the last exposure of the slates, there are several outcrops of conglomerate, which become much finer in descending the river, and are overlaid by greenish and reddish shales and red sandstone. The conglomerate dips from 5° to 10° S. It doubtless owes this dip to its original deposition on the inclined surface of the southward dipping slates. One of the last conglomerate exposures is largely made up of iron pyrites as the matrix. This has been prospected to some extent for gold. It is said that traces have been found. It is also said that the slates on the Blackhoof creek, in about the southwest corner of T. 48, R. 17 W., have been prospected for gold.

THE COPPER-BEARING SERIES.

The rocks which are regarded as making up the Copper-bearing or Keweenawan Series, consist of two classes, widely distinct in character. The one, including mainly the lower and oldest member of the formation, consists of eruptive diabase, melaphyr and allied rocks, showing a distinct stratification and having a thickness of many thousand feet. The other, and mainly younger class, includes conglomerate, sandstone and slate. The latter embrace a thickness on the Moose and St. Croix rivers of nearly 9,000 feet, including one or more thin beds of eruptive rock, and are conformably associated with the crystalline or Keweenawan rocks. They show definitely that they originated from the wearing down of the underlying strata, and were deposited previous to the tilting of the latter.

The eruptive rocks, with a southward dip, cover about 1,100 square miles, in Douglas and Bayfield counties. They are separated from Lake Superior by a belt of horizontal reddish sandstone, from five to ten miles wide. The line of junction on the north is somewhat curved, but in the main pursues an E. N. E. course, nearly parallel with the strike of the crystalline strata. At no point has the absolute undisturbed contact been observed. Most of the northward flowing streams in Douglas county, leave the crystalline area and enter upon the sandstone district through deep gorges and in wild and precipitous falls. In the walls of these gorges both formations are usually beautifully exposed, but the sandstone, for a distance of from twenty to three or four hundred feet from where we would expect to find the point of contact, has evidently been affected by some great lateral pressure, for we find the layers broken into short lengths, and tilted at various angles, generally to the northwest or from the line of strike of the crystalline rocks. In following down the stream, the sandstone layers in the walls of the gorge gradually show the effects of less disturbing influences, and finally assume horizontality and regular bedding. On Middle river, the original lines of deposition have been entirely obliterated, and the very argillaceous sandstone transformed into a transverse cleaving slate, somewhat micaceous. Figs. 2, 5 and 6 more fully explain the condition of the sandstone. The pressure necessary to cause this effect might have, and probably did, come from a slight northward movement, of the eruptive and deep seated strata, against the horizontal sandstones.

That the Keweenawan eruptive rocks are *bedded*, in a certain sense, there can be no doubt. The dip and strike are very persistent, and, indeed, quite uniform. They can be determined at almost any locality, where the rocks are exposed, with but little difficulty. The layers are very seldom less than a foot or two in thickness; more often they are many feet thick, and give the exposure an unstratified appearance. Owing to a great inequality in the hardness of the different beds, the softest have been eroded, and the hardest and firmest have remained; and now outcrop in the form of bare ridges of rock. These ridge-like exposures are very prominent and characteristic between Black river falls and the Aminicon river. They appear to arise directly from the soil, like a great stone wall, and, at least in one or two instances, pass across the country for a mile or more in an almost straight line, with a height of 30 or 40 feet, and a thickness of 50 to 100 feet. Other ridges vary in length from a few feet to a quarter of a mile or more. On the north, the face of each ridge is usually precipitous and somewhat jagged, owing to the exposure of the edge of the layers. The south side descends to the soil with the inclination of the bedding. Ordinarily, the dip is readily obtained, and the trend of the ridges is usually the strike of the formation. East of the Aminicon, the wall-like exposures are less prominent.

The *lithological*[1] characters of the eruptive rocks are subject to

[1] The lithology of these rocks has been very little discussed in this report, for the reason that a complete suite of Douglas county specimens was sent in the spring of 1877, for microscopical examination, to Prof. R. Pumpelly, the eminent authority upon

considerable variation, and still are entirely distinct from all other rocks that occur in the region. They may all be arranged under several groups in one great class. So far as I have determined, they are all basic; that is, they are poor in silica, the content of that acid being nearly always less than 60, and, usually, even less than 50 per cent. They may all be included under the generic term of diabase,[1] except some reddish felsitic porphyries, whose eruptive nature is a matter of question. By far the most common rock is a greenish, dark-gray diabase. Near the sandstones on the north, this rock often has an amygdaloidal structure. There are also beds or layers of amygdaloidal diabase 1,000 or 2,000 feet south of the sandstones. The amygdules are usually either epidote, prehnite or chlorite. A less common rock, but one forming massive beds, is a fine-grained, nearly black kind, having a marked conchoidal fracture, and differing much from the ordinary diabase (Pumpelly's "ashbed type"). Coarse-grained, red-and-black-mottled basic rocks (gabbro) also occur. Felsitic porphyry has been seen only on Black river.

South of the "Copper Range" of Douglas county, for a distance of fifteen miles, the eruptive strata are almost universally buried beneath the vast deposits of quaternary material, which are found nearly everywhere in the district. In all of this area, which is mainly covered by swamps, I have not seen an exposure. I have been informed that there are about three exposures of Keweenawan crystalline rocks in these swamps. But as Mr. Stuntz and one or two other well informed persons, who gave me this information, were unable to place the outcrops nearer than the township, it seemed unadvisable to waste time in searching for them. Along Moose river, in the northern part of township 44, southward-dipping eruptive strata, overlaid by conglomerates and coarse-grained sandstone, are quite largely exposed. The dip is 18°, and the strike N. 55° E. Other exposures are also found in townships 43 and 44, ranges 14 and 15 west.[2] Assuming that the Keweenawan rocks occupy the swampy area between the "Copper Range" and the outcrops on Moose river, and giving them an average dip of 20°, which is certainly small, we find that they have a thick-

this subject. At the time of writing, I am unacquainted with Prof. Pumpelly's results, and shall have to leave his specific names to be inserted by other hands. Everything given here of a lithological nature is then wholly from my own observation, except, as already said, the names of the rocks themselves. The eruptive rocks of this district are often crypto-crystalline or compact, in consequence of which it is absolutely impossible to always give the correct name without the use of the microscope. — E. T. S.

[1] See Prof. Pumpelly's report, p. 29 of this volume.

[2] For details in regard to these exposures, and also those at the Eau Claire lakes, see Mr. Strong's report.

ness of over 36,000 feet. This includes certainly one, and perhaps several, beds of sandstone.

The only *economic minerals* as yet discovered in these rocks, in the Western Lake Superior district, are metallic copper and traces of nickel and silver. A considerable sum of money has been expended in mining and prospecting for the former. Many fine specimens and good "prospects" have been found, but the metal has not been discovered in sufficient quantities to constitute mining in the district a permanent industry. Whether or not it will be found in such quantities is another question. The geological conditions are favorable for its occurrence. The formation doubtless covers a large area, but an exceedingly small fraction of it is accessible to exploration, on account of the heavy covering of drift. New and rich localities may yet be found. However, we regard the expenditure of large sums of money in mining in the region, at present, as investments of a rather precarious nature. A history of the mines and other information upon this subject will be found in the succeeding pages.

In regard to the *age of the Copper-bearing Series*, very little in addition to the suggestions already made in the preceding sections, remains to be said. From their relations in this district, we can only assert that they are more ancient than the Lake Superior red sandstones, for where the latter are conglomeritic, near their base or on their sides, the pebbles have almost invariably been derived from the former. Again, where the sandstones are perfectly horizontal, and approach, in that condition, the dipping crystalline rocks, within fifteen or twenty feet, we may assume that the former unconformably overlie the latter. We have very good reasons, as shown above, for believing that the slates of the St. Louis river are Huronian, and underlie the Keweenawan system, with a close approach to conformity. If such is the case, then, the eruptive and sedimentary strata of the Keweenawan Series were formerly spread out hortizontally above the Huronian system, and partook with them of the regional disturbance, at a period previous to the deposition of the Lake Superior red sandstones, when all of the beds of both formations were tilted, and the great Lake Superior synclinal formed.[1]

The sandstones of the Copper-bearing Series, having a southward dip, overlie, in the main, the eruptive rocks, though to some extent interstratified with them. They are found on Moose river, in T. 44,

[1] See Prof. Irving's discussion in Part I of this volume. Also R. D. Irving, on "Some Points in the Geology of Northern Wisconsin," Am. Jour. Sci., July, 1874, and Trans. Wis. Acad. Sci., Vol. II, p. 107. Also Brooks and Pumpelly, Am. Jour. Sci., June, 1872.

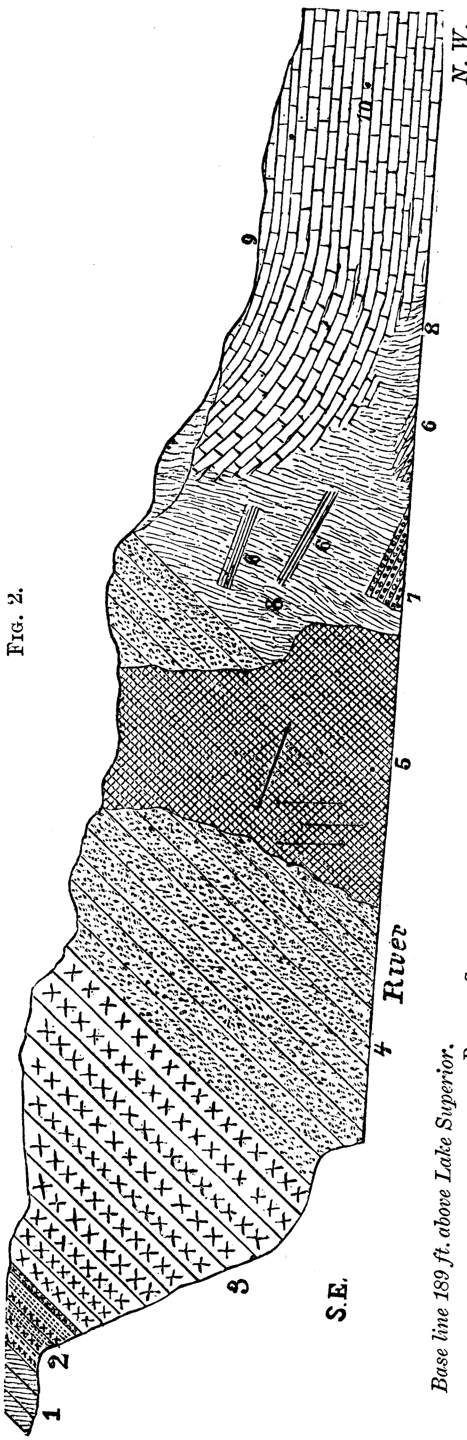
R. 13 W., and on the St. Croix, being spread out over a horizontal distance of about seven miles, and trending N. 54° E., with an average dip of 14° S. They are also found in Ashland county at two points. The lower portion observed, which is most closely associated with the crystalline strata, is made up of conglomerate and coarse-grained sandstone, the pebbles of the former having been derived almost entirely from the underlying rocks. The upper portion, which has by far the greatest thickness, consists of thin-bedded, somewhat indurated, fine-grained, argillaceous, red sandstone. Although the observed outcrops of these sandstones are separated by considerable distances, there is no doubt, owing to the great thickness and to the uniformity in direction of dip and strike, that they form parts of the same great group of strata.

Local Details. The most western exposure of the *eruptive rocks* of the Western Lake Superior district that I have seen, is a short distance west of the lower falls of Black river. It is said by Mr. Fitzpatrick, a farmer living on Sec. 35, T. 48, R. 16 W., that exposures of this rock occur near his house, about a mile west of the Wisconsin state line. This point, it will be observed, is not only at a considerable distance from the range of Douglas county, but is quite close to the Huronian slates of the St. Louis river.

Near the center of T. 46, R. 15 W., commences the distinct elevation, or broad ridge, which is known as the "Copper Range." The escarpment on the north is very much more marked than on the south, and this is true of the entire range, which extends in a more or less broken line, about N. 60° E., across Douglas county, and for some distance into Bayfield county. Between the western end of the range and Black river, there are only two or three exposures, the surface being covered with drift. Two small creeks break through the range, and show inconsiderable outcrops of the crystalline rocks, which are not dissimilar to that at Black River Falls.

The lower falls of Black river are near the S. E. corner of Sec. 21, T. 47, R. 14 W. In this vicinity, the exposures are the largest and most interesting of any observed in the district. Here the river has cut a gorge through the crystalline rocks of the Keweenawan and the breccia conglomerate and sandstone of the Lower Silurian, to a depth varying from 100 to 180 feet, and having a length of nearly one-half mile. Along the walls of the gorge, the measures are most beautifully exposed, but great difficulty has been experienced in satisfactorily making out their relations. An inspection of figures 2, 3 and 4, which illustrate the occurrences here, will, it is thought, serve to convey a better idea of the relations of the exposures in the gorge, or cañon, than a minute written description could do. At the head of the rapids, which extend about one hundred feet above the falls, a dark-colored, fine-grained, hard diabase of the ashbed type, occurs. Although quite indistinct, it appears to have a bedded structure. At the immediate head of the falls, this is succeeded by red felsitic porphyry, and this, again, by the common diabase. The third bed, over which is the main fall, is a dark gray, fine-grained diabase, having also an indistinct bedding. About seventy-five feet above the foot of the great fall, in the left or west wall of the gorge there is a vertical fissure eight inches wide, formed by two smaller fissures dipping towards each other, and making an angle of about 40°. Owing to talus, the fissure can be seen only a distance of ten or fifteen feet. It is filled with a soft, clay-like sandstone. The walls on either side of the

FIG. 2.



PROFILE SECTION THROUGH THE GORGE AT THE LOWER BLACK RIVER FALLS.
Horizontal scale, 200 feet = 1 inch. Vertical scale, 100 feet = 1 inch.

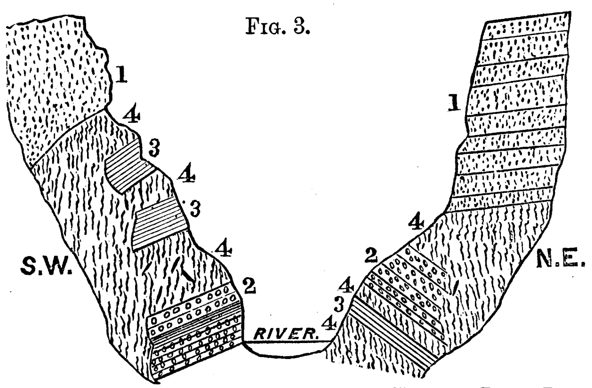
1. Diabase, ashbed type. 2. Felsitic porphyry. 3. Gray diabase. 4. Reddish-brown diabase. 5. Diabase breccia. 6. Shaly sandstone. 7. Porphyry and quartz conglomerate. 8. Talus and unexposed. 9. Broken and dipping red sandstone. 10. Horizontal red sandstone.

fissure are very dark colored, soft and unctuous. The rock is a chloritic alteration of the diabase.

Just above the head of a small fall, near the foot of the great fall, a fine-grained reddish-brown diabase comes in which is frequently amygdaloidal. The dip here is 46° in a direction about S. 20° E. This extends along the wall of the gorge nearly 300 ft. and gradually grades on the west side, into a diabase breccia. The transition, in fact, is so imperceptible, that it is impossible to locate exactly the point at which the diabase ceases and the breccia commences. This is partially owing to the fact, that both diabase and breccia walls are considerably decomposed, and partially to the farther fact that the breccia contains immense enclosed masses of the diabase. In the east wall there is no breccia. Near the southern limit of the breccia the rock consists almost exclusively of angular grains and masses of diabase, while in the north, there is a notable proportion of reddish sand, which seems to be the matrix or cementing material. Imbedded in the face of the breccia are a number of highly indurated layers of reddish sandstone, from four to fifty feet in length, and inclined at different angles, some of them being vertical. About fifty feet above the stream, and near the foot of a perpendicular cliff a hundred feet high, are two of these layers resting together. They are two feet thick, forty feet long, straight, and dip 26° to the N. 70° W. These layers are really quartzite. They have a dark brown color, coarse granular structure, and contain a few disseminated grains of delessite.

One hundred and fifty feet from the breccia, in the left bank of the stream, there is a bed of conglomerate, arising directly from the stream, thirty feet in thickness. Interstratified with the conglomerate are a few layers of sandy shale. The dip of this bed of conglomerate is 25° in a direction S. 20° W. The dip, however, is not uniform. For a few rods down the stream, it is 20°, and twenty-five feet farther, only 15° in the same direction. The pebbles are from one-half an inch to three inches in diameter, and are principally white amorphous quartz. About a third of them are diabase, much more angular than the quartz pebbles, some are sandstone, and a few are themselves conglomerate. The matrix is red sand. On the east, or right side, of the stream, there is also a bed of conglomerate, which is underlaid by thin bedded sandstone. This bed dips 42° to the N. 10° E. The following figure shows the positions of the conglomerate, sandstone, and diabase beds. In this conglomerate bed there are white quartz, gray quartzite, diabase and sandstone pebbles, with reddish sand as the cementing material. It forms so incoherent a mass, that most of the pebbles may be readily picked out with the hand. In other respects it is very similar to the bed on the west side of the stream. The space above the conglomerate for about 50 feet is covered with talus which has fallen down from the nearly vertical cliff of diabase. Many hundred tons weight have recently fallen from this cliff. All of the fragments are very small, angular, and much weathered. Numerous stains of copper carbonate were noticed in the fragments. The dip here appears to be 36° to the S. E.

FIG. 3.



SECTION ACROSS THE GORGE AT THE LOWER FALLS OF BLACK RIVER.
Scale, 100 feet = 1 inch.
1. Diabase. 2. Conglomerate and interstratified sandstone. 3. Thin bedded and shaly sandstone. 4. Talus and unexposed.

On the opposite side of the stream above the conglomerate there are two small exposures of shaly sandstone. The upper exposure dips 20° to the S. 20° W., directly towards a diabase cliff only fifty feet distant, and forty feet high. Clinging to the face of the cliff are, at two or three places, patches of diabase breccia, a foot or more thick. Seventy-five or one hundred feet northwest from the cliff of diabase, in the wall of the gorge, dark-reddish and somewhat indurated sandstones are found. The layers at first are broken into blocks from four to ten feet in length, and are inclined at various angles, usually to the N. W. Gradually they assume more and more of a distinctly bedded structure, and finally, in the distance of a few hundred feet, grade into regularly bedded reddish sandstone, with a dip of only 4° or 5° to the N. W. The nearly horizontal sandstone is found in the banks of the stream at intervals for several miles. It resembles in all respects that occurring along the lake shore in Bayfield county and at the base of the Apostle Islands. In the east wall of the gorge, about one hundred feet northwest of the conglomerate, there is a perpendicular ledge of the sandstone over 100 feet high. The layers near the top are thin and shaly, and dip 30° in a direction N. 10° W.

PLATE, XXV.

UPPER FALL OF BLACK RIVER,

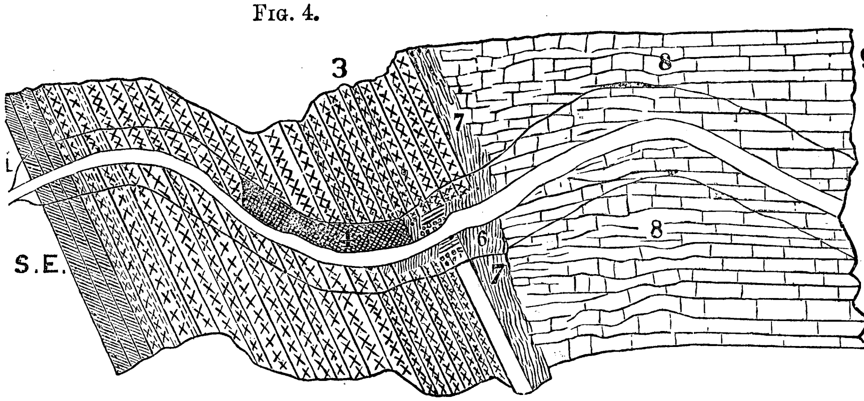
Near Superior, Wis. 31 feet high.

Near the bottom, the layers have the same inclination, but are coarse-grained and from six to eight feet in thickness. Scattered through the layers are diabase and quartz pebbles, an inch or less in diameter. Several hundred feet still further along the gorge, the layers upon this side gradually become nearly horizontal, and are often interstratified with yellowish and white sandstone.

To explain the tilted and crushed condition of the sedimentary beds, it is only necessary to assume that great pressure should have existed between them and the older eruptive strata. The pressure could have been induced by a downward or southward movement of the sandstones, or by an upward or northward slight movement on the part of the copper-bearing rocks. The latter being very deep-seated, and the former, compared to them, somewhat superficial, a slight upward or northward movement of the deep-seated strata, would produce all of the observed phenomena.[1] This probably is the correct explanation, as the crushed and tilted condition is not limited to this locality, but occurs wherever the horizontal sandstones and cupriferous strata come together.

The following figure (4) is intended as an outline map, to show the (horizontal) surface distribution of the different beds of rock, exposed in the walls of the gorge, and occurring for a short distance each side of them. On the surface upon either side of the gorge, of course, the absolute exposures are not quite as extensive as represented:

FIG. 4.



OUTLINE STRUCTURAL MAP OF THE LOWER BLACK RIVER FALLS.

Horizontal scale, 400 feet = 1 inch.

1. Diabase, ashbed type. 2. Porphyry, etc. 3. Diabase. 4. Breccia. 5. Shaly sandstone. 6. Conglomerate. 7. Talus and unexposed. 8. Broken and tilted sandstone. 9. Horizontal sandstone.

By the tortuous course of the stream, the *Upper Fall* of Black river is found one and a half miles above the Lower Fall. Diabase crops out in low ledges, frequently on either side of the very rapid current. The fall is near the east quarter-post of Sec. 28, T. 47, R. 14 W. The descent is 31 feet vertical, over a layer or bed of diabase dipping about 40° to the S. 30° E. One hundred feet below the fall, in the bank of the river, amygdaloidal diabase occurs, having the characteristic greenish color from the presence of epidote. About 200 feet above the fall amygdaloid again comes in. This is the most southern exposure found on Black river.

It is on the N. E. qr. of the S. E. qr. of Sec. 28. A supposed "copper vein" was discovered here in 1865 by Capt. Buchanan, examined and reported upon by Mr. Clark, of Superior, for Mr. Dayton, of St. Paul, who was offered $14,000 for the location a short time afterwards. But being determined to "prove" his "vein," he employed a "practi-

[1] See R. D. Irving, on "Some points in the Geology of Northern Wisconsin," Trans. Wis. Acad. Sci., 1874.

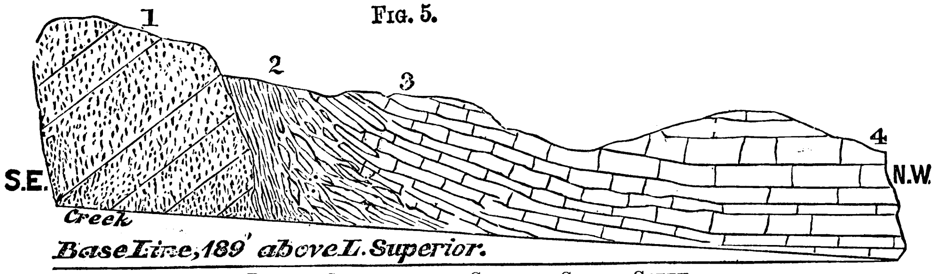
cal " miner from Michigan to blow off the "cap." At the first blast the "cap" was not only removed, but the entire "vein" was eradicated, and nothing of it has since been discovered. It was merely a very small impregnation. Upon the discovery of the deposit, it is said that a number of fine hand specimens of native copper were obtained, and the "surface indications" were excellent. This example is a good illustration of the excitement caused in the region a few years ago by the discovery of a small amount of metallic copper in any amygdaloidal epidotic rock. The conclusion was at once assumed that an immense accumulation of metal was close at hand, and, in order to expose the gigantic vein, it was only necessary to blow off the "cap" or projecting rock which hid it from view.

Starting off in a northeasterly direction from the Lower Falls of Black river, is a somewhat broken line of outcrops, in the form of rounded rock ridges. All trend in a more or less N. E. and S. W. direction; and vary in length from a few feet to a hundred yards. Several test pits have been sunk upon, and in the immediate vicinity of these exposures, but show no evidence of copper. A few small calcite and laumontite veins were noticed, none of which exceed two inches across.

At *Copper creek*, the Keweenawan beds are found for a distance of nearly one mile along the channel of the stream, and in places arise to the height of about one hundred feet above it. In the most southern outcrops, the predominating rock is a dark colored diabase. In the most northern, the rock is usually the more common reddish altered diabase. Near the junction of the forks of the creek, at the S. E. cor. Sec. 15, T. 47, R. 14 W., the most extensive mining operations which have been undertaken in the district, were carried on during several years. A history and detailed description of this and other mining locations will be found in a subsequent chapter of this report. From the union of the forks, the creek has a tortuous course in a general northwesterly direction. It passes through a gorge or valley, a little wider than the cañon of Black river. The rock on each side, for a quarter of a mile, is close grained, dark reddish gray diabase, which frequently rises in great, smooth, rounded or sloping exposures, to the height of from 100 to 135 feet above the stream. Along the stream the bedding is quite indistinct. The layers, if such they may be called, are often fifty or sixty feet in thickness. The most northern exposure, in the banks of the stream, is on the west or left side, and slopes from the creek at an angle of 30° or 40° to the height of 90 feet. The rock is a dark gray amygdaloidal diabase, which readily weathers to a greasy-feeling, soft chloritic rock. It breaks into small, sharp angular pieces, which is due to the almost innumerable small seams or joints traversing the rock in every direction. On the north of this exposure there is a gully, about fifteen feet across, showing nothing except sand, clay, and loose rocks from the adjacent cliffs. In the north side of the gully, there are short layers of sandstone having a high dip to the northwest. Immediately adjoining them is a cliff of dark reddish, coarse-grained, somewhat indurated sandstone. The layers are broken into short lengths, and dip 60° to the northwest. The bedding for a hundred feet is not well marked, and for several hundred feet still farther along the stream, it shows distinct evidences of having at some time been subject to great lateral pressure, for the layers are broken into lengths of from two to ten feet, the thickest often presenting the appearance of a transverse conchoidal fracture. Between the beds are frequently thin layers of fine-grained white sandstone, some portions of which have been manufactured into grindstones, said to be of very fine quality. Many of the reddish layers are themselves mottled, by containing spheres of white sandstone a quarter of an inch or more in diameter. In the course of a few hundred feet the broken layers gradually assume regular and undisturbed bedding, having a dip of only 4° to the N. W. The layers are from one-half inch to two feet thick, often finely cross-laminated, and frequently show most beautiful ripple marks. They are also finer grained, and of a much lighter red color than the broken layers.

The following section illustrates the relations of the diabases and sandstones in the left bank of the creek. On the opposite side they are not exposed together. It will be observed that conglomerate and breccia do not occur. No sandstones were observed in the vicinity of Copper creek, except in the banks of the stream.

FIG. 5.



PROFILE SECTION IN THE GORGE OF COPPER CREEK.

Horizontal scale, 200 feet = 1 inch. Vertical scale, 100 feet = 1 inch.

1. Diabase. 2. Talus. 3. Broken and dipping red sandstone. 4. Horizontal red sandstone.

Some time was occupied in attempting to construct a detailed section of the Keweenawan rocks at this point, but owing to the infrequent exposures away from the creek a general one only was obtained. The beds occur in the following order:

1. Starting near the W. quarter-post of Sec. 23, the uppermost bed exposed consists predominatingly of dark colored diabase. The rock is quite fine-grained, dark colored, hard and slightly influenced from the action of the weather. Silica content of a typical specimen, 49.53. Specific gravity, 2.74. Strike N. 60° E. Dip, 40° S. The bed occupies an observed horizontal breadth of about one thousand feet.

2. Much altered diabase-amygdaloids are the type of this bed. They decompose very readily, and are largely exposed at the junction of the forks near the N. W. cor. of Sec. 23. The amygdules are prehnite, calcite, epidote and laumontite. Small veins of laumontite are very numerous in the bed, and easily decomposing, materially assist in the disintegration of the rock. It is upon this bed that the mine has been worked. Copper is found, principally, in the epidotic amygdaloid. The bedding is indistinct but appears to conform with the underlying bed. The bed has a horizontal breadth of 500 feet. A somewhat weathered specimen has silica, 57.80. Specific gravity, 2.70.

3. Crypto-crystalline, dark gray diabase with a greenish shade, hard, and very little weathered. Silica, 59.89. Gravity, 2.82. This forms the most prominent ridges and rounded exposures in the vicinity. Bedding indistinct, but about N. 55° E. for the strike, and 50° S. for the dip. Horizontal extent of bed about 400 feet.

4. Amygdaloidal, and very similar to No. 3. Silica, 58.30. Gravity, 2.73. Strike, N. 55° E. Dip (?) S. This bed has a breadth of about 300 feet, and on the north joins the sandstones, as explained above. About a quarter of a mile from the mining location and close to the Superior and Copper creek wagon road, there is an exposure upon bed No. 4, which has been prospected for "nickel." Upon close inspection of samples collected from this locality, I was able to detect a few disseminated grains of niccolite, often called nickel from its pinkish tint.

Mr. Barden, of Superior, presented me with a small, fine specimen taken from the locality several years ago. There appears to be a small vein here of quartz, calcite and orthoclase, dipping with the bedding 35° to the S. 25° E. I was unable to find niccolite in the vein matter, but it appears to occur in the hanging wall of amygdaloid.

About one mile northeast from the mining location at Copper creek, there commences a very remarkable exposure. It is in the form of a rock ridge or great wall of stone, almost perfectly straight, nearly a mile long, forty feet high, jagged and nearly vertical on the north side; the top, for considerable distance, as smooth and level as a sidewalk, from ten to thirty feet wide; the south side, even and sloping, and twenty or thirty feet above the soil. The rock is very similar to that of beds Nos. 3 and 4, described as occurring at Copper Creek. A few small calcite and laumontite veins were noticed. The exposure consists merely of the upper edges of some of the hard layers, forming one of the beds, quite capable of resisting erosion. The jagged appearance on the north is owing to rough breaking of the layers which protrude in that direction. The trend of the ridge is N. 55° E., which is exactly the direction of the strike, and the dip is 36° S.

Passing off from the eastern end of this exposure, there are two lines of similar, but much smaller, outcrops. One goes nearly east to the Aminicon river in Sec. 17, where it divides into two or three general lines, the individual outcrops lapping past each other, and each preserving its trend of N. 55° to 60° E. The second passes northeasterly across Sec. 12, and Secs. 7 and 8, T. 47, R. 13 W. Here the exposures are not numerous, but are in nearly a straight line. Most of them are in the form of short ridges. A cupriferous vein is said to have been found on the southeast quarter of Sec. 12, but I did not see it. On Sec. 8, upon this line of exposures, is the Fond du Lac mining location, and upon Sec. 2, the Wisconsin mine. Drift conceals most of the underlying strata in this vicinity. Upon Sec. 1, directly southeast from the Wisconsin mine, exposures are very numerous. They are usually short and ridge-like, varying in length from a few feet to an eighth of a mile; in width, at the surface of the drift, from ten or twenty to two hundred feet, and in height from ten to seventy-five feet. They trend from 20° to 30° east of north; somewhat nearer north, it will be observed, than those a few miles to the west. They are separated from each other by drift-filled valleys from 100 to 700 feet wide. A short distance to the east of most of the small ridges is one very prominent ridge, or rather mound-like exposure, several hundred feet long and seventy-five feet high. The northern face is very precipitous, and the bedding is very distinct. The dip is 30° to the S. 60° E. The rock is dark-colored and closely resembles some of those in the southern part of Ashland county.

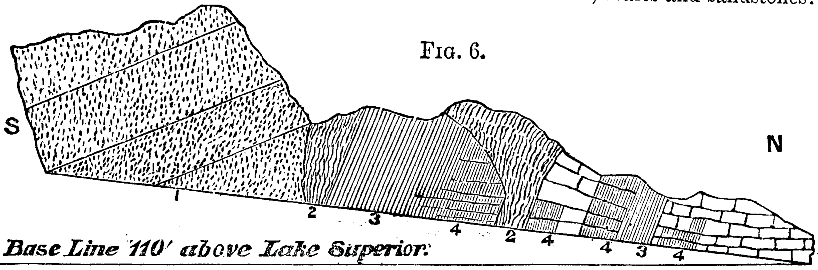
Near the southeast corner of Sec. 32, T. 48, R. 12 W., is the most southern exposure in the banks of the Aminicon river. There are several between here and the crossing of the Superior and Bayfield post road, a half mile below. The rock is a coarse grained gabbro, composed of red and stained plagioclase, a gray plagioclase, and a soft greenish altered (chloritic) diabase, with bright shining grains of magnetite. Below the bridge, a dark colored, coarse-grained variety occurs, in which the several minerals show much less alteration. These rocks are subject to great variation and sudden changes in texture, and degree of alteration. Between the outcrops of the above described rocks are layers, or imbedded masses (I am not able to state in all cases which), of a fine-grained dark rock (ashbed diabase). Farther down the stream the rock becomes fine-grained, and sometimes compact. Several veins of calcite were observed in a compact reddish rock of unknown constituents.

Near the east and west line, running between sections 20 and 29, is the junction of the reddish sandstones with the crystalline rocks. For twenty-five feet only have the sandstones been disturbed. In this distance they are broken into short lengths, and dip northwest from the crystalline strata at angles varying from 60° to 20°, after which they become horizontal and show two well marked systems of vertical joints. The direction of one system is N. 60° E., and of the other N. and S. At the immediate line of junction, or where the sandstone is removed from the crystalline rocks but a very few inches, the layers of sandstone have a facing of fine conglomerate, from a few inches to a foot or more in thickness. The pebbles consist of quartz and melaphyr or diabase, which are cemented by sand. The sandstone layers at some distance from the junction also contain small pebbles of the adjacent crystalline rocks. The sandstone layers are much softer than usual, uniformly reddish in color, and in thickness vary from one to twenty-four inches.

Between the Aminicon and Middle rivers there are very few exposures of the copper-bearing rocks, and none in Secs. 33 and 34, where we would expect to find them. The country is somewhat lower than the remainder of the range, and covered with drift. Near the center of Sec. 4, T. 47, R. 12 W., there are two small exposures of fine-grained blackish diabase, separated by a few rods of drift. Similar rocks are again visible in Sec. 3, and along the banks of Middle river, for about a mile in Secs. 2 and 35. They are all small exposures. In Sec. 35, the rock is often porphyritic. A perfect network of minute laumontite veins occurs at one or two localities. No other veins, however, were observed. In searching for outcrops, several places were found in Secs. 35, 25 and 23, where the magnetic needle was subject to great local attraction.

Near the south line of Sec. 24, T. 48, R. 12 W., Middle river cuts through the northern face of the range, leaving a large surface of the rock exposed. On the south, the stream has exposed between three and four hundred feet of a dark brown diabase, being in places somewhat amygdaloidal. This outcrop is nowhere more than 25 feet in height. A hundred yards northwest from it, in the left bank of the stream, is an exposure of soft, dark reddish, much altered and decomposed diabase-amygdaloid, carrying numerous small veins or "strings" of laumontite and calcite. This rock weathers easily, and is rapidly crumbling away. It is very similar to that described as occurring at the forks of Copper creek. Some of the small veins of calcite were noticed stained with copper carbonate. This rock is found along the stream for 200 feet, is about 50 feet in height, and is very indistinctly bedded. On the north, it is separated from a southward dipping and shaly rock by a gully 30 feet across. The following section illustrates the relative positions of the Keweenawan rocks, shales and sandstones:

FIG. 6.



PROFILE SECTION ALONG THE WEST BANK OF MIDDLE RIVER.

Horizontal scale, 400 feet = 1 inch. Vertical scale, 50 feet = 1 inch.

1. Diabase. 2. Talus and unexposed. 3. Micaceous and siliceous slates and shales. 4. Layers of red sandstone having a transverse slaty cleavage. 5. Horizontal red sandstone.

Nothing can demonstrate more conclusively the former existence of great pressure against the sandstone, than does this exposure. Near the crystalline rock, the bedding has been entirely obliterated, and the outcrop presents the appearance of a bed of shale dipping 79° to the S. 20° E. The layers are from one-sixteenth of an inch to an inch in thickness. All of them contain flakes of mica, and the most of the layers are reddish colored. But thin, hard, light-colored, slaty layers occur between the reddish, shaly layers. In the course of 75 feet, the exposure begins to show evidences of horizontal bedding with a transverse slaty cleavage, as shown in the cut. Beyond this, the layers are broken and dip somewhat, and only one or two of them show the slaty cleavage. After another bed of slate and shale, as shown, and attempts at slaty cleavage, the rock becomes evenly bedded and horizontal. It is fine-grained, and more aluminous than is usual with the Lake Superior sandstones. There are no conglomerates, breccias or thick layers of coarse sandstone seen in the vicinity.

Eastward from Middle river, neither the copper-bearing rocks nor sandstones are exposed for a distance of about seven miles. Between Middle river and the high ground, locally known as the Brulé range, the country is quite level, somewhat swampy, and has an elevation of about 400 feet. The Brulé range, commencing in T. 47, R. 11 W., attains an altitude on the broad summit of about 540 feet. Towards the western end are two or three small exposures of fine-grained, dark gray diabase. On Sec. 29, T. 48, R. 10 W., is an exposure of diabase, fine conglomerate and sandstone, very similar to that described as occurring on the Aminicon river. On the northeast quarter of Sec. 28, at the falls of a small stream, is an exposure of dark gray amygdaloidal diabase, a few feet in height and ten or twelve yards long. A test pit was sunk here on what appears to be a small quartz and epidote vein bearing altered amygdaloid, by the North American Fur Company, in 1847. A small quantity of iron pyrites and copper carbonate were observed with the debris. The dip here is 37°, S. 40° E.

No exposures are found from here to the Percival mining location, a mile to the east. At this location the natural exposures are small and few in number, but the underlying rock is lightly covered with drift, which may easily be removed. The rock is usually a dark greenish gray amygdaloidal diabase, carrying in places shot and nugget copper. The bedding is not very distinct. At the wagon bridge across the Brulé, on Sec. 23, and occasionally along the banks of the stream for a half mile below, there outcrop low ledges of a dark colored amygdaloidal diabase. A quarter of a mile below these exposures there are low ledges of nearly horizontal, reddish, heavily bedded sandstone, in the banks of the stream. Similar sandstones are found along the banks and in the channel, forming numerous rapids nearly to the mouth of the river. No exposures were found on the steep sides of the valley, although, in the vicinity of the sandstones and crystalline rocks, it is over 200 feet deep, and not a half mile across from summit to summit. On the northeast quarter of Sec. 23, a short distance north of the Bayfield road, there is a very prominent and high exposure, forming the western end of that portion of the range east of the Brulé river. The summit of the bare, bald cliff, is 301 feet above the bridge across the stream at its foot, or 553 feet above Lake Superior. From here a most beautiful view of the country to the north, east and west, may be had. Duluth and the whole western end of the lake are in plain sight from this point. On the north, the cliff has a very vertical, jagged face of sixty feet. The dip is 35° S., and the strike N. 55° E. A short distance to the south of this cliff are two other rounded knobs of bare rock at elevations a few feet less than this. The rock upon the three exposures is quite uniform, and consists of a dark reddish, fine grained to compact amygdaloidal diabase, the filled cavities containing usually prehnite; and the empty ones being studded with either chlorite, epidote or quartz crystals. Upon the most southern knob at one place there are some indistinct evidences of an epidotic "bed."

Passing off from the northern and highest knob or exposure, in a northeasterly direction, is the drift covered summit of the range, from five to ten yards wide. Several small outcrops occur in the distance of a half mile, and the "ridge" descends eighty feet, to the surface of the surrounding country or broad top of the range. East of here, but a single exposure of the copper-bearing rocks has been found; a small outcrop on Sec. 10, in the valley of Iron river.

From the altitudes, trend, and general appearance of the ridges or abrupt elevations to the south, a few miles from the lake shore, in Bayfield county, we should expect to find crystalline rock exposures, occasionally, as in Douglas county. The streams are numerous, and, like those to the west, cut deep and narrow valleys through the drift, near the abrupt ascent of the country to the south, and nearly all expose small ledges of horizontal, reddish Lake Superior sandstone, but none of them appear to have uncovered the Keweenawan rocks. In the southwest part of T. 50, R. 7 W., between Frog and Cranberry rivers, there is a ridge having an altitude of over 400 feet, and covered with many large angular boulders of diabase and other Keweenawan eruptive rocks. It presents a striking resemblance to the range, a short distance west of the Brulé river. On the northeast quarter of Sec. 20, T. 50, R. 6 W., a few rods north of the shore of Siskowit lake, there is a flat circular boulder of brecciated conglomerate, eighteen feet in diameter. A few of the angular and some of the round pebbles are diabase, but the most of them are felsitic porphyry. The matrix is reddish sand. The boulder is evidently stratified, and, as it lies, has an inclination of 20° S. Owing to the frail nature of the rock, it probably never traveled any considerable distance. This is one of the numerous so-called outcrops of crystalline rocks to which I was directed by some of the citizens of Bayfield. Others were found to be large boulders, trains of boulders, or ledges of sandstone.

In an executive document previously referred to, Owen reports the Keweenawan eruptive rocks in the banks of the Brulé river, near the mouth of the Nebagamain. I searched in that vicinity three days, and, although many large boulders were frequently seen, no rock in place was observed. If exposures occur anywhere in the vicinity of the Brulé south of the Copper Range, or in townships 45 or 46, Douglas or Bayfield counties, they are exceedingly rare. Mr. Stuntz and the surveyor of Douglas county have told me that there is a small ledge, about the center of T. 46, R. 15 W., from which small specimens of native copper have been taken. In townships 43 and 44, ranges 14 and 15, there are said to be numerous exposures of southward dipping copper-bearing rocks. Mr. Strong was in this region, and he doubtless obtained details in regard to them. In the banks and channel of Moose river, on Sec. 2, T. 44, R. 13 W., there are low ledges of melaphyrs and diabases, dipping 18°, S. 35° E. These are conformably overlaid by fine conglomerates and coarse sandstones. The pebbles of the conglomerate have nearly all been directly derived from the underlying crystalline rocks, and are held together by a coarse red, sandy matrix. None of the very coarse or boulder conglomerates noticed on the northward dipping belt, in Ashland county, and on the St. Croix river, were observed here. In following Moose river southward, towards its mouth several small exposures of the fine conglomerate were seen, but it apparently has no great thickness, for it soon grades with coarse reddish sandstone, and that finally, after reaching the St. Croix, into quite fine-grained, red sandstone, often somewhat argillaceous.

The most northern exposure of this sandstone on the St. Croix, is at the head of a small lake about a mile above the mouth of Moose river. The outcrop is in the east bank. The layers are hard and thin, and contain many red argillaceous spots. Indurated smooth slabs come out readily. A few of the layers are finely ripple marked. The strike is N. 53° E., and the dip 14° S. This place is a short distance below Chase's dam on Sec. 36, T. 44, R. 13 W. For five miles along the St. Croix below Moose river, a few small exposures only are seen. On Sec. 8, T. 43, R. 13 W., the sandstone is exposed in the banks five or six feet high. At the first considerable exposure, the rock is fine grained, very thin bedded, and argillaceous. Circular reddish and bluish spots of indurated clay are of frequent occurrence in the layers. The strike is N. 55° E., and dip 13° S. There are two well marked systems of joints; one trending N. 28° W., and the other N. 55° E. A short distance below here, there is a somewhat larger exposure, showing a strike of N. 53° E., and dip of 14° S. Below this, for a distance of ten or twelve miles, tilted sandstones often form the bed of the stream, although they are seldom seen in the banks. In the banks of Rocky Run on Sec. 9, T. 42, R. 14 W., a half mile from the St. Croix, the sandstones are again largely exposed. In the banks, and channel of the St. Croix at Pine rapids, a quarter of a mile below Sawyer's old dam, on the southwest quarter of Sec. 16, T. 42, R. 16 W., is the most southerly outcrop of the southward dipping sandstone observed. The rock is very similar to that above described. The strike is N. 52° E., and the dip 16° S.

It will be noticed from an examination of the geological map, that the horizontal distance across this series of layers of sandstone and conglomerate, at right angles to the strike, is over seven miles. There seems to be little doubt that the bed is continuous. It chiefly consists of very uniform, thin-bedded, fine-grained, hard argillaceous, red sandstone. Assuming a uniform dip of 14°, a simple calculation gives for the thickness about 9,000 feet. These sandstones are exposed in Minnesota, six miles above the falls of Kettle river,[1] and near the head of White river,[1] in Bayfield county. I have seen them in Ashland county at two localities — on White river, at Welton's, six miles south from the village of Ashland, where a few hundred feet are exposed, showing a dip of 25° southeasterly, and on Bad river, at Leighy's, Sec. 25, T. 47, R. 3 W., where about 2,000 feet of the bed is exposed, having a S. E. dip of 38°. For details in regard to the Ashland county exposures, the reader is referred to Prof. Irving's report, in another part of this volume. The southward dipping bed of sandstone has thus a length, in Wisconsin, of nearly 100 miles, and, as stated above, an estimated maximum thickness of about 9,000 feet. So far as observed, no other sedimentary rocks occur in the immediate vicinity of it. The undoubted horizontal reddish Lake Superior sandstones near Ashland are over eight miles from these dipping sandstones.

The following table of analyses made by myself, shows the relative compositions of the crystalline rocks and sandstones of the Keweenawan system, and of the horizontal Lake Superior sandstone:

Number.	1.	2.	3.	4.
Gravity	2.92	2.69	2.43	2.18
Silica	48.28	53.69	69.78	87.02
Alumina	17.35	22.10	15.43	7.17
Peroxide of iron	11.43	8.53	7.93	3.91
Protoxide of iron	4.02	3.65	....	....
Lime	6.27	4.31	.49	.11
Magnesia	6.58	2.09	1.17	.06
Potassa	1.14	1.39	2.64	1.43
Soda	1.83	1.99	2.42	.22
Water	2.66	2.61	Trace.	Trace.
Total	99.56	100.36	99.86	99.92

No. 1 is an analysis of a fine-grained, dark greenish-gray diabase from the Fond du Lac copper mine, Douglas county. It contains a trace of native copper. No. 2. Brownish-black compact diabase from the Ashland copper mine, Ashland county, near the mouth of Tyler's Fork. No. 3. Coarse-grained, reddish Keweenawan sandstone, from Leighy's, on Bad river, Ashland county. Crystals of feldspar can easily be distinguished in the specimen. No. 4. Typical Lake Superior sandstone from a large quarry on Basswood Island.

LAKE SUPERIOR SANDSTONE.

By this term I refer to the reddish, aluminous, horizontal sandstones which border on the lake shore in Bayfield county, and extend as far south in Douglas county as the northern limit of the Copper Range. In Bayfield county, this rock forms bold and nearly vertical

[1] Owen.

cliffs along the lake shore, sometimes 40 or 50 feet high. Great caverns and picturesque arches have been worn into the base of many of these cliffs by the waters of the lake. In Douglas county, the sandstone nowhere borders the lake shore, but is found in the channels and banks of nearly all of the streams at a distance of from one to three or four miles from the lake, and extending to the crystalline rocks. The sandstone is chiefly composed of small, rounded, and sometimes somewhat angular grains of quartz, cemented by a ferruginous matrix. Most of the grains are coated with peroxide of iron, which imparts a characteristic reddish color to the stone. All of the layers, which vary greatly in thickness, are more or less aluminous, and sometimes so much so as to become somewhat shaly. Circular spots or nodules of indurated clay (altered feldspar grains) are of frequent occurrence in the layers. I have never seen any sign of calcareous admixture. The above analysis (No. 4) shows about the average chemical composition of the rock. It will be observed that it is not a very purely quartzose sandstone, but is much more so than the Keweenawan sandstone, from which it may have been partially derived. The composition shows that the sandstone must at least have had its origin in the highly aluminous and ferruginous crystalline Keweenawan rocks.

The elevation of these sandstones near their southern limit varies considerably. Along the St. Louis river, in the vicinity of Fond du Lac, the sandstones rise to a height of between 200 and 250 feet above the lake. At Black river falls, the upper surface of the sandstone is at an elevation of 365 feet; at Copper creek, 296; on the Aminicon river, about 220, and on Middle river, 155 feet. On the Brulé river, the sandstone is found at an elevation of 212; on Iron river, 150; Flag river, 115, and Siskowit river, Sec. 2, T. 50, R. 6, 95. This inclination of the surface towards the east may be due to a slight dip in that direction.

In regard to the *age of the Lake Superior sandstones*, but very little indeed can be learned in the Western Lake Superior district. So far as my observations have extended, the sandstones are absolutely devoid of organic remains. They are removed many miles, and are separated by intervening older formations, from the unmistakable Lower Silurian strata. These sandstones, with quartzose conglomerate at their base, unconformably overlie the Huronian slates on the St. Louis river, two miles west from the northwest corner of Wisconsin. At the state corner, on the south side of the stream, is a ledge of coarse sandstone, forty or fifty feet in height, with a low dip to the north.

In the preceding pages the relations between the Lake Superior sandstones and the eruptive crystalline rocks have been explained, and we may say that it has been conclusively shown that the sandstones are of more recent age than the Keweenawan strata.

QUATERNARY DEPOSITS.

In treating of this subject, I shall, on account of the limited space assigned to me in this report, omit all minor details and simply present the main facts in a general manner. In the district under consideration, the drift deposits are very largely represented. Either the original and unstratified, or the secondary, modified or stratified deposits, cover very nearly the entire surface of the district. The underlying rocky formations have so very limited a surface exposure, that exceedingly few opportunities are afforded to make examinations for striæ, and thus determine with precision the direction of the great glaciers which formerly occupied the region. No distinct glaciated surfaces have been observed. In the vicinity of Thompson and the junction, the slates show a smooth surface in places, as do also the eruptive rocks a short distance east from Copper creek. A few indistinct striations, trending about northeast, were noticed at these places. However, as some of these rocks show the effects of running water, these observations must be received with some caution, but the abrasion of projecting ledges makes it quite certain that the movement was from northeast to southwest. This is corroborated, in the way of direct evidence, by the movements of the drift materials themselves. Boulders of sandstone and crystalline Keweenawan rocks are found in a number of instances, apparently but a short distance from their original beds. In each case the direction of the boulders from the ledges is about southwest. The trend of the several bays and points along the coast of the lake, and of the largest of the Apostle Islands, is presumptive evidence that the general glacial movement was towards the southwest.

Unstratified glacial deposits. The *materials* of the unstratified drift are sand, gravel, clay and boulders, occurring in relative quantities, on the surface, in about the order named. Sand and gravel are almost the exclusive materials of the so-called Barrens, and occupy the highest portions of the district. The sand consists of light colored, medium sized, round to somewhat angular grains of quartz. The pebbles, making up the gravel deposits, vary in size from large grains of sand to three or four inches in diameter. They are very round and consist chiefly of granite, greenstone, quartz and sandstone.

Sand and pebbles make up nearly the entire surface deposits of the "barrens." On the highest portions they may be said to be the exclusive deposits. A hundred feet below the summit, or at an elevation of between 400 and 500 feet, reddish clay and boulders are found intermingled in various proportions with the sand. When a considerable proportion of clay is mixed with the sand, a soil is produced capable of sustaining in places a dense growth of red pines (Norways). The unstratified clay is very similar to the stratified. It is really a ferruginous, sandy, marly clay. About the average chemical composition has been given in two analyses under the subject of soils. This clay borders the "barrens," and is found upon, and each side of, the Copper Range. South of the range and west of the Brulé and Moose rivers, it is the predominating drift material, and with sand, pebbles and boulders composes the low, broad ridges which usually trend N. E. and S. W. between the many swamps of the region, and support a heavy growth of birch, poplar, maple and pine. These trees also grow at a few places on low land and clayey localities in the barrens.

Boulders are not very numerous, except in the channels or deep, narrow valleys of the streams. They are, however, quite evenly spread over the surface of the district, with the exception of the highest portions of the "barrens." On the summit of the Copper Range, and between the swamps to the south of it, there are trains, or narrow ridges of boulders, sand and clay, extending from a few rods to a half mile or more in length, and trending generally N. E. and S. W. In the channels of the streams, boulders usually a foot or less in diameter are very numerous. On Ts. 46 and 47, R. 10 W., in the valley of the Brulé river, the boulders are very numerous and very large. Many of them are ten feet in diameter, and a few will measure even twenty feet across. In this place, they form trains or ridges at right angles to the valley, nearly across, through which the channel has cut its way. The large boulders are diabase. In general, the boulders belong to the greenstone group, or are granite, gneiss, or felsitic porphyry. Reddish porphyry boulders, of unknown origin, and common in the southern part of the state, also occasionally occur here. Small *native copper* boulders are frequently found, and several of great weight are said to have been discovered. Mr. S. Vaughn, of Ashland, is authority for the statement that a copper boulder was found in 1840 in the channel of Sioux river, six miles from Lake Superior, which weighed 1700 pounds. It was taken to La Pointe, and there sold. A mass weighing 100 pounds was found on Outer island, in 1876, and purchased by Mr. A. C. Heyward, of Bayfield. Many of the boulders in this district, certainly the granites and gneisses, must have crossed Lake Superior, and have traveled a distance of at least 200 miles.

Moraines. Kettle Range. The great Kettle Range of the district is embraced within the "barrens." Its northeastern end commences in T. 50, R. 5 W., and the summit of the range passes almost southwestward across the district. The range, in the Western Lake Superior district, is from six to fifteen miles wide. The kettles, or circular, pot-like depressions, are the largest, and by far the most numerous, in Ts. 47, R. 8 W., 48, 7 and 49, 6. They are often from one hundred to one hundred and fifty feet in depth and no more than four hundred or five hundred feet across the top; and are sometimes so close together that the ridges which separate them are scarcely wide enough for a foot path. Often there are knolls between them, and frequently they are separated by quite extensive areas of level ground. I shall not attempt a critical description of them, but will simply refer the reader to Prof. Chamberlin's description of the Kettle Range in eastern Wisconsin, contained in Vol. II of the Survey Reports, pages 206–7–8. This description applies so perfectly to the range under consideration, that I could not hope to equal it in vividness, and accuracy of details.

It is quite evident that this Kettle Range owes its origin to a cause similar to that which produced the Eastern Wisconsin Range. We may assume that the great glacier which descended from the northeast, was divided into two portions; the one passing southwestward along the general course of the western portion of the lake, while the other took a more southerly course on the opposite side of the Bayfield peninsula; and that the kettle moraine was formed by the joint action of the two.

In regard to the depressions, the results of my observations agree in the main with the conclusions of Prof. Chamberlin (vol. II, page 214). The circular depressions may have been chiefly formed, as Col. Whittlesey states in the Smithsonian contributions, by masses of ice becoming buried in the drift and subsequently thawing. In the Lake Superior kettle range, some of the circular depressions and many of the oblong ones were apparently formed during the melting of the glaciers, by eddies in the angles of slowly flowing streams of water. This is clearly suggested by their frequent occurrence in tortuous lines of depression leading off on either side from the summit. Such depressions could have been easily formed, as flowing water readily holds in suspension and carries off the fine sand and the red marly clays of the district. It is to this fact that I attribute the almost entire absence of clay on the highest portions of the kettle range, and the consequent comparative *barrenness* of the "barrens." During the melting of the glaciers, each grain of sand was literally washed, and all adhering clay carried away in suspension to still water, where it was deposited in horizontal beds. In regard to the thickness of the glaciers, we know but very little, and of the maximum depth of the drift, little more. The glaciers must have been thick enough to have filled the basin of Lake Superior to a depth of nearly 1,000 feet, and to have overtopped the highest points in the district, not over 700 feet above the lake. On account of the probable very irregular surface of the Keweenawan strata, an attempt at the estimation of the thickness of the drift at a given point would be at best guesswork. The stratified drift near the western end of the lake is over 200 feet thick.

Champlain deposits. *Stratified drift.* Owing to the very few fresh exposures of the drift deposits in the district, it is impossible to state precisely the altitude to which the stratified clays and fine sands arise. Very few, if any, stratified clays were observed at an elevation greater than 300 feet. The sands, however, with a small admixture of clay, have an indistinct stratification along some of the ancient channel courses fully 200 feet higher. I found no evidence that the drift materials had been stratified by the waters of the lake, when standing at a relative altitude of 300, or, at most, 350 feet, greater than at present. Along the lake shore in Douglas county, stratified red marly clays, with layers more or less sandy, arise to a height of from ten to twenty-five feet. When the clay is dry it crumbles readily and rolls down the steep banks into the lake, and, when wet, it slips or slides down. The lake is, therefore, quite rapidly encroaching upon the land.

The following section of the modified drift was taken on the left or north bank of the St. Louis river, about one quarter of a mile from the railroad station called Greeley. The river bank is very steep, and the section is continuous, cuttings for a railroad grade having exposed about forty feet. It is introduced as a representative section, instead of several smaller ones of less importance. Commencing at the top, the successive beds or layers are as follows:

	Feet.
1. Sandy soil	2
2. Brownish sharp sand	12
3. Yellowish clayey sand	6
4. Reddish sandy clay	6
5. Brownish sand	1
6. Light colored sandy clay	5

	Feet.
7. Whitish sand	2
8. Reddish sandy adhesive clay	13
9. Slightly sandy reddish clay, somewhat gravelly; bakes in the sun, and crumbles in small angular masses	50
10. Same, wanting the gravel	12
11. Slightly sandy, light red clay; dries and bakes in the sun, becoming exceedingly hard	30
12. Light colored clayey sand	14
13. Like No. 9, but containing a few small boulders	30
14. Unstratified? Boulder clay, above the river	4
15. Elevation of river above Lake Superior	15
Total	202

Terraces. In the vicinity of Fond du Lac, at the western end of the lake, and also southeast from Superior City along the old St. Paul military road, there are quite distinct evidences of lake terraces. I place them at about 15, 35, 80, 120, and, an indistinct one, 300 feet above the present level of the lake. At most localities in the vicinity of the lake shore they have been obliterated. Along either side of the Brulé river, in the vicinity of the mouth of the Nebagamain, T. 47, R. 10 W., there are perfectly distinct river terraces. The river here is about 300 feet above Lake Superior. The first terrace is 30 feet above the present surface of the river, the second 80, and the third 190 feet. From the top of the highest terrace, or level of the surrounding country, to the corresponding top on the opposite side of the valley, the distance is about one mile. As the river is ascended a few miles, the several terraces have a less height above the stream, showing that they are more nearly horizontal than the present channel, and consequently, that the current is much swifter now than it was formerly. In descending the river a few miles, another terrace comes in near the surface. Evidences of river terraces were also observed near the headwaters of Iron and Flag rivers.

CHAPTER III.

ORE DEPOSITS AND MINES.

About $100,000 has been expended in Douglas county, in working mines and making explorations for metallic copper. The most of this sum has been expended in the interests of those who hoped to speculate on the mining stock, or who had a very strong desire to "get up a company." In consequence of the funds mostly being used by those who had not the greatest pecuniary interest in the successful development of the mines, and, also, owing to the fact that most of the work was undertaken before the occurrence of the metal, and the proper system of mining, were well understood by anybody, a large proportion of the $100,000 was not judiciously expended. Although none of the mining enterprises have proven successful, they do not demonstrate, by any means, that valuable deposits of native copper do not exist in the district, or even that one or two of the partially developed mines may not yet economically produce considerable quantities of copper. It usually requires but a very inconsiderable outlay of money or labor to demonstrate the general character of a deposit. After this has been accomplished, in any future attempt at mining, I would most strongly recommend that some extensively known, and universally recognized, thorough mining expert, one who has had experience with the copper deposits of Michigan, be employed to examine, and report upon the proposed mine. Better pay a few hundred dollars, and have your mine properly condemned, if need be, at the outset, than to expend many thousands and finally condemn it yourself.

Character of the Metalliferous Deposits. Metallic copper occurs under the following conditions in Douglas county:

1. Indiscriminately scattered through belts of epidotic and calcareous rock of various thickness, and lying usually with the bedding of the formation, as at the Percival mine.

2. Irregularly disseminated fine particles of native copper in the layers or beds of diabase, as at the Fond du Lac mine.

3. In true fissure veins, as at the Wisconsin mine.

I have noticed indistinct indications of *contact deposits* at Black river falls, and on Middle river, between the eruptive rocks and breccia or sandstone. As these deposits are of great importance in Michigan, I would suggest to explorers to hereafter carefully search for them. Another locality in which to search for contact deposits is along Moose river, and to the west of that stream, at the junction of the crystalline rocks and overlying and interstratified conglomerates.

One consideration which will probably be found somewhat unfavorable to mining enterprises in Douglas county, especially upon fissure veins, may be mentioned in this connection. The layers or beds of uniform rock, apparently, have no very great thickness, but differ considerably in lithological characters. A vein, therefore, in passing from one to another, will doubtless be found to be somewhat irregular. In this respect, the beds of Douglas county strikingly resemble those of Isle Royale.

History and Descriptions of the Douglas County Copper Mines. Through the kindness of several of the old settlers of Superior City, Mr. James Barden in particular, and of some of the officers of the various mines, I have been able to collect many interesting and important facts in regard to the history of each location. These will be included and blended with my own observations from a recent personal examination of each location.

Pre-Historic Mines. Although from present indications, I assume that their work was very limited, there is, nevertheless, but little doubt that this district was "prospected" by that strange pre-historic people, whose greatest efforts at mining were apparently upon Isle Royale. Mr. Stuntz, of Superior, has informed me that some years ago several small pits were found near the upper falls of Black river, and lying on top of one of the heaps of gravel and earth thrown out, was a rude and broken stone hammer. He also states that long ago he saw indications of pre-historic mining two or three miles east of Copper creek. Almost directly across the stream from the junction of the eruptive rocks and sandstones on Copper creek, I found a tolerably well defined pit three or four feet deep, and six or eight feet long. In the center of the depression was standing a dead spruce, about a foot in diameter, and under the roots were remains of charred wood. In the bottom of the pit, and under a slight covering of soil, were many small boulders, two of which, although very rude, had apparently been used as mauls. In this connection, it may be interesting to state that a fine copper knife, eight inches long, was found a few years ago on Presque Isle, one of the Apostle islands. Mrs. Heyward, of Bayfield, has it with her fine collection of minerals and antiquities.

At Black River Falls, the North American Fur Company sunk a shaft a few feet, and prospected about the falls considerably during the years 1846–7. Since then there appears to have been little or no work done at the locality. A short distance along the northeast wall of the cañon from the foot of the great fall, a fine-grained reddish brown diabase comes in, which is frequently amygdaloidal. The dip is 46° about S. 20° E. In this rock there is a band of amygdaloidal diabase, one or two feet thick. The cavities of the amygdaloid are chiefly studded with small acicular crystals of epidote, and the rock is quite highly charged with the green and blue carbonates of copper. A small amount of galena was also noticed in the vein matter, which induced me to make an assay for silver. A distinct trace was found. A trace of silver was also found in a sample of the debris piled up upon the bank near the head of the falls. Galena was also noticed in this.

Copper Creek Mine. This mine is located on the west half of the S. W. qr. of Sec. 14, and the east half of the S. E. qr. of Sec. 15, T. 47, R. 14 W., comprising 160 acres. The North American Fur Company, in the years 1846-7, sunk four shafts on this location, which appear from soundings to be 28 ft., 28 ft., 46 ft., and 35 ft. deep, respectively. So far as I was able to determine, they do not appear to be on a vein, or even a metalliferous bed. This tract of land, immediately after the government survey in 1853, was secured, after a litigation with the Fur company, by J. H. C. McKinney. From him it passed with one intervening title, to Gen. Geo. B. Sargent, of Davenport, Iowa, and Jas. O. Sargent, of Boston, Mass. Explorations were made by the latter gentleman in the fall of 1863, with such encouraging results that a company was organized to mine for copper on an extensive scale. During the years 1864–5, a large force of men was employed, and about $30,000 expended on the location. Considerable surface exploration was carried on, three shafts were sunk, and drifts were run in various directions, generally from the bottoms of the shafts. The aggregate depth of shafts sunk was about 190 feet, and the length of drifting about 260 feet. The surface indications were considered good, but, as there is no true vein, the deposits, of course, were found very irregular. It was supposed that there were three distinct veins. A perpendicular shaft was sunk at the junction of the forks of the creek, to strike one of the hypothetical veins, which was supposed to be exposed on the surface to the west of the shaft, and to apparently dip towards it. As the lode (?) was not struck at a depth of 60 feet, a drift was run towards it at a distance of about 40 feet, and then to the north 15 feet. It is needless to state that no "vein" was found. A drift was also run from the bottom of the shaft 15 feet to the east, but without striking a "vein." The rock which came out of the shaft is very amygdaloidal, soft and earthy, and decomposes with exceeding rapidity. A large amount of very epidotic rock, quartz and calcite, carrying more or less fine shot copper, were also taken from the shaft and drifts. The other shafts, tunnels, and drifts, afforded no more encouraging results than those first described. One of the shafts is located about 100 feet south from the junction of the forks. A large amount of quartz, carrying small flakes of native copper, came from this shaft, which would seem to indicate the presence of a quartz vein. However, I saw no surface indications to warrant such a supposition. The third shaft is located about 400 feet northeast from the forks of the creek. It was sunk upon a bedded "epidote vein," which is two feet wide on the surface, where it appears at the mouth of a tunnel, 50 feet long, run to intersect the shaft. The dip is about 50° S. E. In the shaft, above the water, a clay-like material, somewhat reddish, probably derived from laumontite, composes the "vein," about four inches wide. Epidote is found in the walls about a foot either side of the vein, and grades into amygdaloidal diabase. These shafts are all filled with water to very near the surface. The buildings belonging to the location are now so thoroughly decayed as to be entirely worthless. The wagon road, which was constructed to Superior City, thirteen and one half miles, since the abandonment of the mine, has become impassable for teams.

Fond du Lac Mine. This location comprises the N. E. qr. of Sec. 8, T. 47, R. 13 W.—160 acres. The land was purchased from the government by A. A. Parker and C. Kimball, both mineral explorers from Ontonagon, Michigan. In 1855 a company was organized under the general laws of Wisconsin, with local officers residing at Superior, and with a subscribed capital of $50,000. W. S. Crowell, from Michigan, was appointed superintendent, and a regular force of miners was employed during 1856–7. During this period there was expended about $12,000 in sinking two shafts upon what the company supposed to be a "well-defined vein." The depth reached was 40 feet in one shaft, and 60 feet in the other. The operations at this location were suspended "on account of the financial crisis in 1857," and have not been resumed. The shafts are nearly one-fourth mile apart. The one near the road leading from Copper creek to the Wisconsin mine, has an inclination of about 40°, S. 30° E. The debris consists largely of a pinkish, dark-gray diabase, often containing minute flakes of native copper, which, I conclude from the indications about the shaft, came from the foot wall of an epidotic belt. The hanging wall is mainly gray amygdaloidal diabase, containing no copper. The vein stuff is very epidotic, but contains no copper. A determination of copper from a selected specimen of the foot wall, gives me less than one-fourth of one per cent. The rock from the second shaft is chiefly amygdaloidal. A small quantity of epidotic rock, and small pieces of coarsely crystallized calcite were noticed with the debris. Copper was only found in diabase from the foot wall, and in quantities nothing like sufficient to induce a re-opening of the mine. This mine was opened with the idea of finding mass copper. It was supposed that it was only necessary to open a mine almost anywhere in the crystalline eruptive rocks, in order to develop a lode which would produce large masses of pure copper. The shafts at this location are nearly full of water, which renders their interior exploration impossible. The buildings have decayed and tumbled down.

Wisconsin Mine. This mine, locally known as the Edwards Mine, is in the N. E. qr. and the S. E. qr. of Sec. 2, T. 47, R. 13 W., comprising 320 acres. A company, composed of James Edwards, J. Mallory, J. V. V. Platto, J. W. Cary, J. A. Noonan and A. Finch, was organized in the spring of 1863, under chapter 331 of the general laws of Wisconsin for that year, having the name of the "Wisconsin Copper Mining and Smelting Company," with a capital stock of 20,000 shares, of $100 each. A regular and well-defined fissure vein, from four to six feet wide, was found in this location, and the shafts were sunk on it between 300 and 400 feet apart. Work was commenced in June, 1863, under the direction of Capt. Jas. Edwards, and continued for nearly a year. About $14,000 was expended, when the work ceased on account of lack of funds. The owners of the location are confident that it is rich in copper, and that it only requires skill and capital to develop it. The vein is composed of an epidotic rock, carrying a considerable amount of crystalline and drusy quartz, with prehnite and granular calcite. It carries a considerable quantity of shot and nugget copper. Nuggets weighing from one to fifteen pounds are frequently found. In sinking one of the shafts to a depth of fifteen feet below the surface, a half ton of copper was taken out. One of the shafts was sunk to a depth of 58 feet, and the other 72 feet. The vein trends nearly N. E. and S. W., and dips about 75° N. W. The country rock is amygdaloidal, and is very uniform over an area of several acres. The base of the rock is rather soft, dark brownish and granular to compact. The amygdules are prehnite, calcite, and an altered prehnite. Often the cavities are studded with quartz or epidote crystals. The shafts, now nearly filled with water, are very large, being seven feet wide, and ten long. The wagon road to Superior, eight and one-half miles distant, is in very good condition, but the buildings at the mine have been destroyed.

This location, being upon a true vein, as is known from the polished and striated condition of the walls, and the well marked selvages, I regard as the most desirable piece of mining property in Douglas county. It ought to be prospected still farther. At least, levels ought to be run on the vein from the shafts. A small expenditure would do this much.

In this connection it may be interesting to note the cost of sinking the shafts, or running the levels or tunnels. The average cost per foot of sinking the shafts and running the drifts at Copper creek in 1864–5, was $66. At the Fond du Lac mine in 1856–7, the cost per foot in sinking the shafts was $120, and it cost to sink the shafts on the Wisconsin location in 1863, $107 per foot. It may be observed that these figures are extraordinarily high. At the present time (1877), numerous contracts are taken in various mining districts of Colorado, some of which are vastly more inaccessible than was the Copper Range of Douglas county, for sinking shafts and running tunnels, in much harder rock than the diabases of Wisconsin, and at a price a good deal less than half the sum it cost the Wisconsin companies.

The Percival Mine. This location, named in honor of J. G. Percival, the eminent scholar and geologist, comprises the north half of Sec. 27, T. 48, R. 10 W.— 320 acres. It was owned principally by the late Gen. Geo. B. Sargent, of Duluth, Minnesota, who was also the owner of over 11,000 acres of mineral lands upon the Copper Range of Douglas county. Work was commenced on this location in September, 1873. The mine was visited September 30th, by the geological party, at whch date a force of eight men were employed in tracing the "veins." Mr. E. McNair, who was largely interested in the location, was upon the ground and greatly assisted the geological party. Owing in part to the bad condition of the roads, and the consequent difficulty of obtaining supplies, but very little work has been done on the mine, not enough, in fact, to warrant me in drawing definite conclusions in regard to the character of the deposits. The owners claimed to have four parallel "veins," separated from each other by 50 or 100 feet, and trending nearly east and west. There are very few natural exposures in the vicinity of the mine, nearly the whole range in this locality being covered with a slight coating of drift. The country rock in proximity to the "veins," is a dark gray granular diabase, often having a pinkish tinge, and occasionally contains amygdules of prehnite.

"Vein" No. 1 is the most southern of the series of metalliferous deposits, and consists mainly of a calcareous and laumontitic gangue, containing small quantities of the carbonates of copper, derived from the native metal, and occasional nuggets of metallic copper weighing from one to seven pounds. From the indications about several shallow test pits sunk along the line of this so-called vein, it is probable that a number of surface impregnations were struck instead of a vein being followed.

"Vein" No. 2 I regard as merely a vein-like impregnation. Several pits were sunk in tracing it, and a shaft was put down 15 feet, at a point supposed to be the junction of a leader with the main vein. Here the dip is about 45° N., and the impregnation has a width at the surface of only two inches, while at the bottom of the shaft it is indistinctly fifteen inches. Shot, and strings of native copper are found in the "veinstone," of epidote and quartz, which grade into the walls. A determination of the amount of copper in a carefully selected average sample of the epidotic rock gave me 2.61 per cent.

"Vein" No. 3 is fifty feet north of No. 2. It is a belt of the common epidotic altered amygdaloid, with impregnations of copper in the walls. More work has been done upon it than upon all of the other deposits. It has been followed about 2,000 feet. The gangue is a quartzose epidotic rock carrying shot and nugget copper. Several nuggets weighing over twenty pounds each have been taken out. An analysis of what was regarded as a fair average sample of a pile of the vein stuff, gave me 3.50 per cent. of copper. Of course I do not intend to assert that the entire vein will average that amount. The country rock is a dull ash colored diabase, very amygdaloidal. The amygdules are chiefly prehnite and calcite. Two shafts have been sunk, 300 feet apart, each to a depth of thirty or forty feet. The bed is from twenty to forty inches wide and dips about 40° to the south. It grades somewhat into the country rocks.

"Vein" No. 4. But very little prospecting has been done upon this. If metallic deposits are found here they will probably be impregnations. Work was discontinued upon this location in December, 1873, and has not been resumed. "Hard times" was the alleged cause for the discontinuance. Several thousand dollars were expended upon this mine, and buildings suitable for the accommodation of forty men were erected. Upon a reëxamination of the location in the spring of 1877, the buildings were found to be in good condition, but as the shafts were filled with water, and no additional stripping or test-pitting had been done since my former visit, very little additional information was obtained.

From the present facts accessible to me, it is impossible to condemn or approve the mine. If copper shall hereafter be proven to exist in quantities sufficient to remunerate the expense of mining it, the indications are that it will be found in the vein-stone as "stamp-work." The facilities for conveying the ore from the mine to the Brulé, only one mile distant, and working it with stamps, are particularly noticeable. The descent from the mine to the river is gradual, and about 200 feet. The expense, therefore, of conveying the ore to the river and working it under stamps, which should be run by water power, would be merely nominal. The soil upon the range in the vicinity of the mine is excellent, and the timber, consisting of sugar maple, oak and birch, exists in great abundance.

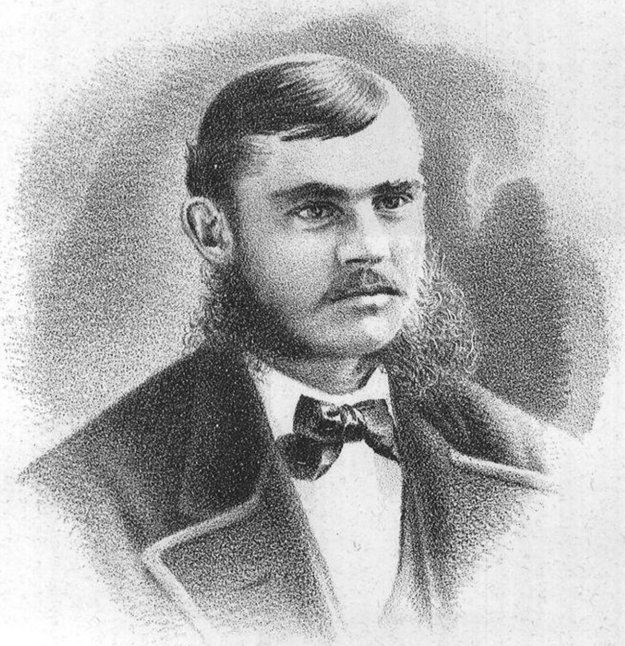
How and where to search for deposits of copper. It is not at all improbable that much more valuable deposits of copper exist in the cupriferous series of Douglas and Bayfield counties, than have yet been discovered. Exposures of the rock in which these deposits may be expected to occur are rarely met with except in the vicinity of the streams, so universal is the distribution of the drift. In many places, however, upon the range of Douglas county, the drift is light, and might readily be removed, at any point where there are indications of a deposit in the underlying rocks. Of course such indications are difficult to discover. They may sometimes be found by tracing pebbles and fragments of rock, found in the channels of small streams, or in the drift, in their origin. If the indications are found in the channels of streams, or dry runs, the water-course must evidently be followed up, if in the drift; always remember in tracing them, that the movement of the drift was from the north or northeast.

It is known that deposits of metallic copper usually occur in belts of rock, having an unusually large amount of the magnetic oxide of iron. It is said that explorers in the Michigan copper districts frequently take advantage of this fact, and carefully watch the magnetic needle. At localities where the local attraction or variation is greatest, they make careful and minute examinations. From personal observations, I am unable to state whether or not this can be relied upon.

By referring to the geological map of this portion of the state, it will be observed that all of the mines and all of the reported "veins," except that at the upper falls of Black river, which was a small impregnation, are within one-half mile of the line of junction of the eruptive rocks and the Lake Superior sandstones. The most favorable known belt, then, for the occurrence of metalliferous deposits, is from the sandstones about a half mile to the south, along the northern face, and on the summit of the range. A belt 2,000 feet wide will include nearly all of the known deposits.

I would also suggest that careful search be made very close to the sandstones, in fact, between them and the crystalline rocks. Deposits of metallic copper may be discovered almost anywhere *south* of the sandstones in Douglas or Bayfield counties. An almost totally unexplored, and very inviting field to the explorer, is along Moose river, and in the townships to the west from it. The drift is not heavy in this region, and many small copper boulders are found to the south of it. Conglomerates and sandstones overlie the eruptive crystalline rocks, which are doubtless the equivalents of the Isle Royale copper-bearing beds, and of the great beds, in the other side of the synclinal, in which the vast deposits of Michigan are found.

PLATE, III.



Very truly yours

Moses Strong

PART VI.

THE

GEOLOGY

OF THE

UPPER ST. CROIX DISTRICT,

BASED ON THE NOTES OF THE LATE

MOSES STRONG.

EDITED BY T. C. CHAMBERLIN.

INTRODUCTION.

The greater portion of the data upon which the following report is based, was gathered by the late Moses Strong, in the years 1876 and 1877.[1] In the former year, a belt extending from St. Croix Falls, on the Minnesota border, northeastward to the watershed of Lake Superior, was examined by him, and in the spring of 1877, he investigated a triangular area lying between this belt and the territory examined by Mr. Sweet on the north. With the exception of the surface description of the townships, which will be found included in this report, his notes at the time of his lamented decease had not been wrought into a formal report. These notes form the main basis of this report. It is to be borne in mind that all geological field notes, however well taken, are more or less provisional in their nature and abbreviated in expression; and in their elaboration into a final report, the memory of the observer, aided by subsequent study and reflection, plays an important part; and practical geologists will appreciate the difficulties of preparing a report on the basis of another's notes. In the present instance, the nature of the formation increases the difficulty. The rocks of the region are largely fine-grained crystalline species of igneous origin, modified by subsequent chemical and molecular changes, so that it is quite impossible, in many cases, to determine their exact nature by simple inspection in the field. Only careful chemical and microscopical examination, subsequently, in the laboratory, is competent to decide many questions, and hence the use, for the time being, of provisional terms and conventional phrases is well nigh a necessity. No one can interpret these in the light of subsequent study so well as the observer himself. An additional embarrassment arises from the fact that it was impracticable to take specimens from all outcrops examined, much less a full suite from the different layers or varieties of rock in a given locality. The territory

[1] The circumstances attending the death of Mr. Strong, while engaged in the active prosecution of the survey, may be found in the annual report for 1878, pp. 11–13.

belongs to the great forest region of northern Wisconsin, in which the only practicable means of exploration is by traveling on foot, and packing tent, provisions, instruments and specimens on the back. Under these conditions, it will be at once evident that the number of specimens was necessarily limited, when it is stated that, in 1876, when the larger part of the field work was done, the party left St. Croix Falls on the 15th of July, and only reached Lake Superior on the 23d of September, having traveled on foot, the most of the time under burden, over one thousand miles, with but a single opportunity to send out specimens.

Notwithstanding these difficulties, it has been the hope and endeavor of the writer to so compile the observations that they shall stand as an additional monument of the merit of his deeply lamented associate.

The specimens collected have passed under the skillful hands of Prof. Pumpelly, and a portion of them have been sliced and microscropically examined by him, and this has been of inestimable value in the preparation of the report.

For the purpose of becoming somewhat familiar with the general aspect of the region, of adding some new data, and of verifying some points of doubt, the writer has twice briefly visited the district since he began the study of Mr. Strong's notes. During these he was much aided by Mr. D. A. Caneday, who was Mr. Strong's assistant, and whose verbal descriptions have been of important service.

T. C. C.

BELOIT COLLEGE, *July 23, 1879.*

GEOLOGY OF THE UPPER ST. CROIX DISTRICT.

CHAPTER I.

SURFACE FEATURES.

Topography. The district about to be considered may be conveniently described as including that portion of the basin of the St. Croix river which lies north of township 31, except, of course, that part which is included in the adjoining state of Minnesota, and a small area on the northern border included in the district already described by Mr. Sweet. It is mainly embraced within the counties of Polk and Burnett, but the extreme northwestern corners of Barron and Chippewa, the southwestern township of Ashland, and the southern margin of Douglas counties, are also included. But as these are mainly new and large counties, whose boundaries are liable to be soon changed, little reference will be made to them in this report; and the region will be discussed, either on the basis of its natural topographical relations, or, where greater precision is desired, recourse will be had to the more permanent and systematic artificial divisions found in the township system.

The district constitutes an elongated area, having a N. E. and S. W. trend, embracing about 3,000 square miles. The channel of the St. Croix river runs along, or near, the northern margin, and, at length, the western, so that the immediate slope of the surface is for the greater part northwestward; at the same time, the inclination and discharge of the valley is toward the southwest and south. This, while not an especially unusual feature, is a departure from the symmetrical slopes of an ideal river basin.

It would scarcely merit mention, however, except for its geological relations and significance. It is a somewhat singular and quite interesting fact that the St. Croix river takes its origin within the area of the stratigraphical trough of Lake Superior, and discharges into the broad synclinal basin that stretches southward into Minnesota and beyond; and it is also interesting to note, more precisely, that, in its upper portion, the St. Croix channel lies very nearly in the axis of the Lake Superior stratigraphical trough, and that, in the southern portion, it likewise lies near the center of the broad depression of the strata that extends for an undetermined distance southward, though in the latter case it is impossible to speak with exactness, owing to the breadth of the trough and the presence of minor undulations within it. It is probable that it lies somewhat east of the main axis. It will be observed that the upper portion of the valley of the St. Croix trends southwestward, while the lower course is nearly due south. If we project the upper course to the northeast, it will coincide with the major axis of Lake Superior. If we likewise extend the axis of the lower valley, it will approximately coincide with the broad stratigraphical valley of southern Minnesota. It appears that the axes of these two synclinal troughs approach each other quite obliquely near the middle of the St. Croix valley. The low ridge in the basal formations which separate these two basins, appears to cross the valley of the St. Croix near the southern limits of the district under consideration. The division of the region into the upper and lower St. Croix districts, therefore, while geographically arbitrary, has, geologically considered, profound significance. The upper St. Croix district, though a portion of the Mississippi drainage system, is geologically associated with the formations of the Lake Superior region. Indeed, our district may be defined as that portion of the Lake Superior *geological basin* that lies within the Mississippi *drainage basin.*

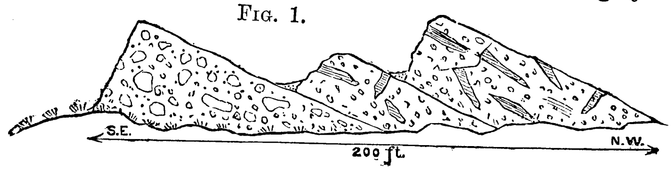
In the preceding reports, it has been made sufficiently clear that the copper-bearing or Keweenaw beds of Lake Superior are deeply depressed along the central line, and that the upturned edges form the ridges on either side of the great lake. It is the southern edge of the strata thus upturned that forms, approximately, the southeastern watershed of the St. Croix basin, and it is the slope of these strata to the northwest that appears to determine the surface inclination in that direction already alluded to. While this may seem to afford a very evident and satisfactory explanation of the slope of the sides toward the axis of the trough, it leaves unexplained the fact that the St. Croix river flows *away from*, instead of toward, the great stratigraphical basin occupied by Lake Superior, and that the area now belongs to the Mississippi drainage system. The anomaly which this seems to present will largely be removed, when we consider that, subsequently to the formation of the Lake Superior basin by the flexure of the copper-bearing and earlier strata, the Silurian sea advanced from the south, and eroded and overwhelmed the rim of the basin —

in the St. Croix region — and deposited over the whole the Potsdam sandstone, forming *a new surface*, which doubtless sloped seaward; *i. e.*, toward the Mississippi basin. We have no *positive* knowledge that any marine deposits later than the Potsdam were ever formed over this region, but there is much indirect evidence making it probable that such was the case. This subject will be discussed elsewhere All that concerns us here is the explanation of the topographical features which the region now presents, and for that purpose the above fact is sufficient.

When the sea retreated after having covered the region with Silurian strata, the drainage would naturally follow it, and, having once established its channel in the surface strata, would remain permanent without regard to the nature or dip of the underlying beds. There are many similar anomalous features in the drainage systems and the resulting topography of the Lake Superior region, to which a similar explanation is applicable.

This explanation does not apply, however, to the immediate channel of the St. Croix river, for it is clear that that was formed after the glacial period, and its *special* course was determined largely by drift

Fig. 1.



Profile of an Outcropping Ledge of the Keweenaw or Copper-Bearing Series.

accumulations; but there seems to the writer no sufficient evidence for believing that the *basin*, as a whole, was of glacial origin, and it is certainly not post-glacial. The later drift movement was *across* the valley, a direction not favorable to its excavation. We cannot speak positively as to the glacial course in the earlier portion of the ice period, for the grooving and fluting that remain are the *last* that was impressed on the rocks, and it is possible to suppose that at an earlier stage the movement might have been in a different direction. There is, however, a total absence of evidence that such was the case, and a like want of evidence that any profound erosion was accomplished by the drift agencies, either earlier or later. As will hereafter be seen by the perusal of the detailed descriptions, one of the most marked and common forms of the outcropping ledges, consists of a serrate outline or a stair-like arrangement of the strata, each massive bed of eruptive rock forming a step, presenting an inclined surface in the direction of dip and an abrupt face in the opposite direction, as shown in the preceding figure, which is a *fac simile* of a profile taken by Mr. Strong.

The drift groovings and flutings strike across these steps, and yet the glacial agencies were manifestly too feeble in abrading power to bevel the projecting edges of the strata to a common plane; how much less, then, to excavate the St. Croix basin. If, at an earlier stage in the glacial period, the movement of the abrading ice was parallel to the valley, and hence to the strike of the step-like projections, it may fairly be supposed to have left some traces of the fact in a longitudinal fluting and abrasion of these, since the conditions for preservation are exceptionally favorable; but no such traces have been observed. Moreover, it would be all the more remarkable that abrupt prominences, such as abound in the southeastern part of the valley, should remain, if the region had been subjected to a cross filing at the hands of successive glacial rasps. We are not concerned here with the general question of the competency of glaciers to excavate broad and deep valleys under favorable circumstances, which, at present, we are rather inclined to accept than dispute, but with the simple question whether or not the St. Croix valley owes its origin to glacial agency; and this we are compelled by the evidence to answer in the negative, so far as the general features of the basin are concerned. It appears from the data at command that, while the older formations had previously undergone much wear, the definite excavation of the St. Croix basin by its own drainage did not commence till after the Potsdam period — not until about the Devonian age, in the judgment of the writer — and that it was well advanced at the commencement of the glacial period;[1] that during that period, it was both eroded and filled; but, lying in the main out of the great channel of glacial flow, it gained in material rather than lost;[2] was more filled than excavated; and that the minor topographical features and the special channels of the streams are of glacial and post-glacial origin.

Minor topography. If we descend to a more special study of the superficial contour of the district, we shall find it presenting nothing bold and striking; while, on the other hand, it is not without something of diversity. Its surface types may mainly be gathered into three classes: (1) the level areas, (2) the rolling and swelling hill districts, and (3) the knoll and basin combination.

The first includes the so-called "barrens," which border the larger

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[1] Gen. G. K. Warren has attempted to show (Am. Jour. Sci., Dec., 1878) that the Mississippi valley above the Ohio has been formed "since the deposition of the glacial drift." While this may be true of the upper portion in Minnesota, it is, I think, demonstrably not true of the portion lying on the border of Wisconsin.

[2] This opinion is expressed only of the restricted district under consideration, and probably may not be true of the northwestern border of the area drained by the St. Croix river, since that lies more nearly within the main drift channel.

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DALLES OF THE ST. CROIX.

streams, and some elevated plateaus, together with smaller scattered areas. The third class may be described, in general terms, as a belt lying near the southeastern watershed, and stretching from the vicinity of Lake Nemakagon southwestward to the St. Croix. The second class includes most of the territory that remains.

There are also some very limited areas where the projecting strata give to the surface their peculiar cliff-and-slope contour, and others wherein river terraces are a conspicuous feature. Details in respect to topography may be found on subsequent pages, in the township descriptions left by Mr. Strong, and to some extent under the head of Quaternary Formations. Concerning these special details of surface contour, it is to be remarked that, in the main, they are not primarily due to drainage erosion, although they have been somewhat modified by it. When a surface has been carved out simply by surface wear, it presents a complete system of drainage channels, which usually gather themselves together in regular dendritic symmetry, and the surface has a correspondingly methodical contour. All its features are readily traced to the carving agency. There is, from the nature of the case, an absence of lakes and marshes, except in the river bottoms. This is beautifully exemplified in the driftless region. But in the upper St. Croix district, the surface is such, in many instances, as could not be produced by surface drainage. There are thousands of depressions whose excavation cannot be explained by the action of ordinary surface streams. Several hundred of these are occupied by lakes without inlet or outlet. See Atlas maps XIX and XX. Besides these decisive features, the configuration of the hills and valleys is such as to indicate to the practiced eye some other agency than simple sub-aërial erosion. This is true more especially of the second and third classes, which may be said, for want of a better term, to present a drift or glacial topography; the second being the more common form for wide-spread drift deposits, while the third presents a less usual morainic contour. The first class we shall find reason to attribute to the action of surface waters, acting under special conditions.

Altitudes. Concerning the altitudes of the district, our data is quite imperfect. The field party of 1876, by whom most of the exploration was performed, were in the woods continuously from the 15th of July to the 23d of September, without once having an opportunity to refer to any point whose elevation was known; and being, on the average, about 75 miles distant from any point where systematic observations were being taken by a stationary barometer. It is impracticable, under such circumstances, to secure trustworthy results with an aneroid barometer.

The only railway traversing any portion of the upper St. Croix basin, is the Lake Superior & Mississippi R. R., in Minnesota, the elevations along which are given in the First Annual Report of the Geological and Natural History Survey of Minnesota, 1872, p. 49. Along this line the altitudes, above Lake Michigan, vary from 317 feet at Wyoming Station, opposite St. Croix falls, to 586 feet at the summit within 33 miles of Lake Superior. Mr. Sweet gives the watershed between the sources of the St. Croix and Brulé rivers as about 445 feet.

The St. Croix river below the falls at low water is about 52 feet above Lake Michigan, making the entire fall of the river within the district about 393 feet. Some of the tributaries on either hand, however, have a greater descent.

Drainage. The total drainage area of the St. Croix river above the falls, is 6,000 square miles. It has already been seen that the inclination of the surface is considerable, and the total fall from the watershed to the St. Croix falls quite large. The streams generally run briskly and falls and rapids are numerous. Were the surface contour entirely subordinate and subservient to the drainage system, as it is in the driftless region, and as it may become here, under the wear of ages, the rainfall would be very promptly discharged from the district, too promptly for the good of the region, or the safety of property in the valley below. There are, however, numerous small depressed areas scattered over the district, that have no visible outward channel of discharge, and the waters collected in these, either sink into the earth or return to the atmosphere through evaporation. In many of these cases, the open nature of the drift in which they are situated, doubtless affords a ready passage for the accumulated water, not, perhaps, of the nature of a definite underground channel, but rather of a porous medium through which the waters percolate with facility. The existence of lakes in such depressions, however, unless their surfaces lie at, or near, the common underground water level, is to be taken as evidence of an impervious bottom; and the varying height of adjacent isolated lakes is to be accepted as satisfactory proof of the absence of free underground communication of any kind. Aside from these basins which have no visible connection with the general river system, there are shallower depressions whose means of discharging accumulated waters are imperfect, and which, therefore, become marshes or lakes. There are some extensive cranberry marshes in the town of Marshland and elsewhere, and tamarac and cedar swamps abound in certain sections. On the whole, however, marshy tracts are less prevalent than might be inferred from the unusual number of lakelets, these having to a large extent steep, dry shores, with little associated marsh. The number of lakes visibly connected with the river system is large, though it probably does not include half of those embraced in the district. These, in their natural state, have performed a very important function in regulating the drainage discharge of the region by acting as reservoirs, temporarily staying the too rapid rush of floods. This function has been considerably increased by the erection of dams on their outlets in the interest of lumbering. These dams are closed so as to retain the floods as much as possible, and are subsequently opened gradually, so as to discharge the accumulated waters as they may be needed to maintain a "driving stage" of water for floating out the logs. This checking and regulation of the floods affect, of course, the whole stream below, even as far as the gulf, though with continually diminishing effects. In the future development of the region, these lake reservoirs are competent to play a much more important part. The St. Croix river and its tributaries offer very large water power facilities. These, though not now utilized, will, in the judgment of the writer, be called into requisition in the not distant future; and to give steadiness and reliability and freedom from damaging floods, a well regulated reservoir system is indispensable. A further important advantage to be derived from such reservoirs, will be the maintenance of a more uniform stage of water in the Mississippi, thus greatly facilitating its navigation.

If all the lakes on the headwaters of the Mississippi were utilized as storage basins, and drawn upon during low stages of water, a very large advantage both to water powers and navigation would result. A secondary effect would probably be the transportation down stream of less sand and silt, whose accumulation in the river channels forms the most serious permanent impediment to navigation.

The water of the region, owing to the fact that it passes almost exclusively over trappean rocks and sandstones, and the drift derived from them, is generally quite soft, and contains but a small percentage of mineral ingredients. It is usually amber colored, from the presence of organic coloring matter. The water of many of the smaller streams is pure and cool, and abounds in brook trout. Below St. Croix falls, the Potsdam sandstone is calcareous in certain horizons, and near Osceola, is capped with Lower Magnesian limestone; and from these sources calcareous, magnesian and other salts are derived by the waters percolating through them. The water, thus charged, on reaching the face of exposed cliffs, usually deposits a portion of the lime and magnesia held in solution, forming travertine, or calcareous tufa. This deposit is common along the cliffs bordering the river, especially in the vicinity of Osceola, where it is burned for lime. At some points the deposit has taken the form of a coating of vegetation, especially moss, which is then popularly termed, not with strict propriety, petrified moss.

Springs issue quite frequently from the Potsdam sandstone of this vicinity. One of these has attracted considerable attention, and a commodious hotel has been erected in its vicinity to accommodate those who resort to it for its hygienic and remedial effects. It is known as the "*St. Croix Mineral Spring*," and is beautifully situated on the east bank of the St. Croix river, about a mile and a half below the village of Osceola Mills. Its horizon is about 100 feet below the top of the Potsdam series. An analysis of the water, by Dr. J. V. Z. Blaney, gives the following results:

	Grains in 1 gallon.
Chloride of sodium	.053
Sulphate of soda	.524
Bi-carbonate of soda	.790
Bi-carbonate of lime	11.193
Bi-carbonate of magnesia	7.248
Iron and alumina	.492
Silica	.265
Organic matter	a trace
Total	20.565

Lakes. In addition to what has been said of the lakes of the region as an element of the drainage system, and in addition to the fact already sufficiently indicated, that more than one-half of them are without visible outlet, it may be remarked that they form in the main two classes, in respect to their topographical situation and surroundings. The one class are sunken in the surface of the level areas previously mentioned; the other occupy depressions in broken, hilly belts. There are a considerable number of lakes, however, that do not clearly belong to either of these classes, but, compared with the vastly larger number which do, they cannot be said to form a very important exception. By examining the atlas maps, areas J and K, plates XIX and XX, it will be seen that the lakes are grouped into two main belts, stretching N. E. and S. W. One of these lies immediately southeast of the upper St. Croix river and parallel to it, from its headwaters to its turn southward. The lakes of this belt lie mainly in the sand and gravel plains, known as the "barrens." While sometimes shallow, in many cases they occupy abrupt depressions in an otherwise nearly uniform plain. There are similar lakes in some of the level clay tracts.

The second belt of lakes is situated in, or closely associated with, a range of drift hills and ridges occupying the southeastern watershed of the St. Croix valley, and forming a part of the great Kettle moraine, a portion of which, with its associated lakes, was fully described in Vol. II, pp. 139, 205, 615 *et seq.* The greater number of these lakes occupy depressions in the peculiarly irregular surface that characterizes that formation. Some, however, are quite analagous to the former class in that they occur as basins in level areas flanking or included within the range.

There are other lakes in the district that do not belong to either of these classes, and have little that is peculiar or interesting connected with them.

All these are drift lakes; none of the several hundred are known to occupy basins excavated from the rock. They are simply the aqueous filling of undrained depressions in the drift surface, and as such testify to the limited amount of general denudation which the surface has experienced since the drift period. They stand as a check against extreme views as to the amount of post-glacial erosion, while, on the other hand, the excavation of the deep St. Croix channel forbids a too meagre view of post-glacial time and its effects.

Soil and vegetation. The specific details relating to these subjects, so far as they were gathered, may be found under the description of the townships to follow. It is only incumbent here to present a few general views.

The soil of the so-called "barrens" or "plains" is sandy and generally poor. It is not uniformly so, however, and, although there is an abundance of hardwood lands to be had at little more than government prices, a considerable number of farms have been located upon the "barrens;" and it is stated that of late years there has been an increased tendency to settle on these more open and readily reclaimable lands, especially where they are low and near the common water level beneath.

The timber occupying these tracts is peculiar and does not justify the application of the term "barrens." Some portions are covered with scrub pine to the exclusion of all else save underbrush. Most nearly similar to these are the patches of Norway pine. Other areas are covered with burr, black, and even white oak bushes, with occasional trees of these species. With these are associated the common white poplar, or trembling aspen, which is the most widely prevalent and abundant arboreous species. Curiously enough, the great toothed poplar is not uncommonly associated with it. There are also areas where white pine occurs associated with both poplars named; with the three species of oaks — though the burr oak is less common in this group — with the soft maple, and with scrub and red pines, forming a very strange association of plants that usually seek quite diverse conditions of soil and moisture. Probably the explanation is to be found in the contribution which the diabases and melaphyrs — the prevalent crystalline rocks of the region — have made to the soil, by virtue of which it is less purely siliceous than most soils of similar physical appearance. The agricultural capabilities of these areas are probably greater than appearances would seem to warrant.

Analagous to the "barrens," are the areas known as "*brush prairie*" and simply "*prairie.*" These are covered with a scattered growth of the shrubs that are usually associated with the more open timber of the region, but fully developed trees are absent. On some of these "prairies," however, young trees are springing up, and bid fair, if undisturbed, to attain the usual size. These have been appealed to as examples of *prairies returning to forest*, since annual fires are no longer permitted to ravage the region. So far as these areas are concerned, the appeal seems to be well taken, save that we might, perhaps, justly dissent from the use of the term "prairies" as applied to them; for there seems to be no evidence that these ever were prairies in the sense of being completely and compactly covered by prairie grasses, to the exclusion of all shrubs and stubs of arboreous plants, as is the case with true prairies. They rather appear to have originally been open forest areas, which, on account of the character of the soil, were especially subject to dryness, and thus to the destructive action of annual fires; while moister adjoining areas escaped. On the cessation of the destructive agent, they appear to be returning to their normal condition. It will be observed that even under this hypothesis, the primary conditions are those of soil and moisture, and that annual fires are impotent without them. Otherwise, these so-called prairies should have covered the whole region, instead of being confined to circumscribed areas. While conceding to annual fires all the potency that there seems any evidence they ever exercised, they do not seem to the writer competent to account for the vast treeless plains of this and other continents. It seems also an open question whether the meagerness of vegetation on the so-called "barrens" is not largely due to the repeated fires, which not only destroy the life of the vegetation best adapted to such a soil, but also consume the dead vegetable matter whose accumulation would otherwise cover and enrich the soil.

The remainder, the greater portion of the region, is covered with continuous forest. A considerable portion of this, especially in Polk county, is hard wood, and belongs to the group described on page 179 of volume II. This merges into the mixed hardwood and conifer group (p. 180, Vol. II), and this again is replaced by true pine forests.

The soil occupied by the first two classes is of an excellent loamy or clayey character, while that covered by pine is more arenaceous. When the wealth of forest is removed, there will remain large agricultural capabilities.

The open marshes are divided between the hay meadows and heath or cranberry marshes (groups X and XI, pp. 181 and 182, Vol. II). The former are very important to the lumbering interest, and the latter are receiving some culture at present, which will doubtless be much increased in the future.

The conifer swamps are either an almost impenetrable jungle of white cedar, or are covered with tamarac and spruce (classes XII, XIII and XIV, pp. 182 and 183, Vol. II). In the latter classes, the growth is usually densest near the margin, and not unfrequently the center is open. These marshes contain large quantities of crude peat, and not unfrequently shell marl.

BRIEF DESCRIPTION OF THE SURFACE FEATURES, SOIL AND VEGETATION, BY TOWNSHIPS.

The following brief descriptions of the surface characters by townships, are inserted as left by Mr. Strong, almost verbatim:

Range 8 W. *Town 41.* This township is very hilly, and covered with drift. It is heavily timbered with hard wood and some white pine. There is some good hay meadow along Musquito brook.

Town 42. This town is traversed from section 2 to section 31 by the Nemakagon river. On each side of the river for about a mile and a half is a strip of "barrens," with some Norway pine; the rest of the town is covered with heavy timber and is quite hilly.

Town 43. There is a strip of "barrens" in the southeast part of the town; the rest of it is heavily timbered and contains considerable pine. The township is hilly, covered with drift.

Town 44. The township is densely covered with hard wood timber, such as maple, white and yellow birch, elm, etc. It is very hilly, and contains numerous cedar and tamarac swamps bordered with pine. Outcrops of the Copper-bearing series are quite numerous.

Town 45. The southern part of the township is similar to town 44. The northern and western parts are "barrens," with scattered Norway and jack pine.

Town 46. Consists entirely of "barrens" and sandy soil.

Range 9 W. *Town 41.* The Nemakagon river flows through the town from section 12 to section 33. There is a strip of "barrens" about a mile wide on each side of the river. The rest of the town is heavily timbered with pine and hard wood. The land is rolling and hilly.

Town 42. The township is hilly and heavily timbered; there are also many cedar and tamarac swamps. It is watered by the Totogatig river and its tributaries. The township is covered with drift.

Town 43. This township is rolling and contains a large amount of white cedar, spruce and tamarac swamp. It is covered with drift and heavily timbered.

Town 44. The southern and western parts of the town are very hilly and heavily timbered; the remainder is occupied by the Eau Claire lakes. The country in their vicinity is "barrens."

Range 10 W. *Town 41.* In this township, sections 25 to 36 are "barrens," with considerable Norway pine. The rest of the township is quite hilly, and covered with white pine and hard wood timber. The town is heavily covered with drift.

Town 42. This township is quite hilly and heavily timbered, and contains numerous small swamps. The Totogatig river waters the northern portion of the town. In many places the soil is quite good, and there is not as much drift as usual; outcrops of the copper-bearing rocks are numerous.

Town 43. The line between the "barrens" and hardwood timber runs from section 1 to section 3, following the course of the Totogatig-once river, the "barrens" occupying the northwestern half of the town.

Town 44. This town lies entirely in the "barrens," and contains some Norway pine. The soil is sandy.

Range 11 W. *Town 37.* The western part of the town is hilly. The eastern part is more level near Long lake. There is considerable Norway and white pine in the western part, and the soil is sandy. In the eastern part there is more hard wood timber with clay soil and a few settlers.

Town 38. The northern portion is well timbered with white pine; in the southern part the timber is scattering and ground rolling. The soil is poor.

Town 39. The southern part of the town is well timbered, with white pine; the remainder consists of "barrens" covered with poplar brush and jack pine, except in the central part, where there are numerous swamps and some good hay meadows.

Town 40. Consists chiefly of pine "barrens" and sandy soil. The land is hilly, except in the valley of the Nemakagon and its tributaries, where there are some good meadows.

Town 41. The township is comparatively level, with poor soil. There is some white and Norway pine, much mixed with tamarac and cedar swamps.

Town 42. The south half is timbered with hard wood and pine, and is rolling, rocky ground, much covered with drifts. The north half consists of pine "barrens" and tamarac swamps, and is quite level. There are good meadows on Frog creek.

Town 43. Consists chiefly of pine "barrens." The land is rolling and the soil poor and sandy. There is some meadow in the southwestern part.

Town 44. Consists almost entirely of "barrens."

Range 12 W. *Town 37.* This town is heavily timbered with pine mixed with hard wood. The land is rolling and the soil tolerably good, and contains considerable clay.

Town 38. The land is quite hilly, and the timber the same as in town 37, but less dense. The soil is rather poor.

Town 39. The town consists mostly of "barrens," with scattering white and Norway pine. The land is rolling and the soil poor and sandy.

Town 40. The town is covered with pine "barrens," and a heavy growth of poplar brush in the central part, where there is some good soil. The land is rolling, with some meadow in the southeastern part.

Town 41. The land is quite level, and consists of tamarac and cedar swamp in the south part. The northern part is covered with pine and hard wood timber. The soil is poor.

Town 42. Consists entirely of scrub pine "barrens" and rolling land, except some hay meadow near the Totogatig river and about the lakes.

Town 43. Consists of rolling, sandy land, covered with scrub pine and some groves of Norway pine. There is some swamp and meadow land on the south side of the town.

Range 13 W. *Town 37.* Consists of rolling land, with good soil, and is one of the best townships for pine timber on the waters of the St. Croix. It contains considerable hard wood mixed with it.

Town 38. The south half of the town is hilly, and covered with pine and hard wood timber, and sandy soil. The northwestern part of the town is level and has a rich soil, covered with brush prairie.

Town 39. Consists of pine "barrens" and scattering groves of white and Norway pine. The land is rolling and the soil poor.

Town 40. Is very similar to town 39.

Town 41. Contains considerable meadow in the northeast part, and on the south side. The rest of the town is quite hilly, with sandy soil and pine "barrens."

Towns 42 and 43. Consist entirely of pine "barrens" and poor, sandy soil.

Range 14 W. *Town 37.* Rather hilly land, with good soil throughout. The timber consists of a dense growth of white pine and hard wood mixed. The town is heavily covered with drift.

Town 38. The south half of the town resembles town 37. The north half consists of scrub pine "barrens" and sandy soil.

Town 39. The south half consists of brush prairie and good soil, and is mostly level. The north half is pine "barrens" and poor soil, with some hay meadow near Yellow river.

Town 40. Consists of pine "barrens" with pine and hard wood skirting the swamps, which are numerous. The country is rolling and has many small lakes.

Town 41. Consists of "barrens" with a little Norway pine. The country is rather hilly and the soil poor. There is but little swamp land, but some hay meadow near Webb's lake.

Town 42. Consists chiefly of "barrens" to the St. Croix river. There is considerable meadow near the streams.

Range 15 W. *Town 35.* Consists of rolling land heavily timbered with a mixture of white pine and hard wood. The soil is good but rather rough for farming.

Town 36. Similar to town 35, and mostly entered for pine.

Town 37. *Loraine* (in part). The town is covered with a dense growth of hard wood mixed with some pine. There is a great deal of drift in the town, as indeed there is in this entire portion of the country. The soil is very good in most parts.

Town 38. The south half of the town is rolling ground covered with brush prairie, and has a fine, rich soil. The north half consists of pine "barrens."

Town 39. Contains some white and Norway pine in the northern and southern parts. The rest is "barrens" and swamps. The land is rolling and the soil sandy.

Town 40. About half of the town is covered with small lakes, and the rest is "barrens." The country is level and the soil sandy.

Town 41. Consists of rolling land, sandy soil, and pine "barrens."

Range 16 W. *Town 32.* *Black Brook* (in part). The township is comparatively level, and well watered. The soil is good and is heavily timbered. The underlying formation is Potsdam sandstone.

Town 33. *Lincoln* (in part). This town resembles town 32. It is heavily covered with drift and has numerous small lakes. The formation is Potsdam.

Town 34. *Balsam Lake* (in part). The land is rolling and hilly, and the soil sandy. East of Apple river the country is "barrens;" west of that river the country is densely timbered with hard wood. There are numerous small lakes and swamps.

Town 35. Milltown (in part). There are several large and beautiful lakes and numerous small ponds in this town. The soil is rich and the timber chiefly hard wood, with some pine.

Town 36. Luck (in part). The land is rolling and hilly, and the soil generally good. It is quite heavily timbered with hard wood and some pine, and is well watered.

Town 37. Clam Falls. The town is very hilly and densely timbered with hard wood and some pine. It is well watered by the branches of Clam river. The soil is generally good.

Town 38. The southern and western parts are hilly and covered with hard wood and pine. The rest of the town is quite level, consisting of pine "barrens," marshes and lakes, and some meadow.

Town 39. The land is rolling and the soil sandy, covered with scrub pine "barrens," except some heavy meadow along Yellow river.

Town 40. The eastern half consists of brush prairie with numerous small lakes, and is fine agricultural land. The town is hilly near Yellow lake, otherwise level.

Town 41. The soil is good in the southern part. The eastern part is hilly and covered with sandy "barrens."

Range 17 W. *Town 32. Alden* (in part). Consists of rather level land, well adapted to farming, and well watered by Apple river and its branches. The formation is Potsdam, covered with drift.

Town 33. The town is quite level, heavily timbered with hard wood, and diversified with numerous lakes and ponds. The soil is clay and produces good crops.

Town 34. Balsam Lake (in part). The south part of the town is similar to town 33. The northern part is more hilly, and contains some pine timber.

Town 35. Milltown (in part). The southeast part has considerable pine timber, sandy soil, and rocky, rolling land. The rest is covered with hard wood and is well suited to agriculture.

Town 36. Luck (in part). Consists of rolling land with good soil, timbered with pine and hard wood mixed. The settlements are confined to the southern part.

Town 37. West Sweden. Similar to town 37. Settled in the northern part by Scandinavians.

Town 38. The land is rolling and the soil good. The timber is pine and hard wood mixed. Well settled about Diamond and Dunham lakes.

Town 39. Consists chiefly of pine "barrens" with some meadow along Clam river, and considerable cranberry marsh in the central part of the town.

Town 40. The eastern part is hilly and the soil sandy. The western part is level, and consists of "barrens." There is some good farming land and hazel brush prairie in the north and northwest parts, and some meadow near the St. Croix.

Range 18 W. *Town 32. Alden* (in part). The land is rolling and diversified with numerous small lakes. It consists of good and poor land in alternating strips running in a north and south direction. The timber is chiefly hard wood.

Town 33. Osceola. The town is rather hilly, with numerous lakes abounding in fish. The land is nearly all well adapted to agriculture, the soil being usually clay but sometimes sandy. It supports a good but not dense growth of maple, elm, poplar, basswood and oak timber, with much underbrush.

Town 34. St. Croix Falls. The town is generally heavily timbered with hard wood, and has a rich clay soil. The land is rolling and well watered, and good farming land.

Town 35. Eureka. This town is quite similar to town 34. The land is hilly and heavily timbered.

Town 36. Laketon. The land is rolling and hilly on the east side, but comparatively level on the west side. The soil is good and the timber heavy. There are numerous small lakes and marshes.

Town 37. This town is very similar to the preceding. There is some pine timber in the northern part.

Town 38. Consists of numerous swamps and hay meadows in the vicinity of the streams; elsewhere the soil is good and timbered with pine and hard wood.

Town 39. About one-half of the town is cranberry marsh and the rest is pine "barrens."

Town 40. Consists chiefly of pine "barrens," with some meadow along the St. Croix

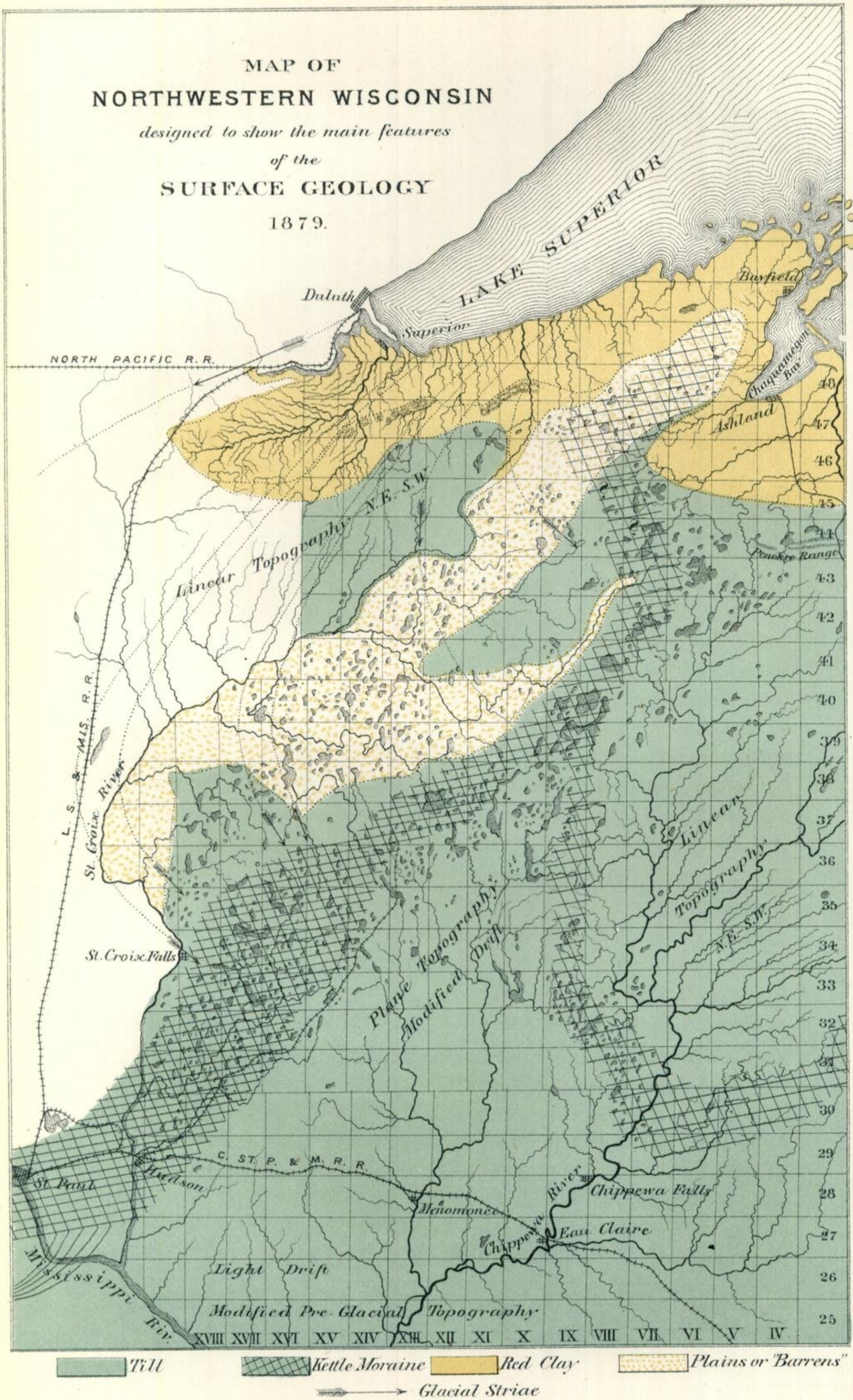
CHAPTER II.

QUATERNARY FORMATIONS.

The study of the drift deposits in such a region as that under consideration is attended with grave difficulties. Artificial excavations, such as wells, railroad cuts and the like, that are of so much service in settled regions, are here mainly wanting. Naturally exposed sections are rare, and occur only along streams where they are most liable to the suspicion of local modification. Even the surface is largely concealed by underbrush and leaves; while the prevailing forests cut off all extensive views, and interfere with that critical topographical study which forms so important an element in a rational investigation of the drift deposits.

In addition to these inherent difficulties, the copper-bearing formation was the main subject of investigation, and all less important subjects were subordinated to it; so that the belts or tracts of the drift formations were not consecutively traced out, but were merely observed as they could be when crossed in search of outcrops of the copper-bearing series. The rarity of general landscape views, from which comprehensive observations of these tracts could be obtained, increased the embarrassment attending the collocation of detached observations. It is not, therefore, to be presumed that, under these circumstances, the following chapters will possess an entirely satisfactory completeness. The writer should alone be held responsible for the views advanced.

Direction of drift movement. The observations of drift scratches and grooves are not numerous, but quite harmonious with each other. The only glacial engraving observed on the north side of the St. Croix river, is found in the southeast quarter of the northeast quarter of Sec. 14, T. 44, R. 13 W. The polishing and grooving are very fine and excellently preserved, and indicate a movement in a direction S. 13° W. (magnetic). This corresponds with the linear topography of the region, and may doubtless safely be considered as representative of the general movement in the immediately adjacent region. A little more than twenty miles east of this, in the northeast quarter of Sec. 15, T. 44, R. 9 W., Mr. Strong noted glacial marks bearing S. E. At three localities near Clam Falls (T. 37, R. 16 W.), the writer observed


MAP OF
NORTHWESTERN WISCONSIN
designed to show the main features
of the
SURFACE GEOLOGY
1879.
LAKE SUPERIOR
Duluth
Superior
Bayfield
Chaquamegon Bay
Ashland
NORTH PACIFIC R.R.
Penokee Range
Linear Topography N.E.-S.W.
L. S. & MIS. R.R.
St. Croix River
St. Croix Falls
Linear Topography N.E.-S.W.
Plane Topography
Modified Drift
C. ST. P. & M. R.R.
St. Paul
Hudson
Menomonee
Chippewa Falls
Chippewa River
Eau Claire
Mississippi Riv.
Light Drift
Modified Pre-Glacial Topography
48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25
XVIII XVII XVI XV XIV XIII XII XI X IX VIII VII VI V IV
Till
Kettle Moraine
Red Clay
Plains or "Barrens"
Glacial Striae

grooves trending S. 25° E., S. 10° E., and S. 18° to 20° E., respectively; and also in the south half of Sec. 28 of the same township, obscure markings bearing S. 20° to 25° E. In Sec. 2, T. 36, R. 18 W., striæ bear due south. In the southeast quarter of Sec. 36, T. 35, R. 19 W., glacial smoothing is shown, the planing agent having apparently moved S. 40° E. At another point, fine hair-like lines bear due east. Near the St. Croix falls (Sec. 29, T. 34, R. 18 W.), numerous broad, shallow, glacial flutings bear on the average about S. 45° E. The definite data furnished by these striations, is supported by the abrasion suffered by protruding ledges of rock, by the trend of drift ridges and depressions, and by other forms of linear topography, all of which indicate movements in the same direction.

We learn from various authorities and from personal observation, that the glacial movement in the vicinity of the southwest extremity of Lake Superior was S. W., or parallel to the great lake valley.

Combining these observations into a consistent system, our view of the glacial movements may be expressed as follows: The main glacial current of the region passed from the Laurentian highlands, beyond Lake Superior, southwestward into Minnesota, through the trough of the great lake. From this main channel the glacial currents diverged toward the margin of the glacier, as in the case of the Green Bay and Lake Michigan ice streams, in eastern Wisconsin (see diagram opposite page 204, Vol. II).

On the north side of the upper St. Croix river, this divergence was not great, so that the trend was still west of south a few degrees. But on the south side of the valley the movement was invariably east of south, and increasingly so with the degree of advance in that direction. The striæ nearest the margin of the glacier, point directly towards the Kettle moraine hereafter to be described. These movements are presented to the eye on the accompanying outline map, Plate XXXVII.

The area under consideration, then, only represents a segment of the southeastern margin of the glacier whose main channel was the Lake Superior trough, and whose prolongation was southwestward, but owing to the divergent lateral motion of the marginal portion, the movement was southeasterly in the circumscribed district we are considering. This view harmonizes all the observations thus far made, and explains them, and at the same time corresponds to the method of glacial movement found to obtain in eastern Wisconsin, and, in the judgment of the writer, quite extensively elsewhere.[1]

[1] See paper on the Extent and Significance of the Wisconsin Kettle Moraine, Trans. Wis. Acad. Sci., 1878.

DIVISIONS OF THE QUATERNARY DEPOSITS.

The quaternary formation of the district may be divided, superficially, into three parts: (1) The morainic belt, or Kettle moraine, on or near the southern watershed; (2) an intermediate area of boulder clay; and (3) the plains or "barrens." Subordinate to these, and included within their boundaries, are fluviatile and lacustrine flats of contemporaneous and later date.

Kettle moraine. The morainic belt consists of a series of drift hills and ridges of irregular, undulating or broken contour, associated with basins and hollows, the whole constituting a peculiar formation, which has been described in detail in volume II, pp. 205 to 215, under the name of Kettle Range.

Our investigations have connected the Kettle moraine of eastern and central Wisconsin with the morainic belt under consideration as portions of one extensive range,[1] and the descriptions already given render unnecessary a detailed discussion here. To this common range, I have applied the name Kettle moraine. The range lies on the southeastern border of the district, stretching from the south central part of Polk county to the vicinity of Lake Nemakagon, and probably beyond. Mr. Sweet has described in the preceding report a belt of drift accumulations in the adjacent region on the north, which he identifies as an analagous formation. It seems quite probable that this is definitely connected with that under consideration. Though our knowledge is not complete, the line of this connection appears to lie west of Long lake, through towns 44, 45 and 46, ranges 7 and 8, in which Mr. Caneday describes areas presenting the characteristic features of the formation.

In Polk county the southeastern, or outer, margin of the moraine passes through the towns of Black Brook, Clayton and Apple River. Its course here is more northerly than the average trend of the range. The surface on the east of it is gently undulating, subdued, in portions, to nearly level areas; the whole underlaid mainly by boulder and pebble clay, with occasional sandy tracts. But on encountering the Kettle moraine, the surface is seen to change at once the character of its undulations, assuming the knob-and-basin topography characteristic of the range. The drift becomes much more largely composed of rounded boulders and gravel, the latter being the predominating element. The dense hard wood and pine forest of the level region is replaced by more open oak timber or "brush prairie."

This outer ridge of the range is not more than one or two miles

[1] See paper above cited.

wide where it was observed, and is not much elevated, nor is it very conspicuous as a ridge. It is succeeded by a more subdued surface that does not present a distinctively morainic aspect. The composition of the drift, however, as far as could be seen, remains essentially the same. Beyond this, we find a second belt of more pronounced character. There then succeeds a clay formation, having a more level surface and bearing heavy hard wood timber. Beyond this another kettle range is encountered, which is more elevated than the preceding, and of more pronounced character. This passes only a short distance east of St. Croix falls. The above is merely a local section between Black brook and St. Croix falls, and, while it fairly illustrates the character of the belt in this region, is not to be regarded as everywhere applicable to it in detail.

To the northeast of this, the moraine is more narrow and strongly developed. I am informed that one or two projected lines of the North Wisconsin Railroad were found impracticable on account of it. Much in respect to its detailed features yet remains to be learned. What is known of its location may be best seen by reference to Plate XXXVII.

This moraine, in the opinion of the writer, was formed along the margin of a glacier that passed southward through the trough of Lake Superior into Minnesota as far as the Leaf hills, which are regarded by him as a portion of the same moraine, they being formed on the southern and western margin of the glacier at the same time this range was being accumulated on the southeastern, and both are considered but parts of the great Kettle moraine of the lake region.

Boulder clay. Within this moraine there is a sheet of mixed glacial debris that constitutes the ground moraine or bottom bed of detrital matter, left by the melting of the glacier. In general, it may be termed a boulder clay, though varying in its intimate composition. Ideally, this extends over the whole region north of the Kettle moraine, underlying the sand and gravel plains and the level clay areas; but for want of excavations there is little positive evidence of this. It occupies the greater part of the surface between the moraine and the "barrens," but is locally concealed by lacustrine and fluviatile deposits.

The "barrens." Next to the Kettle moraine, the so-called "barrens" possess most geological interest among the superficial formations. They consist of extensive tracts of sand and gravel, the former predominating. Their general surface is plain, or, less frequently, gently undulating. It is, however, much pitted by depressions, many of which are occupied by lakes, others by marshes, while some are dry. These depressions are not unfrequently from 30 to 50 feet deep, and, including the depth of the water, probably sometimes exceed 100 feet. While they quite often have sloping sides, the more characteristic ones have abrupt banks rising, as steeply as such incoherent material will lie, from the lake margin to the level of the general plain. To what extent this steepness may be due to the original form of the basin, and to what extent to the action of the lake eroding its banks at the water level, is not evident.

Within the district, these sand tracts are mainly confined to the vicinity of the St. Croix river and its tributaries, particularly the Nemakagon, Totogatig, Yellow and Clam rivers. But in their continuation to the northeast, Mr. Sweet describes the "barrens" as extending along the summit of the Bayfield peninsula.

Viewed as a whole, these pine plains constitute a linear tract from twelve to fifteen miles in average width, stretching from a point within about twelve miles of the extremity of the Bayfield peninsula, nearly due southwest to the mouth of Wolf creek, in Polk county, a distance of about 125 miles. This tract is joined on the east by a tapering belt about fifty miles in length, and lying mainly in the valley of the Nemakagon river. The tract is terminated at the southwest by the encroachment of the higher lands on either side of the St. Croix. These rise abruptly from the plains to a height averaging, perhaps, 100 feet, and gradually approach the river until they form steeply sloping bluffs on either side 200 feet and upwards in height. Along the sides of these bluffs there are remnants of river terraces, with the second one of which, the plains seem to be continuous. The "barrens" at the point where they are replaced by the terraces are, according to a not very reliable aneroid measurement, about 290 feet above Lake Michigan. From this the tract rises with approximate regularity to the headwaters of the St. Croix, where it mounts somewhat more rapidly on to the kettle belt of Bayfield peninsula, where it attains an average elevation of perhaps 650 feet. Mr. Sweet records one measurement as high as 693 feet, one at 675 feet, and one at 670 feet above Lake Superior (713 feet, 695 feet and 690 feet, respectively, above Lake Michigan), but these are above the average.

The main tract of the so-called "barrens" may therefore be succinctly described as a sand and gravel plain 12 to 15 miles wide and 125 miles long, sloping southwestward in the direction of its length, nearly three feet to the mile on the average.

In respect to *the origin* of this deposit, the writer had prepared a somewhat full discussion for this place, but, as it became unavoidably quite extended, it has been omitted. The general answer that it was due to the assorting and stratifying action of water may be given with much confidence. That, in the main, it owes its origin to a broad, lake-like stream or widely wandering river, may be accepted with almost equal assurance. That the action of the water was not very violent, is shown by the prevalence of sand; and that it was not very quiet, is equally proven by the presence of gravel and absence of fine detritus. But when we attempt to consider the more definite questions, whence came the floods that formed the deposit, and at what precise stage of quaternary history did the deposition take place, we are compelled to speak more circumspectly, and to take into consideration a wider range of facts, the discussion of which has proved too lengthy for the limited space here available.

POST-GLACIAL EROSION AND DEPOSITION.

Since the formation of the preceding quaternary deposits, geological action has been mainly confined to erosion and re-deposit by surface waters and to accumulations through the agency of organic life, such as peat and shell marl.

Pot-holes. The erosion accomplished by the St. Croix river is exhibited in the vicinity of the falls, not only by the deep valley it has cut into the drift deposit and the solid rock, but by the remarkable "pot-holes" that are found at various heights up to 100 feet above the present surface of the river. These were excavated from the solid melaphyr-porphyry by rolling stones kept perpetually circling by the eddies of the river in former times, while cutting its way down through the rock. Some of these are mere bowls, but others are gigantic wells from 5 to 25 feet in diameter, and sometimes 20 feet or more in depth. In some cases they are now filled at the bottom with water or gravel, and their full depth is unknown. The sides of these wells are smooth-worn, but somewhat uneven, owing doubtless to the varying force of the eddy and the unequal resistance of the rock. In general, the walls are nearly vertical, but they are sometimes inclined. In some cases the well is larger below than at the surface. In one instance at least, the excavating waters found an escape below through a well-worn passage, by means of which the pot-hole may now be entered. These lie at a height ranging up to 60 feet above the present river, while smaller ones occur as high as 100 feet. Altogether this is one of the most remarkable groups of pot-holes known.

Peat. Among the later surface accumulations, peat deserves mention, though in this region of abounding forest it has no immediate importance as a fuel; and until the native fertility of the soil is somewhat reduced by continued cultivation, it is not likely to be much used as a fertilizer, though it is well suited to the sandy soils. It is, nevertheless, a resource in reserve. It forms extensive deposits beneath the marshes of the district.

Marl. Deposits of this substance, arising from the debris of fresh water shells, are quite common in the lake and marsh basins of the district. In some cases, the beds appear to be quite extensive. Among the localities noted, are the farms of Mr. Thompson, in the S. W. qr. Sec. 36, T. 37, R. 19 W.; of Mr. Holmes, in the N. E. qr. Sec. 36, T. 37, R. 19 W.; of Mr. Hart, in the S. E. qr. Sec. 5, T. 38, R. 13 W., and other points in the vicinity. These deposits will furnish an excellent permanent fertilizer for the more arenaceous soils of the district, which stand in need of a finely comminuted calcareous ingredient.

Lignite, or bituminous coal. Among the ingredients of the drift, there are two that deserve especial mention, because the source from which they were derived is not evident. One of these is a lignite, or bituminous coal, and the other a limestone. No specimens of the former are in the possession of the survey, yet the testimony as to its occurrence, coming from different parties, seems too direct and specific to be altogether ignored. A possible though remote source of this is found in the basin of Hudson's Bay, towards the northeast, the direction whence the drift was derived. Prof. Bell, of the Canada survey, describes the occurrence of lignite in the drift; reported also to be *in situ* in the valleys of Moose and Albany rivers, that empty into James Bay.[1] On the other hand, it may not be impossible that the cretaceous strata that are known to have encroached largely upon Minnesota from the west, may have reached as far as the St. Croix valley, and that the carbonaceous drift may have been derived from that source. In either case, the occurrence is not to be regarded as having industrial importance.

Limestone boulders. Large erratic blocks of light gray magnesian limestone are occasionally observed in the district. These very closely resemble the prevailing type of the Niagara limestone as found in the state, and the obscure fossils have a concordant aspect. It seems safe at least to say that they are Silurian. It is important to note in this connection that drift limestone has been observed not unfrequently about the head of Lake Superior. Dr. Norwood, in Owen's report of 1852, described compact, drab colored, limestone erratics, containing Silurian remains, as occurring on the St. Louis river above the entrance of the Swan tributary, and again between the Two rivers and the upper Embarrass, the specimens being there

[1] Report of Progress for 1875–76.

large, thin slabs of Silurian limestone; also on the Big Fork river at different points, and again on the Ondodawanonon river, where they are also said to be Silurian; also on the headwaters of the Mississippi.

Limestone fragments are also described by Prof. G. M. Dawson,[1] as occurring on the southern and western shores of the Lake of the Woods, and as belonging, in part at least, to the upper Silurian; and the same has been noted by Dr. Bigsby.[2] The view of these writers that the limestone erratics were derived from a drift-concealed area of upper Silurian limestone lying along the base of the Laurentian terrane in the Lake of the Woods region, seems too local to satisfy all the conditions of the problem. It would be necessary to extend this supposed upper Silurian formation over a considerable portion of the Lake Superior basin, or else to assume drift movements in directions of which we have no evidence, and at variance with all present data.

It is not improbable that upper Silurian strata were deposited in the Lake Superior region, and remnants of this may have escaped denudation till the glacial period, and given rise to these erratics; but from their wide distribution, I incline rather to the opinion that they were derived from the Silurian strata of the Hudson Bay basin. This hypothesis, however, I hold very feebly, as we are yet without satisfactory evidence that any drift agency passed from that basin over the Laurentian highlands.

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[1] Quarterly Journal of the Geological Society for Nov., 1875.

[2] Ditto for 1851 and 1852.

CHAPTER III.

GENERAL DESCRIPTION OF THE INDURATED FORMATIONS.

The Archæan floor. The oldest formation that is known to appear at the surface within the district, is the series of igneous and detrital rocks that constitute the Keweenaw or Copper-bearing Series. From the study of the adjacent regions, however, we gain a theoretical view of the still older rock floor upon which the later formations rest; and though we may not assert that this view is demonstrably correct, it is rendered sufficiently probable by the evidence collected, to justify an attempt to picture it to the mind, for the sake of the clearness and completeness it may give to our comprehension of the general geological structure of the region.

Lake Superior, in the main, lies in a great rock trough formed by the downward bending of the Archæan formations. The axis of this trough is prolonged southwestward, not through the Duluth finger of the lake, as might be expected, but through the upper St. Croix valley.

In its extension through this region, it gradually curves southward, and near its apparent extremity in the vicinity of the Minnesota border it seems to have a decidedly southerly trend; for the Keweenaw beds on Snake river below Chengwatona lake, strike S. 10° to 15° W., and have a high dip eastward, and in the vicinity of the St. Croix falls the strike is even east of south, with a moderate dip southwestward.

At this extremity, the Lake Superior trough is met by a much broader, shallower, Archæan basin, stretching up from the Mississippi valley on the south. The two troughs come together, point to point, at a large angle, and are only separated by a low swell of the lower formations. Between them on the east lies a broad swelling anticlinal ridge of Archæan strata. Near the junction of the two basins this is narrow and depressed; but as it stretches eastward, it becomes broader and higher, forming the great Archæan protuberance of northern Wisconsin and Michigan. On the farther side, in Minnesota, the basins are bounded by a similar Archæan arch, running northeasterly and southwesterly, but having at present less topographical prominence than the Wisconsin heights.

The basal portion of the main Wisconsin highland is formed of Laurentian strata, but as it extends westward into the angle between the two basins and becomes lower, narrower and flatter, it seems to be nearly, or entirely, capped by Huronian beds, dipping northward and southward, forming a low anticlinal ridge. This, probably, rises again as it joins the Minnesota Archæan axis, thus forming a sort of geological saddle. It is the later rocks overlapping or reclining against this saddle, and forming part of the western extremity of the Lake Superior synclinal trough, that claim our attention, though only a portion of them are embraced in the district under consideration.

It is to be observed, prudentially, that the final shaping of these ridges and troughs was not accomplished previous to the deposition of the strata to be considered, as some of the bending certainly took place subsequently; but the salient features appear to have been distinctly outlined as early as the era of Huronian deposition.

THE KEWEENAW OR COPPER-BEARING SERIES.

The rocks of the Copper-bearing or Keweenaw group lie almost wholly within the Lake Superior stratigraphical basin, but it appears that they do extend a little over the arch of our figurative saddle into the Mississippi basin, for we find the beds at St. Croix falls and vicinity dipping to the *south* of west. But with this slight exception, they may be conceived as occupying the south side of the western end of the Superior trough, and hence as dipping northward and westward toward the valley of the depression.

This dip is greatest near the margin of the basin, and least near the central line. It varies from about 35° down to complete horizontality.

The Keweenaw series is composed of two entirely distinct classes of rocks. The first, which greatly predominates, is composed of a series of massive crystalline beds, which appear to owe their origin to a succession of overflows of molten rock, which probably issued from fissures in the earth's crust, rather than from typical volcanic craters. These rocks are popularly known as traps, a convenient, but not wholly unobjectionable term. They consist, so far as our immediate district is concerned, of diabases and melaphyrs, and the porphyritic and amygdaloidal varieties of these, and quartziferous porphyry. Diabase and diabase-amygdaloid constitute by far the most common rocks. The typical Keweenaw melaphyr is confined, so far as can be learned from outcrops, to a few localities, notably a belt on the north side of the St. Croix river. Melaphyr porphyry has a large development at St. Croix Falls and vicinity.

The special rock varieties are distinguished from each other with much difficulty, often only with the aid of the microscope, but they all possess a similar general appearance, and explorers may readily learn to distinguish them from the members of the other crystalline series with very little liability to error, except in a few instances. With a single exception, they are all dark, fine or medium grained, crystalline rocks. The prevailing shades of color are dark green, iron gray and brownish red. The exception is a pinkish rock in the vicinity of Clam Falls. These rocks are usually tough, though not very hard, and often pack under the hammer, instead of flying into angular fragments after the habit of hard, brittle rocks. Their fracture is usually irregular, rough, or hackley, though occasionally sub-conchoidal. To those unskilled in lithological distinctions, the presence of small cavities, filled with minerals differing from the mass of the rock, known as amygdules, will form the most convenient, as it is indeed the most significant, characteristic, since it points to an igneous origin. There are but few extensive outcrops in which these do not appear in greater or less numbers, while their abundance at many horizons renders the rock an amygdaloid. The more common minerals filling these amygdaloidal cavities are a dark green chlorite, quartz, calcite, epidote, orthoclase, laumonite, and native copper, with occasionally other minerals. Prof. Pumpelly has called attention to the absence or rarity of prehnite in these western rocks, though it is common on the Keweenaw peninsula, and also to the presence of pyrite in the St. Croix region, though unknown in Michigan.

The mineralogical constitution of these rocks, as we now find them, is not entirely that which they possessed when first cooled from the molten state, but rather such as has resulted from the chemical and molecular modifications that have since taken place. Some of these have been of a very important character, but as they pertain equally to the whole formation, it is sufficient here to refer to the able writings of Prof. Pumpelly on the subject in this volume and elsewhere.

The true beds of this portion of the formation are due to the successive overflows, each molten deluge forming a bed. When these are very massive, however, subordinate planes, parallel to the bedding joints, have been formed, and give to the rock an appearance of much more complete bedding than it properly possesses. The true beds may usually be distinguished by the change in the structure which the stratum presents near its face. It is usually at and in the vicinity of these bedding faces that the copper deposits, when present, occur, except when they occupy true fissure veins. The beds in the upper St. Croix region vary in thickness from a few feet upwards to probably not less than 100 feet.

Vertical systems of joints are very prevalent features of these beds, often being more conspicuous, and commonly more uniform and smooth than the bedding joints. They usually form two systems that cross each other at nearly right angles. The frequency of these joints sometimes gives to vertical cliffs an obscure pseudo-columnar appearance. True prismatic structure has, however, nowhere been observed in the district.

The second class of rocks that enter into the formation of this series, consists of conglomerates, sandstones and shales, derived from the wear of the igneous rocks above described, and of the older formations. They are in part interstratified with the igneous beds, and in part overlie them. The base of the series is very poorly exposed in the region under consideration, and we can safely say very little as to the presence or absence of these detrital beds, particularly as they are less enduring and less liable to outcrop than the igneous rocks. But so far as our knowledge goes, the conglomerates, sandstones and shales are interstratified much the most frequently in the upper portion of the series, and there are probably several thousand feet at the top, here as elsewhere, that are exclusively detrital. This preponderance of fragmental deposition in the upper horizon of the formation does not, however, in the judgment of the writer, justify a division of the period into epochs of igneous and of detrital deposit. It is probable that the wear of the waters that occupied the basin was essentially continuous from the beginning to the close of the period, and that the deposition of detrital matter was consecutive; disturbed, it may be, but probably not suspended by the igneous eruptions. It would be more in harmony with the accepted basis of geological chronometry, to regard the period as one of detrital deposition interjected by igneous cataclysms. The cataclysms, though very striking in their results, were very brief in their activity and local in their prevalence; while the detrital accumulations must have been vast in their periods, and must be represented by equivalent deposits elsewhere. There are no means within the district, except the data already discussed by Mr. Sweet, of ascertaining the thickness of the combined shale, sandstone and conglomerate deposits. They are almost entirely concealed by drift.

The nature of these deposits, so far as exposed to observation, is precisely like that of the districts already described. They are composed of the worn material derived from the previously formed rocks. In the main, this is the debris of the underlying igneous beds, but a portion is derived from the still older metamorphic strata. The constituent grains are not, therefore, so largely pure quartz, as is the case with most paleozoic sandstones, but instead are mainly silicates of various bases, feldspars especially.

Deep red and brown are the prevailing colors. The black shales of the Ontonagon and Montreal regions have not been seen in the St. Croix valley. The beds exhibit ripple-marks, rain-drop impressions, cross lamination, and other indications of littoral and marine deposition.

No remains that can be positively identified as having an organic origin have yet been discovered in these strata, though there are some obscure indications that life existed.

Economic considerations. This formation is not only the equivalent, as the name implies, of the great Copper-bearing terrane of Keweenaw point, but is directly continuous with it and forms its western prolongation. The demonstration of this connection is one of the fruits of the present geological survey. The copper, which is the most abundant metal of value derived from the formation, occurs sometimes in the igneous rock, mainly in amygdaloidal portions, sometimes in the detrital conglomerates, sandstones or shales, and sometimes in fissure veins traversing these. But in all these cases the metal was deposited in its present condition after the formation of the strata, and, without reasonable doubt, by chemical means. The theory that the copper was injected in a molten condition is wholly irreconcilable with the facts.[1]

It seems to have been originally distributed through the molten rock, and to have been taken up thence by solution and redeposited in its present concentrated form. So that, without regard to whether it is now found in igneous or detrital rock, or in fissures, the igneous rock is to be considered its primary source.

It is difficult to assign any satisfactory reason why an igneous overflow should be richer in a metal at a given point than at any other, and still more difficult to understand how a succession of such overflows, separated by considerable periods of time, should be exceptionally rich in the same region. Theoretically, therefore, there is little or no reason for believing that the igneous rocks of one district are less rich in copper than other portions. Practically, however, the question is

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[1] This, it seems to the writer, has been sufficiently shown by Prof. Pumpelly in the Geol. Surv. of Mich., Vol. II, 1869–1873, Part II, p. 19 *et seq.*, but, if necessary, much additional evidence could be adduced.

not so much what is the absolute richness of the series in copper, as what is its degree of *concentration*, and hence availability. This concentration, if our views are correct, is dependent on the chemical and molecular activities that have ensued since the original formation of the strata. But here, again, it is difficult to find a specific tenable reason why these activities should not have been as great in Wisconsin as in the well known productive portion of Michigan. There appears to be, therefore, no good theoretical reason assignable why we should not expect the occurrence of valuable copper deposits in this portion of the formation, as elsewhere. Their actual existence is a question which exploitation can alone determine. A practical difficulty lies in the fact that the surface is so largely covered by drift. The ledges that project through the drift-covering are usually the more solid and compact portions of the formation, which are, theoretically, the least promising. The excavations that will be incidental to the settlement of the region will disclose the formation somewhat more fully, but considerable portions of it will doubtless always remain concealed. There are reasons to hope, however, that valuable discoveries may be made. The localities at which copper was found by the survey, and the single instance in which mining has been attempted, will be found described among the local details that are given below.

What has been said of the deposit of copper, also applies to the silver of the formation, though this has not yet been found on the south shore of Lake Superior, in quantities that have thus far been mined profitably (except in connection with copper), though closely approximating it. The silver-bearing horizon of the Ontonagon district was definitely identified by the writer where it crosses the Montreal river into Wisconsin, at which point it bears traces of silver and a little copper; but it has not been found in the St. Croix district, and is probably wholly concealed by drift.

POTSDAM SANDSTONE.

The Keweenaw beds were originally deposited in an essentially horizontal position. After their accumulation was completed, they were bent into their present trough-like form, a process which doubtless occupied a very considerable period. Subsequently to this, there elapsed an interval of which we have no record, save in the erosion which was wrought upon the strata. This, making due allowance for what might have been accomplished during the time the Potsdam sandstone was being deposited, would seem to have been immense.

The edges of the upturned Keweenaw strata were cut away very extensively, and their surface deeply channeled or worn into precipitous cliffs. Upon this very irregular surface the Potsdam sandstone was deposited. It is now impossible to ascertain the full extent to which it originally covered the older strata, but it is quite certain that it overlapped them widely. We now find remnants of the formation along the St. Croix river, reaching up into the trough of the Keweenaw series; and on the Kettle river in Minnesota, it is found at elevations nearly or quite equal to the height of the Lake Superior watershed, and considerably higher than any known Keweenaw strata in the trough of the synclinal. There seems no good reason, therefore, to doubt that the Potsdam seas swept across the district into the Lake Superior basin and deposited their sands in a continuous belt, uniting the Mississippi and Superior primordial areas. Within the district under consideration, the Potsdam sandstone has only been observed in the vicinity of the St. Croix river. Below the St. Croix falls it occurs in vertical cliffs on either side of the stream. In Eagle bluff, near Osceola, the upper face of the formation, capped by Lower Magnesian limestone, is exposed. This is the most northerly point at which the upper portion of the formation is known to exist at present. The upper portion of the formation here is composed of yellow and white sandstone, corresponding in character and position with the Madison sandstone. This is underlaid by calcareous strata, which appear to correspond with the Mendota beds of central Wisconsin, and which, from their greater resistance, give rise to the beautiful Osceola falls. Beneath these there are greenish shales, interstratified with the friable sandstone that makes up the mass of the formation, and does not essentially differ from the Potsdam elsewhere, which has been repeatedly described in these reports.

The quarries just north of the village of Osceola are exceptionally rich in primordial fossils, among which trilobites predominate. One of the earliest of known gasteropods, Holopea Sweeti, is found here. In the vicinity of St. Croix falls, the formation abuts against and overlies the traps of the Keweenaw system. At several points the actual contact of the formations may be seen, and no doubt exists as to their true relationship. Near the point of contact in some places, the sandstone changes to a conglomerate, the pebbles of which are derived from the trappean rocks. The pebbles are sometimes well rounded, but in other cases only somewhat abraded on the angles, and they are in some instances of large size. From this it is evident that the Keweenaw rocks stood as reefs and cliffs in the Potsdam ocean, against which the waves beat, breaking off fragments and rounding them by attrition in various degrees, and imbedding them in the sands and shells of that ancient sea.

In more protected places a finer sediment, mingled with immense numbers of the shell *Lingulepis pinnaformis*, accumulated and afterwards became a shale. The fossils were deposited so closely in contact with the crystalline trappean rock, that hand specimens may be obtained which contain the crystalline rock on one side and Potsdam shale containing fossils on the other. The view of Dr. Owen that the trappean rocks were thrust up through the sandstones after their formation, is wholly untenable. The traps are immensely older than the sandstone, and, as before remarked, were extensively eroded before the sandstone was deposited upon their worn surface. The detailed statements subsequently given, abundantly verify these statements.[1]

At St. Croix falls, the Potsdam sandstone seems to occupy an ancient channel cut into the crystalline rocks; for it occurs for some distance above the Dalles, at elevations but little above the river, while the crystalline ledges rise at short distances on either hand to altitudes of 200 feet or more. Whether this was the gorge of an ancient river, the prototype of the present St. Croix, or a channel worn by the encroachment of the primordial ocean, it may be impossible now to determine. As the outcrops of this formation in our district are limited, and for the most part intimately associated with the Keweenaw series, they will be found described in connection with the latter, on subsequent pages, as they are encountered in the systematic review of the outcrops of the district.

LOWER MAGNESIAN LIMESTONE.

This formation merits only a passing notice in this connection, as it barely appears in the southwestern portion of the district in isolated areas, the most northerly of which, as before mentioned, forms the cap of Eagle bluff, near Osceola. These patches are undoubtedly the remnants of a continuous formation that formerly stretched northward into the Lake Superior basin, but which has been worn away by erosive agencies. It is an impure, buff, magnesian limestone, identical in character with the formation so fully described in Vol. II.

In former times, I have no doubt, higher members of the Paleozoic series overlay this, but they appear to have been entirely removed, leaving the Lower Magnesian limestone the uppermost of the indurated series. It is highly valuable in this region of prevailing

[1] See, also, Notes on the Geology of Northern Wisconsin, by E. T. Sweet, Trans. Wis. Acad. of Sci., Vol. III, 1876, p. 50.

siliceous rock as a source of lime, and at the same time is serviceable as building stone. Lime is manufactured from it near Osceola by Mr. Samuel Wall, in a continuously operating kiln, which has a capacity of 100 barrels in twenty-four hours. The kiln is situated on the bank of the St. Croix river, so that the facilities for shipment are excellent. Two kinds of lime are manufactured; one is a brown lime made from the formation in question, of which there is a thin stratum crowning the bluff above the kiln; the other is a white lime made from a travertine deposit near the water's edge. Large masses of limestone appear to have fallen down from the bluff, and the interstices and cavities between them have been filled up with a secondary deposit of limestone.

CHAPTER IV.

DETAILED DESCRIPTIONS OF THE LOCAL FORMATIONS.

In the preceding reports the Keweenaw or Copper-bearing series, as it occurs on the Lake Superior border, has been discussed; and its general relations to the great mass of the formation stretching northward to Keweenaw point, and beyond, has been indicated. In pursuing the study of its local development, as traced southwesterly from the Lake Superior trough into the borders of the Mississippi basin, it may, perhaps, be most convenient to begin with the exposures of the formation that lie adjacent to those previously described, and to trace the ranges thence along their trend southwesterly to the limits of the state in the St. Croix valley.

In doing this, we shall find the natural outcrops of the region clustered into about five quite distinct groups; one about the headwaters of the Nemakagon river, which we may designate the Nemakagon district; one on the upper Totogatig river — the Totogatig district; one in the vicinity of Clam falls, extending westerly and southerly — the Clam falls district; one centered about St. Croix falls, and named thence, and one along and north of the upper part of the St. Croix river, and designated the north St. Croix district.

The great Keweenaw range, the most protuberant part of the formation, has been traced connectedly as far southward as the vicinity of Nemakagon lake, T. 43, R. 6 W. And we may advantageously make that our point of departure.

THE NEMAKAGON DISTRICT.

In 1876, Mr. Wright traced the magnetic belt of the Huronian series to the north shore of Nemakagon lake, and on its southwest side he found, for a few miles, a broad belt of feeble magnetic attractions. He also found the Copper-bearing series apparently encroaching on the Huronian belt from the north and overlapping it, as it were, to meet the closely adjacent granitic rocks on the south. It is at this interesting point where the Keweenaw and Laurentian series seem to be converging towards each other, involving the burial of the intervening Huronian belt, that we begin our review of the observations of Mr. Strong.

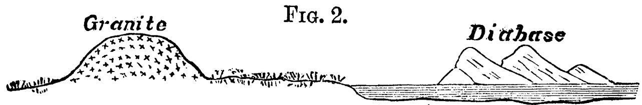
T. 43, R. 7 W. In Sec. 21 of the township next west of Lake Nemakagon (T. 43, R. 7 W.), the diabases of the Keweenaw series and the granitic rocks of the Laurentian, are observed within a few rods of each other, and, presumably, come in contact beneath the drift. In the N. E. qr. of that section, on the south side of the Nemakagon river, and about 200 feet from its bank, an outcrop of granite is observed, consisting of flesh-colored feldspar, quartz and a little black mica (biotite). Many of the crystals of feldspar are large and distinct. The rock is fissured so as to present a bedded appearance. In some portions the granite passes into gneiss by the development of a parallel arrangement of the constituent minerals. The bearing of the banded structure thus formed is about S. 40 ° E., which, it will be observed, crosses at a large angle the trend of the Keweenaw range. The dip seems to be almost vertical. About 150 feet northwest of this is another exposure of gneiss, in which the banded structure is very distinct, and often much contorted. The average course of the bands is here nearly east and west. Farther down the river is a low ledge of red granite and gneiss in the banks and bed of the stream. About 1,000 feet below this, in the S. E. qr. of Sec. 16, the river crosses a ledge belonging to the Copper-bearing series.

To the southeast from these granitic outcrops, the surface features and the composition of the drift favor the belief that the region is underlaid by the granitoid series. Near the N. W. corner of Sec. 26 of this town, the summit of a hill exhibits boulders of granite, some of which are of such enormous size as to give the impression of rock in place, and they are probably near their original position. This evidence from the drift is strengthened by the existence of an outcrop in the S. W. qr. of the N. E. qr. of the same section, on the south side of a small stream. The rock is a dark gneiss, composed of flesh-colored feldspar, quartz, and a large ingredient of biotite, with which there is associated some hornblende. The composition, however, varies. The exposure is small and much obscured by brush, so as to render observations on its strike and dip unsatisfactory.

The several characteristics of these granitic masses, as well as their position, favor the view, in which all the members of the corps coincide, that they belong to the Laurentian series.

Returning to the granitic ledges on the Nemakagon river, we find, on the opposite side of the stream, an exposure of the Keweenaw series, as illustrated by the accompanying figure:

FIG. 2.



SECTION SHOWING THE RELATIONS OF THE GRANITE (LAURENTIAN) AND DIABASE (KEWEENAW) ON THE NEMAKAGON RIVER, SEC. 21, T. 43, R. 7 W.

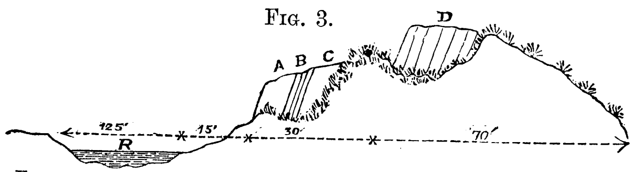
As previously stated, about 1000 feet below the granitic ledge, the members of the Copper-bearing series cross the Nemakagon river and appear on its south side. The rock is here, in general, fine-grained, minutely crystalline and nearly black, or dark greenish black. It is not usually amygdaloidal, but in places there are small particles where amygdules of chlorite and laumonite occur, and, occasionally also, small spherical nodules of calcite, with which are sometimes associated small grains of pyrite. Some portions of the rock contain a large proportion of non-magnetic iron ore. The dip is given as 38° on a course N. 30° E.

On the south side of the river, the rock, which is a diabase and diabase-amygdaloid, shows seams and small veins of epidote and amygdaloidal cavities, containing orthoclase, calcite, epidote and chlorite, the latter in dark, shot-like spherules.

About 250 yards south of the river, there is a small exposure in which pyroxene forms a large ingredient, and with this, quartz and considerable chloritic matter in thin layers are associated. About 100 yards west of this is another similar small ledge.

Four miles to the northeast of this, on the town line between ranges 6 and 7, town 43, and extending thence up the Nemakagon river for about quarter of a mile, there is a succession of trappean ledges — composed mainly of dark diabase — (specimens 314 to 318). The following figure shows a profile of the outcrop nearest the town line.

Fig. 3.



Section of Exposure on the North Bank of the Nemakagon River, near the Range Line between Ranges 6 and 7, Town 43.

The ledge next the river is rather a fine-grained, reddish brown diabase. Adjoining this, the rock is darker and softer, having in some portions a somewhat greasy feeling, apparently from the presence of chloritic material. This passes into a very dark, close-textured diabase. The upper ledge consists of a more obviously crystalline rock, probably a diabase. It shows a notable tendency to split into rudely rhombohedral blocks. The succeeding outcrops along the river above are but slight exposures in the bank. About a quarter of a mile above, there appears a very minutely crystalline, almost black diabase, containing scattered amygdules of chlorite, with copper pyrites and a little malachite. It also contains large isolated patches of epidotic rock, through which chalcopyrite is disseminated in grains. The exposure extends about 50 feet along the north side of the river, and is much riven and dislocated on the surface. It reappears about 50 feet below, where it is more coarsely crystalline, and contains spherules of epidote enclosing a core of copper pyrites.

About one mile below the above series of outcrops, on the line between Secs. 1 and 2, T. 43, R. 7 W., the river has again denuded the formation for a space of about 100 yards. It is here a coarsely crystalline augitic rock, verging in places into an amygdaloidal diabase, containing large spherules of dark chlorite. In one place in the river the rock becomes unusually coarse, and contains crystals of feldspar one-half inch across. On the south side of the river, it appears as a finely crystalline diabase, containing a notable ingredient of magnetite, and strongly affecting the needle. Its tendency is to fracture into sharply angular blocks.

The foregoing constitute the outcrops of the Keweenaw series observed in this vicinity. Others were reported, and were sought, but escaped discovery. Doubtless others exist, but the wildness of the forest renders it very difficult to find them.

THE TOTOGATIG DISTRICT.

To the southwestward, along what is presumed to be the southerly margin of the Keweenaw series, the surface is occupied by heavy drift accumulations, which quite effectually conceal the underlying formations. To the northwest, however, about 12 miles, there is a parallel belt nearly 30 miles in length, over which are scattered, in comparative profusion, bare or slightly concealed ledges. This belt, which is here called the Totogatig district, extends from Pigeon lake, in Sec. 34, T. 45, R. 8 W., southwesterly to T. 41, R. 11 W. With two exceptions — viz., a sandstone and a conglomerate — the series is formed of trappean rock, mainly diabase and diabase-amygdaloid. The general strike is nearly due S. W., and the average dip about 24° N. W.

T. 45, R. 8 W. From near the southwestern extremity of Pigeon lake, a range stretches diagonally across the S. E. qr. of Sec. 33, T. 45, R. 8 W., and enters the adjoining township on the south. The character of the rock varies somewhat, but in the main, consists of two principal varieties, one of which is very dark and quite soft, from the presence of chloritic material, and contains some amygdules of epidote and quartz, while the other is an iron gray, very hard, pseudo-amygdaloidal diabase (spec. 369).

T. 44, R. 8 W. Proceeding southwestward, on this line, in Secs. 5 and 8 of T. 44, R. 8 W., frequent ledges are encountered, some of them rising in perpendicular acclivities into considerable hills. One of the more noteworthy of these is found near the quarter-post of the sections mentioned, and consists of a dark greenish black diabase, in which amygdules are rare.

Passing on southwestward to the center of Sec. 7, we find two large parallel ranges of trappean rock, having the common trend of the formation. The southeasterly ridge is composed of a dark reddish diabase, containing some small spherules of chlorite and calcite. The northwesterly range consists of hard, dark brown, finely crystalline melaphyr or diabase, containing occasional large crystals of pyroxene (spec. 368). Three hundred paces northeast of the center of the section, the rock is coarsely crystalline, and at five hundred paces, while retaining its general color, it presents numerous small reflecting faces of augite.

At 963 paces northeast of the southwest corner of this section, is another outcrop belonging to the same series, which shows, what is a common feature of this belt, an abrupt southeasterly exposure with a gentle northwesterly declivity; a feature due to the inclination of the beds. The dip is 25° in a direction N. 33° W. The rock is a rather coarsely crystalline diabase of dark, slightly reddish color. About 350 paces southwest of this is an outcrop of dark, granular crystalline melaphyr (spec. 367), and about 100 paces farther (500 paces from the S. W. corner of the section), an exposure of hard, dark brown diabase, of medium crystalline grain (spec. 366).

T. 44, R. 9 W. On entering the adjoining town, we encounter near the S. E. corner of Sec. 12, a bluff of eruptive rock, probably melaphyr; and to the north and south of this for nearly a mile along the range there are numbers of high, steep hills of similar trappean rock, which are largely concealed, however, by soil and vegetable mold, and covered by a dense growth of heavy timber. In the N. E. ¼ of Sec. 12, between the quarter-post and a brook lying north of it, is a high, steep hill of trappean rock that probably represents a variety of the Keweenaw melaphyr, characterized by "luster mottlings," though these are small and inconspicuous. It is hard, reddish brown, compactly crystalline, irregular in fracture and contains a little magnetite (spec. 365).

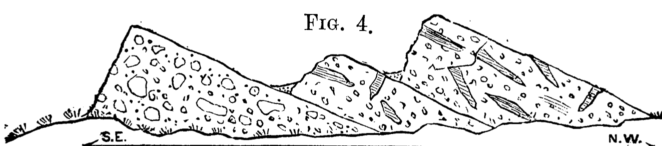
About two miles southwest of this (N. E. ¼ Sec. 15, T. 44, R. 9 W.), a hill of diabase-like rock forms the extremity of a chain of hills stretching southwesterly as far as Sec. 28. The rock is of a dark reddish color, brittle, fine grained, and contains amygdules of calcite, chlorite and epidote. In some places there are veins of the latter mineral containing particles of native copper. The tendency of these veins is to follow the southwesterly trend of the crest of the ridge. One was traced a quarter of a mile. The ridge has the usual abrupt southeast face, with a gentle slope to the northwest, in which direction the beds dip 20°. On this ridge glacial striæ were seen bearing S. E. This ledge is overlaid on the northwest by a similar one, likewise containing epidote veins flecked with malachite, native copper and its red oxide. It also contains red sedimentary rock in the seams and fissures. The two ridges are parallel and perfectly straight for one-half mile. They reappear near the line between Secs. 15 and 22, forming at one point a conspicuous hill, 100 feet high, from which is afforded a fine view of the Eau Claire lakes, and the copper ranges of Douglas county in the distance. This is the "Smoky Hill," or "Wani-baju's Blacksmith Shop" of the Indians. Its constituent beds dip 27° N. W. The basal bed of these ridges is a quite soft, mottled, eruptive rock, which appears to the unaided eye to be mainly composed of augite. In the S. W. ¼ of Sec. 22 there are several long, high ridges, which occasionally expose a similar mottled augite-bearing rock, and which are to be correlated with beds underlying those above described.

To the southeast of these, is a hard, dark reddish brown, fine grained diabase, containing some spherules of chlorite, but wanting in the veins of epidote so conspicuous in the other exposures. The ridges continue southwestward into the S. E. qr. of Sec. 21, the rock being always dark colored, fine grained, with a reddish tinge, and often amygdaloidal.

Near the quarter-post between Secs. 21 and 22, there is an outcrop of dark colored eruptive rock consisting of two beds. The underlying one is very fine grained and contains amygdules of calcite, epidote, chlorite and quartz, the latter often lining the cavity concentrically, giving rise to an agate structure. The overlying bed is a very fine grained, hard, dark greenish gray, amygdaloidal diabase, the cavity-fillings being quartz, chlorite, laumontite, epidote, and occasionally malachite. One or more outcrops occur within the S. E. qr. of Sec. 21. There is also an outcrop of rather soft, coarse grained, reddish brown trap lying off the range we have followed, on the east, in the S. W. qr. of Sec. 14.

Near the N. E. corner of Sec. 28, the formation exposes itself in an interesting and characteristic way by the protrusion of the upturned edge of its beds, forming monoclinal ridges after the prevalent fashion of the region. A profile is given in the accompanying figure. The dip of the whole is about 29° to the N. W.

FIG. 4.



SHOWING PROFILE OF OUTCROP SITUATED NEAR THE N. E. CORNER OF SEC. 28, T. 44, R. 9.

The rock belongs to two distinct classes, the uppermost consisting of trappean beds and the lower of conglomerate. The former consists of an amygdaloidal diabase, rendered somewhat porphyritic by distinct feldspar crystals. The amygdules are noted as mainly quartz and epidote. Particles of sulphide of copper were observed in places. An interesting feature of these beds is the inclusion, in cavities and vertical and horizontal seams, of red sedimentary rock. (See Fig.) The lines of stratification of these included portions, conform to the strike and dip of the formation. The phenomena indicate that the trappean rock was much broken and fissured previous to the deposition of the sedimentary mud and sand which filled the fissures, and was subsequently hardened and tilted with the whole series. Directly underlying the amygdaloid is a stratum of coarse conglomerate, the pebbles of which reach a foot in diameter and are always round and smooth. They are chiefly composed of a hard, reddish quartz-porphyry. The observed thickness of the conglomerate was about thirty feet.

Westward, about half a mile, near the quarter-post of Secs. 21 and 28, T. 44, R. 9 W., there is a fine-grained, dark-gray, slightly amygdaloidal trap. Southwestward a mile and a half is a brown stone diabase, exposed near the center of Sec. 32 (spec. 361), which is closely allied to one found about a quarter of a mile southeast of the latter in the S. E. qr. of Sec. 32. These outcrops are concealed by thick brush, and were struck in a random search.

Town 43, R. 9 W. The adjoining town on the south (T. 43, R. 9 W.), is largely low, flat, marshy country, but wherever there is an island in the prevailing cedar swamp, it usually exhibits Keweenawan rock. The difficulties of traversing it, except when frozen, are a serious obstacle to exploration, and only a few of the more accessible outcrops were examined. In the S. E. qr. of Sec. 6, the Totogatig-once river is bordered on either side for half a mile, by bluffs of trappean rock, reaching at some points an altitude of 200 feet. The uppermost beds are a dark, slightly reddish diabasoid rock of fine grain, which is underlaid by dark reddish brown diabase amygdaloid, enclosing quartz, epidote and chlorite. From this point, for half a mile, there are dark augitic beds, succeeded for 100 yards by a soft, dark red diabasoid rock, followed for 200 yards by a coarse-grained diabase, and for 50 yards by a very dark, soft diabasoid rock with very large spherules of dark chlorite; again by 50 yards of very fine-grained gray diabase amygdaloid, with calcite as the cavity filling.

If we follow down the Totogatig-once into the west half of the section, we shall encounter, about a quarter of a mile above Whalen's dam, light colored, greenish diabase amygdaloid, the cavities of which are numerous and well defined, and are occupied mainly by quartz. Adjacent to this, the surface is occupied for 100 yards by a dark diabase of close grain, which is succeeded by a very fine-grained, dark-reddish crystalline rock containing nodules of chlorite. Following down to the dam, near the east quarter-post of Sec. 1, T. 43, R. 10 W., we find the stream making its bed in a dark colored, rather coarsely crystalline, diabase-like rock, usually having a somewhat reddish hue, associated with nearly black, feebly amygdaloidal beds, with small nodules of calcite and epidote.

Below the dam the rock is entirely of a coarser augitic, mottled character, probably melaphyr, and is very much fissured and broken. The partings between the dipping beds frequently contain irregular seams of quartzose and chloritic substance, striated in the direction of the dip. This was not observed in any of the numerous other fissures. The dip is 25° to the N. W.

Below this, in the southeast bank of the stream, is a long, low ledge, little more than two feet high, and only accessible in low water. It forms the base of a hill about twenty feet in height. The rock is of medium hardness, dark, minutely crystalline texture, and is without amygdules. Its dip is 25° to the N. W.

A little over a mile down stream, southwestward, near the quarter-post between Secs. 11 and 12, the Totogatig-once is joined by a creek coming in from the southeast. This latter is bordered for two miles by a continuous succession of cliffs, rising in some instances 200 and 300 feet in height. The dip is 32° to the N. W. The dip of the ledges gives to the cliffs a moderate slope on the northwest, but they have a precipitous face in the opposite direction, producing a serrate sky-line. The entire series apparently consists of diabase and diabase amygdaloid in alternating beds. Within about half a mile of the eastern extremity of this range, in the S. W. qr. of Sec. 18, T. 43, R. 9 W., there is an outcrop of dark brown, fine-grained, epidotic diabase amygdaloid, with cavity fillings of epidote and quartz (spec. 359). North of this, in the west half of the section, there are several exposed ledges of diabase.

For half a mile along a creek that flows from Sec. 7 of this town, through the northern part of Sec. 13 of the adjoining town (T. 43, R. 10), there is a range of black mottled diabase, replaced toward the northeast by a soft, dark brown amygdaloidal rock, containing nodules of calcite and epidote. At one place in this, an east and west vein eight feet wide was found, consisting chiefly of epidotic rock, and carrying crystals of epidote, quartz, calcite, chlorite, and orthoclase, the latter occasionally measuring a half inch across. In one place small specks of malachite were seen. The south wall of this vein consists of hard, dark brown, non-amygdaloidal diabase-like rock.

T. 43, R. 10 W. In the N. W. qr. of Sec. 13, T. 43, R. 10 W., is a small ridge which reveals a dark brownish red, rather soft, crystalline rock, containing irregular masses of epidotic material, and, in some places, large amounts of dark green chlorite in amygdaloidal form. The vertical faces of the ledge show large, irregular holes, and the rock generally has a partially decomposed appearance.

About thirty rods west of north of this, is an outcrop of similar rock, containing amygdules of calcite. Northwest from this, at the dam, on the Totogatig-once (also noted as Whalen's, S. E. qr. of Sec. 11, T. 43, R. 10 W.), there is a ledge running in a northeast course along the left bank of the stream for a quarter of a mile, and having a height of about 50 feet. It consists of a very hard, fine-grained, dark red diabase, with occasional seams and nodules of calcite.

In the N. E. qr. of Sec. 14 of this town, is a hill composed of finely crystalline, dark, slightly reddish non-amygdaloidal diabase. A half mile south of this is a protuberance of more coarsely crystalline, reddish diabase, containing some small amygdules of chlorite. Three miles southwest, near the quarter-post of Secs. 28 and 33, T. 43, R. 10, a hill in the woods exposes a very hard, dark colored, crystalline rock, with considerable epidote running through it in irregular masses. Near the top of the hill is found a very hard, greenish epidotic rock — probably epidotic diabase amygdaloid (spec. 347) — containing nodules and sometimes geodes of quartz and some specks of malachite. In miner's parlance, the "mineral indications" would be considered good here.

T. 42, R. 10 W. Within a mile south of this, in the northern tier of sections of the adjoining town (T. 42, R. 10 W.), we reach the Totogatig river, along which, throughout the entire township, there are numerous exposures of the formation. It will, perhaps, be most convenient to notice them as they are encountered, descending the stream, which will, in general, be in the ascending order of the strata. A little below the dam on the Totogatig, probably in the S. E. qr. of Sec. 12, T. 42, R. 10 W., on the left hand side of the stream, the timber road runs over a small hill of diabase, which is hard, tough, compact, close-grained, black, and free from amygdules. About a quarter of a mile below, on the same side of the stream, is a small denuded surface of rock, near the edge of the river, consisting of a greenish black melaphyr or diabase, containing a little copper pyrites.

A quarter of a mile farther down, the river runs in rapids over a ledge of rock similar in texture to that nearest the dam, but of dark gray color, rather than black, and giving, on weathering, a thin, brown, ferruginous coating, in distinction from that of the preceding, which was nearly white. Near the line between Secs. 1 and 2, there is a ledge on the west side of the river, exposed about 80 yards in length, and terminating at the Big falls. The upper part of this ledge consists of a fine-grained, dark-gray diabase amygdaloid (sp. 329). Thirty yards down the stream, the rock becomes a reddish-brown amygdaloid. At the falls, the rock is a very hard, compactly crystalline melaphyr of a dark, iron-gray color, modified by a very slight reddish tinge (sp. 330). On smooth weathered surfaces, it has a dark, dirty red hue. The river here rushes through a narrow channel of 15 feet, between melaphyr on either side, and falls, in a short cascade, about 10 feet. The ledges are much cut up with seams and joints on all directions. About 50 feet west of the falls there is a fine exposure, rising about 20 feet in height, in which the rock is light gray, very hard, fine-grained, and contains a large amount of quartz and epidote, mingled in small amygdules. It also occasionally exhibits small quartz veins and seams.

At an old camp on the river, near the east line of Sec. 2, is a fine-grained, greenish-black diabase, forming the nucleus of a small hill. About 100 yards southwest, on the timber road, is another outcrop of light greenish-gray diabase amygdaloid, containing considerable quartz and epidote.

On the road, in the N. W. qr. of Sec. 2, is a small flat exposure of dark, reddish-brown diabase amygdaloid, calcite being the chief filling of the cells (sp. 332).

Somewhat north of the center of Sec. 3, is a limited outcrop on the west side of the road. It consists of a fine-grained, dark, reddish-brown diabasoid rock, containing a large amount of epidote, both in the rock and in small amygdules, and also in large, irregular patches, some of which have an indistinct stratified appearance. In this exposure there is a remarkable bed of stratified rock, two feet in thickness, entirely conformable to the under and overlying trappean beds. It consists of a hard, dark-brown, very fine-grained schist, apparently the indurated product of a laminated shale. It still splits readily into its original constituent leaves, which are distinctly shown in the cross fracture by variations in color and composition, and also on the weathered edge by the different degrees of resistance they have opposed to abrasion. It is closely associated with the igneous rock, both above and below, and hand specimens may be obtained including both at once; yet the line of demarkation is distinct. Its metamorphism was perhaps due to the heat of the superposed igneous bed.

Near the west line of Sec. 3 is a rather large and conspicuous hill, about the base of which are several rock exposures. These consist of a black diabase; in some places very minutely crystalline, and in others more coarsely so, showing cleavage faces of augite. Near the centre of Sec. 4 there is a small outcrop of epidotic amygdaloid (sp. 338).

About one-half mile below the mouth of Shelldrake creek are the "Middle Falls" of the Totogatig, where the river shoots through a narrow channel with a fall of about 8 feet in a distance of 100 feet. The rock exposed here is a mottled diabase. Dip, 25° to the N. W. About 200 yards below, the formation is well exposed on the west side of the river along the rapids for 200 yards, the rock being of the same kind as at the falls. About 150 yards below, the diabase is finely exposed in a bluff about 40 feet high, also on the west side of the river. On the east side a light green, quite peculiar rock, which appears to be a highly altered diabase amygdaloid, is found (sp. 339). Trappean rocks of the more usual kinds occur at intervals along the river for 200 yards.

In the road, about one-fourth of a mile above Bean's camp, at the mouth of the Shelldrake brook, in Sec. 4, are numerous small exposures of trappean rock (N. E. qr. Sec. 4, T. 43, R. 10 W.). In one the rock is dark greenish black, and somewhat epidotic. In another it is a light greenish gray, epidotic amygdaloid, containing numerous nodules of quartz. In another the amygdules are mainly of epidote and chlorite.

On the west bank of the Totogatig river, in the N. W. qr. of Sec. 4, T. 42, R. 10 W., near the water's edge, is a small, low outcrop representing the sedimentary portion of the Copper-bearing series. The upper six inches consists of a trap-derived sand, in which particles of nearly all the varieties of the igneous series can be detected. Below this lies a bed of conglomerate, containing besides trappean grains, seams and irregular pieces of brown indurated shale. These exhibit no lines of lamination, but lie with their longest plane parallel to the lines of stratification. At the base of the limited exposure there is a very fine-grained, brown, indurated sandstone, of quartzite-like aspect and conchoidal fracture. It shows distinct lines of deposition. The whole dips 25° to the N. W., thus conforming to the general dip of the series. The whole is underlaid by a fragmental rock which Prof. Pumpelly identifies as the typical Keweenaw conglomerate.

About 300 yards below, the formation reappears in a hill 100 feet west of the river. The red shale mentioned above as a constituent of the second layer, here shows lines of stratification. Above this, a red sandstone of trappean derivation discovers itself in the face of the bluff.

Proceeding down the river, which here has a course about S. 30° E., the conglomerates and sandstones appear in alternating layers. At the head of the rapids, about a half mile below, called the "Slough of Grundy," there is a fine exposure on the west side of the stream. The dip is here, as before, 25° to the N. W. The beds are generally thin, and the conglomerates and sandstones persistently alternate with each other. The conglomerates appear to contain nothing which might not be derived from the trappean series. The lower beds of the conglomerate contain larger and more rounded fragments, one variety of which is a porphyritic rock, not observed in place.

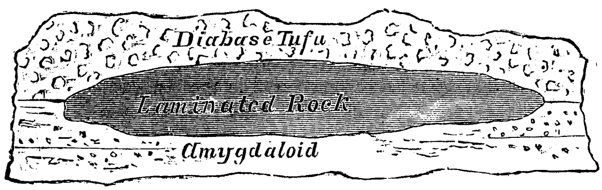
In one place in the conglomerate there is a layer of epidote rock about two inches thick, as hard, and precisely similar to that found in the igneous beds, but which shows lines of lamination on the weathered surface. All these are conformably underlaid by a fine-grained, greenish black, igneous rock of considerable — though not fully exposed — thickness.

About the middle of the "Slough of Grundy," on the west side of the stream, is an exposure of diabase in a vertical wall, about 8 feet high and 100 feet long. About 100 yards below this, on the east side of the river, the formation presents a very interesting phenomenon. The rock all appears to be a fine-grained, hard, black diabase. It is, however, mottled on exposed surfaces, and presents the appearance of a conglomerate in which the matrix and the pebbles are of the same material. Large round boulders from 1 to 4 feet in diameter are enclosed in it at irregular intervals, and about these the rock is much cracked, and shattered in all directions. Fifty yards below this the rock has the same composition, but contains large amygdules of chlorite and irregular masses of epidote a few inches in circumference, orthoclase, quartz and chlorite. The conglomeritic character of the rock is here better defined than at the locality mentioned above. It contains seams of epidote running in all directions, and in one place includes a red shale showing apparent lines of stratification.

Below this 200 yards, a ledge of fine-grained, dark, reddish diabase-like trap crosses the river, and 200 yards below that, rapids again begin, having for their barrier rock a dark diabase. Next below is a disclosure of about 10 feet of gray diabase, the individual crystalline ingredients of which are more distinct and conspicuous than usual, though not very large. Next succeeds a coarse, dark, mottled diabase, 12 feet in thickness, followed by a bed of 6 feet of a coarse, diabasoid rock of irregular and varying structure, somewhat chloritic and epidotic in irregularly distributed portions. Next succeeds a coarser, mottled diabase 20 feet in thickness, followed by a bed of epidotic rock 5 feet in thickness, which is, in turn, succeeded by twelve feet of rock of distinctly individualized crystalization, similar to that described above.

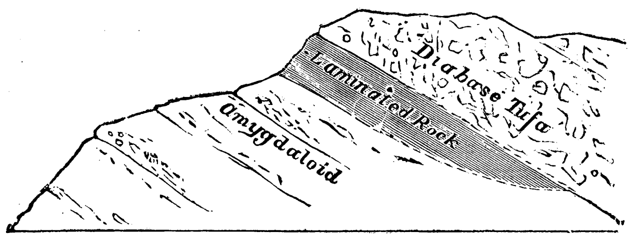
In the N. E. qr. of the S. E. qr. of Sec. 5, T. 42, R. 10 W., is a small hill of very dark, close-grained amygdaloid, containing calcite. In the N. W. qr. of the S. W. qr. of Sec. 5 are two small exposures of trap in low hills. The first consists of dark reddish, somewhat amygdaloidal rock, containing epidote and calcite. The other, about 50 yards S. E. of this, has for its lower bed a light greenish gray epidotic rock. This bed is overlaid by a fine-grained, dark brown diabase pseudo-amygdaloid. The amygdules are largely of calcite. In some parts, there are seams of chlorite, which is here less dark and ferruginous than is common. This is succeeded on the S. E. by a dark mottled diabase, which was traced 100 yards, when it became concealed. About 200 yards N. 70° W. of the last exposure, and about 200 feet south of the river, is a small hill of what has been identified by Prof. Pumpelly as diabase tufa of the ashbed type (sp. 337). It has a thickness of at least 50 feet. The main constituent is a fine-grained and dark reddish brown rock, This, in portions, is very highly amygdaloidal or tufaceous, but a portion of it very closely resembles the indurated sedimentary formation. The cavities are largely occupied by calcite and epidote. At the base of this stratum, in one locality, and lying between it and the amygdaloid that underlies it, there is a hard rock of quartzitic aspect, conchoidal fracture, and laminated structure. It appears to be the indurated product of a semi-metamorphosed shale, or fine sand, derived from the igneous beds. It seems to occupy a hollow in the surface of the underlying rock, and conforms to its dip. The following figures represent its surface and sectional appearance:

FIG. 5*a*.



SHOWING THE RELATION OF THE INDURATED STRATIFIED ROCK TO THE AMYGDALOID BELOW AND DIABASE TUFA ABOVE — SURFACE VIEW.

FIG. 5*b*.



THE SAME — PROFILE VIEW.

The underlying bed is amygdaloidal, probably a diabase, enclosing chlorite; and below this is a minutely crystalline trap, probably a diabase. The dip here is 24° to the N. W.

On the S. E. bank of the Totogatig river, near the line between Secs. 5 and 6, there is a small, uncovered area of a dark reddish, highly crystalline, diabase-like rock. About 30 yards below, on the opposite side, the rock has the same color, but is more minutely crystalline, and carries considerable epidote. About a fourth of a mile below the section line, there is a low ledge of epidotic rock, of light greenish gray color, associated with a dark greenish trap containing some chlorite. About a quarter of a mile below this, at some short rapids, there is a fine exposure on both sides of the river, consisting of a minutely crystalline, greenish black, epidotic amygdaloid containing nodules of calcite and chlorite, and occasional seams of quartz. The bed has a thickness of 10 feet. In this exposure is also found a hard, bright green, epidote rock, having a somewhat resinous lustre. At the middle of the rapids, a very fine-grained black diabase is exposed for a thickness of 15 feet, and at the foot there are 4 feet of fine-grained crystalline rock, in which there is much irregularly distributed epidote and quartz. It also contains small specks of native copper. It is underlaid by 5 feet of hard, greenish gray, epidotic diabase amygdaloid, with quartz and epidote filling the vessicles (sp. 342). The strata at these rapids are noted as having the singular dip 24° on a course N. 60° E. The lower two feet are characterized by a more irregular arrangement of the secondary minerals (sp. 243). About one-fourth of a mile below this, we come to the lower falls of the Totogatig. These falls, together with the rapids, extend for about 100 yards, and descend 25 feet. They offer a very fine water-power. At the head of the rapids, the rock is minutely crystalline, black and dark red, frequently containing amygdules of chlorite. At one point, a small vein of dark green chloritic material, much decomposed and carrying considerable quartz, was observed; and, near it, a vein of quartz carrying particles of native copper.

About 20 feet below this, the rock is a reddish-brown amygdaloid, containing calcite, chlorite and orthoclase. The beds are here very much broken up and shattered, and seem to dip in all directions, but chiefly toward the N. W. Short veins of quartz and chlorite are very numerous, and often contain small particles of native copper and malachite. This ends the series on the Totogatig.

In the N. E. qr. of Sec. 8 (T. 42, R. 10 W.), there is a ledge of dark reddish-brown amygdaloid, containing chlorite. It has a dip of about 20° N. W. Commencing in the northwestern portion of this section and the southwestern of Sec. 5, there extends southwestward to Frog creek, on the west line of Sec. 13, T. 42, R. 11 W., an almost continuous range of exposed trappean ledges. It has a width of from 20 to 80 rods, and consists of a dark diabase (sp. 322), which maintains a quite constant character throughout the range, save a variation in coarseness of crystallization. The ridge is heavily timbered with birch, maple, balsam and some pine. Above this, on and adjacent to Frog creek, there is a large area of the formation, mainly denuded of superficial accumulations, occupying parts of Secs. 13 and 24, T. 42, R. 11 W., and Secs. 17, 18, 19 and 20, of T. 42, R. 10 W. Commencing near the range line on the east side of Sec. 13, Frog creek channels through trappean rock for about one-fourth of a mile. To this the name "Darnells" has been given. The rock is in general a diabase amygdaloid, containing large quantities of dark chlorite, and also, in places, a large amount of epidote. At one locality near the middle of the Darnells, a north and south fissure, about six inches wide, was seen, the walls of which were lined with a seam of quartz one-half inch thick, faced with crystal points directed toward the center. The interior of the fissure seems to be occupied only by loose rock.

About 100 yards west of the Darnells, there is another good exposure, in the bed of the stream, consisting of a hard greenish-black, rather coarsely crystalline diabase, containing considerable magnetite.

East of the Darnells, about 200 yards beyond the range line, and in the wood, 50 to 100 yards south of the river, are several low, long ledges of dark, hard, greenish-black amygdaloid, containing considerable quartz and epidote in cells and seams.

Starting from the west quarter-post of Sec. 18, T. 42, R. 10 W., there stretches, for a mile northeast, a range of coarsely crystalline diabase, having a dip 24° N. W. It forms a ridge about 100 yards wide. This seems to be overlaid in places on its northwest side by a more closely crystalline, dark-reddish amygdaloid.

Proceeding from the northeastern extremity of this in a southeasterly course about fifty yards, another ridge about 120 yards wide is encountered. This is a comparatively soft, rather coarsely crystalline, dark red, slightly amygdaloidal rock, containing chlorite and some epidote, as occasional constituents.

Advancing southeasterly 200 yards, we find a small outcrop in the middle of a tamarac swamp. This rock is a very hard, medium, or fine grained, epidotic diabase amygdaloid. Calcite is associated with epidote in the amygdules.

The foregoing ridges have a marked northeasterly trend, and in contour, present an abrupt southeast side, often forming a cliff exposure of a few feet, with a gentle slope to the northwest. The timber on these is hard wood. Low flat ground, usually swampy, lies between them.

The height of the ridges above the intervening swamps is seldom more than fifty feet, and may be averaged at thirty feet. The rock continues to appear in low exposures, for about 200 yards down stream.

Returning to near the center of Sec. 18 (T. 42, R. 10 W.), at the dam noted as the second one, are numerous exposures of the formation. In these there appears to be a general parallelism of the abrupt southeast sides of the outcrops, and a gentle slope of about 12° to the northwest. The rock appears to be a dark, hard melaphyr (spec. 321), presenting a mottled aspect on the weathered surface. There are some faces on the east side of the river that dip about 30° in a direction N. 50° W.

In the N. W. qr. of the S. W. qr. of the section, there is a small exposure on the "tote" road consisting of a dark, reddish brown diabase amygdaloid (spec. 320). This rock is softer than is common and packs under the hammer. About 100 feet west, the rock becomes more coarsely crystalline, and very hard, containing much quartz in amygdules.

Ascending Frog creek to the S. W. qr. of Sec. 17 (T. 42, R. 10 W.), about 100 feet below the upper dam, on the east side of the stream, are several large ledges of very hard, reddish brown, coarsely crystalline diabase. This, and much of the trap in the vicinity, on weathering, presents a mottling of white spots. Near the S. W. corner of Sec. 17 (T. 42, R. 10 W.), at Dunn's old camp, are several low denuded ledges of amygdaloid, containing chiefly chlorite, with some quartz and epidote, as cell-filling, with occasional seams of the latter. In some of the quartzose portions, small particles of native copper were seen. Much of the rock here is soft and will pack under the hammer. About forty rods northeast of Dunn's old camp, there is quite a large hill of very hard, distinctly crystalline, dark iron gray, epidotic diabase amygdaloid.

Passing on into Sec. 20, about 300 feet below the Dalles we encounter a small ledge of very hard, fine-grained, greenish gray, epidotic amygdaloid. At the Dalles (N. E. qr. of N. W. qr. of Sec. 20, T. 42, R. 10 W.) there is a fine disclosure of diabase, forming the barrier rock of the falls and the Dalles. This is the highest point on Frog creek where rock *in situ* is known to occur. The rock first encountered is of a dark red color, somewhat soft, and full of large amygdules of chlorite, which are sometimes surrounded by a shell of epidote. Ascending, a very fine-grained, iron gray, non-amygdaloidal rock is found, followed by a very hard, compact, nearly black diabase amygdaloid, containing chlorite and epidote. The dip was not satisfactorily made out. There are a great number of small ledges scattered over this quarter section, appearing here and there in the brush.

T. 42, R. 11 W. Returning to the adjoining township (T. 42, R. 11 W.), we find near the southeast corner of Sec. 13, about 200 feet south of the lowest exposure on the adjacent portion of Frog creek, a ledge consisting of very fine-grained, dark reddish brown diabase amygdaloid, carrying nodules of epidote and quartz. The bed is about 75 feet thick. This is overlaid by soft, brown, chloritic amygdaloid, 100 feet thick. Next there is 30 feet of dark, rather coarsely crystalline, diabase amygdaloid, carrying, in the cavities, quartz and epidote. There follows this a hard, finely crystalline, reddish gray, diabase amygdaloid, containing spherules of quartz, epidote, and a little laumontite Thickness, 10 feet. This is succeeded by a dark brown, rather coarsely crystalline, diabase, in thickness 10 feet. To these outcrops then succeed a belt on the hill side, wanting in exposures, but in which all the surface rock is sandstone, which is usually dark red, and contains much quartzose material and grains derived from trappean rocks. It is to be noticed that there is little foreign drift in this vicinity.

About a quarter of a mile southeast of this, there is a low exposure of rather coarsely crystalline diabase. Near the W. line of the S. E. qr. of Sec. 13, about 200 feet south of the creek, is an outcrop of rather coarse, very dark diabase.

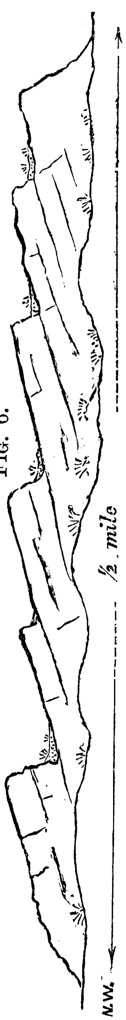
About 200 feet southeast of this, a small ridge shows much loose sandstone of trappean derivation. About one mile south of the above, near the S. E. cor. of Sec. 24, (T. 42, R. 11 W.), and on the north of a small brook, is a low exposure of dark, rather coarsely crystalline diabase (sp. 322).

About one mile west of this, in the S. E. qr. of Sec. 23, there is a low exposure of similar diabase, on both sides of a small tributary of Frog creek. Near the centre of Sec. 23, on the south bank of the same stream, is a low outcrop about 100 yards in length, of a nearly black, fine-grained diabase.

In the N. E. qr. of Sec. 23, T. 42, R. 11 W., is a small uncovered area of a rather coarsely crystalline, dark, reddish brown, amygdoidal diabase, carrying quartz and calcite.

About 300 yards northwest of this, is a very fine grained, compact, brown diabase, with amygdules of quartz only. This is overlaid by a rock similar to that seen in the preceding outcrop. Above this the rock shows planes of division, not unlike cleavage planes. On the northwest brow of the dome, the rock is dark brown, rather coarsely crystalline, with aggregations of quartz and epidote and specks of magnetite.

FIG. 6.



PROFILE OF TRAPPEAN OUTCROP IN N. W. QR. OF S. W. QR. OF SEC. 7, T. 37, R. 15 W., SHOWING THE EFFECT OF THE DIP AND BEDDING UPON THE CONTOUR.

About 200 yards northwest of the last exposure, is another ledge, rising about 20 feet high, and dipping 24° to the N. W., in which the beds are quite distinctly individualized, having an abrupt and irregular slope to the southeast — this representing their fractured edge — but more gentle and regular slope to the northwest — this representing their upper face.

The lowest bed is a rather coarsely crystalline diabase, 10 feet in thickness. This is surmounted by a fine grained, black, or dark gray diabase of 30 feet thickness, when there follows, a bed of the same, save the presence of red, jasper-like particles; and this again is overlaid by rock like that beneath. The dip is 24° N. W. About 150 feet southwest of this is another small hill of coarse diabase. Its position is such as to indicate that it may form a bed about 50 feet in thickness, underlying the base of the preceding outcrop.

Next underlying this is a bed of fine-grained, brown diabase amygdaloid, containing a large amount of calcite in the amygdular cavities. Thickness, 20 feet. This reclines upon rock of similar general aspect, but mainly wanting in calcite, yet it contains considerable chlorite, and is rather coarser and softer than the above. Thickness about 50 feet. This, again, is supported by a hard, dark diabase amygdaloid, with a thickness of 40 feet. This is underlaid by a chloritic amygdaloid, 20 feet in thickness, and underlying this, is a rather coarse epidotic diabase. Beneath this, again, is a fine-grained, dark, reddish brown diabase amygdaloid, 25 feet thick, and this is finally supported by a fine-grained, dark gray and greenish gray, epidotic diabase amygdaloid about 50 feet thick. Near the S. W. cor. of this section (23, T. 42, R. 11 W.), there is a small exposure of a dark gray, fine-grained, somewhat amygdaloidal diabase. This is part of a very low, long ridge that runs for about a mile from N. N. E. to S. S. W.

Near the N. W. cor. of Sec. 26, there is a very fine exposure, in a break in the ridge, known as the "Hole in the Wall." The rock here breaks down precipitously about 15 feet, forming a pass which is occupied by the road. Lithologically the formation is here similar to that of the last exposure, but contains more augite. It develops a white mottling on its weathered surfaces. The dip is 30° to N. W. There is a noticeable uniformity in the character of the rock for long distances on the line of strike, showing the persistence of the same beds. This rock is thought to lie at the base of the series found in the N. E. qr. of Sec. 23, and to immediately underlie the epidotic diabase amygdaloid. It probably has a thickness of 200 feet. In the S. W. qr. of Sec. 28, T. 42, R. 11 W., on the south side of the south fork of Frog creek, there is a small outcrop of a hard, tough, fine-grained diabase pseudo-amygdaloid, containing calcite and chlorite, and weathering to a light color to the depth of an eighth of an inch. Southwest from this, there are reported to exist one or two small outcrops, very difficult to find in the wilderness, but the formation becomes essentially, and at length completely concealed beneath the surface deposits. Indeed, it is doubtful whether this particular horizon of the formation again appears within the state, or at any point to the southwestward. But if we pass almost due southwest about 36 miles to the vicinity of Clam Falls, we shall encounter another cluster of outcrops extending onward to the state line.

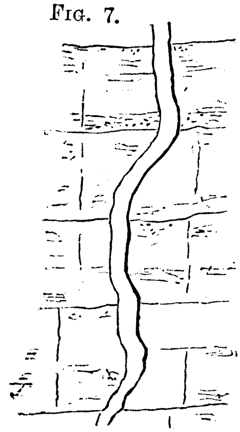
It should be remarked that there are a considerable number of small exposures of trappean rock reported to lie to the eastward of the line we have, in imagination, pursued, bridging, in the main, the interval. Some of these were sought for, but the brush being thick, and the outcrops low, the exact spot was not found. As there is no rational ground for doubting the continuity of the formation, they possess only their own inherent interest, which, owing to the feebleness of their exposure, is not great.

THE CLAM FALLS DISTRICT.

T. 37, R. 15 W. The first individual outcrop of the Clam Falls group, met in coming from the northeast, is in the N. E. qr. of Sec. 7, T. 37, R. 15 W., but the main exposures of the formation are nearer the falls, in Secs. 12, 13, 14, 23 and 24.

In the N. W. qr. of S. W. qr. of Sec. 7, the rock protrudes from the drift in typical trappean, or step-like, outline, as shown in the profile on the preceding page.

FIG. 7.



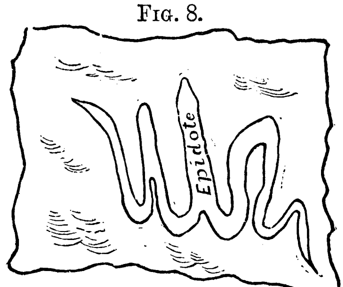
SKETCH SHOWING VEIN OF AMYGDALOID TRAVERSING TRAPPEAN BEDS.

The rock is a dark, fine-grained diabase amygdaloid, and contains much quartz and orthoclase in small patches, associated with epidote, in small veins and crystalline clusters. The amygdules of epidote often have a central filling of quartz; magnetite in small grains is also observable. The rock is much cracked and no distinct system of joints was discerned. Some portions of the rock are greenish, apparently due to disseminated epidote, containing an epidotic diabase amygdaloid, with dark chlorite as the main cell filling. Drift groovings here bear nearly south.

The figure opposite represents a vein of amygdaloid, noted as crossing the beds nearly vertically. It is about three inches wide, with a soft chloritic seam one-fourth inch wide on either side:

There was also noted as occurring here, a very peculiar wrinkled appearance, as though the igneous mass had flowed in a pasty condition. This is in the vicinity of a contorted vein of epidote as represented by the sketch opposite.

FIG. 8.



SKETCH SHOWING CONTORTED VEIN OF EPIDOTE AND PECULIAR WRINKLINGS OF THE SURFACE.

North of the river near the falls, the ledges mount up in steps of from 20 to 50 feet to a height of about 230 feet above the river at their base, forming a bold and conspicuous ridge, from which an extensive view to the north may be obtained. The slope of the strata is about 15° to the W. of N. The superficial portion of the beds, which is that mainly exposed, is highly amygdaloidal; while the central and lower portions are less markedly so.

On the southwest side of the stream, near the quarter-post of Secs. 13 and 24, and elsewhere on that side, the rock is generally less amygdaloidal; indeed the mass of the formation is not amygdaloidal, but contains scattered patches that are so. It cannot be distinguished in the field from the common dark diabase of the formation.

T. 37, R. 16 W. The S. E. qr. of Sec. 14, T. 37, R. 16 W., possesses interest as being one of the two localities where quartziferous porphyry is exhibited in the region described in this chapter. The other locality is a little over two miles due south of this, in the N. W. qr. of the N. E. qr. of Sec. 35 of this township. The rock (spec. 309) in both instances is essentially the same. It is close-grained, pinkish red, and breaks readily into sharp-edged, angular blocks.

This tendency, under the action of the elements, especially frost, is exhibited in the natural outcrop to such an extent that the surface is mainly reduced to a mass of sharply angular blocks. The larger, distinct crystals of feldspar vary from one-fifth to one-tenth of an inch in length, and are imbedded among a mass of much smaller crystals of the same mineral, associated with small particles of quartz, the whole forming a minutely crystalline base. It is not apparent to the unaided eye that there is any strictly unindividualized matrix. The formation has a dip of 20° to N. 20° W. Taking this in connection with the position of the two outcrops, it appears evident that they do not belong to the same horizon, but, on the contrary, constitute portions of separate beds.

In the S. E. qr. of Sec. 23, there is a low outcrop of fine-grained, nearly black diabase. The small exposure gives no reliable indication of its dip or strike. A quarter of a mile north of this, there is another small outcrop of dark green, trappean rock, containing distinct cleavage faces of augite, and large numbers of red particles, probably hematite, a product of chemical metamorphism.

In the N. E. qr. of Sec. 23, a short distance north of the last, is an exposure of amygdaloidal diabase. To the north of this, there is a succession of exposed ridges extending to the road leading to Clam Falls. The dip of these varies from 10° to 20° to the west of north. The rock is slightly amygdaloidal, and contains small veins of epidote.

In the N. E. qr. of Sec. 28, there is a very coarse grained, greenish gray, trappean rock, having a porphyritic aspect, owing to large crystals of feldspar. South of this, near the range line between towns 36 and 37, there are numerous small outcrops, lying mostly in Secs. 33 and 34, the locations of which are shown on the accompanying atlas map. They possess little to distinguish them from the common non-amygdaloidal diabase rocks of the series, and are too feebly exposed to give reliable measurements of dip and strike. A small outcrop, found in the N. W. qr. of Sec. 35, may be classed with these, being almost identical in character.

In the N. W. qr. of Sec. 10 of this township, there is a dark, almost black, highly magnetic diabase, which has a white, mottled appearance on weathering, due doubtless to the kaolinzation of the feldspar. The outcrop is covered with large, angular blocks, due probably to the riving action of frost. This prevents a definite measurement of the dip, but the longer slope of the ledge is northward.

T. 38, R. 16 W. In the N. W. qr. of the S. E. qr. of Sec. 33, T. 38, R. 16 W., is a small exposure of a fine-grained, dark greenish diabase. Such amygdules as are present are confined to the upper surfaces of the beds, or what appear to be such. A northward slope of the surface of about 15° probably indicates the true dip of the beds.

In the S. W. qr. of the section, about a quarter of a mile west of the last, is a ledge of similar rock, which is, however, very amygdaloidal in some portions and not at all so in others. This outcrop has been much planed by glacial action, but no distinct striæ were observed. This forms the most northerly exposure of this group.

T. 37, R. 17 W. About three and a half miles southwest of this, in Secs. 11, 12, 13 and 14 of T. 37, R. 17 W., the ledges of the formation are exposed in frequent succession. In the S. E. qr. of Sec 12, the trap is hard, black and very fine-grained, changing to a dark greenish rock, mottled by black crystals of augite.

Near the S. W. corner of the section, on the west side of a small creek, the formation consists of an amygdaloid, with chlorite as the main filling of the cavities. In the S. E. qr. of Sec. 11, the rock is also quite amygdaloidal, carrying epidote, often with a central core or interior lining of quartz, containing also sometimes orthoclase. South of the center of the section the rock is dark, almost black, very fine-grained, and contains very few amygdules. At one point a large amount of epidote was observed.

Crossing Wood river to the west, we find near the quarter-post of Secs. 10 and 11, a cliff about 100 feet high and half a mile in length. The rock is a greenish black diabase, associated with diabase amygdaloid. It contains much chlorite, and in the amygdules, quartz, epidote and orthoclase. It acts strongly on the needle, indicating a large content of magnetite. A three inch vein of epidote rock was traced several yards, when it became concealed by soil.

In the S. E. qr. of Sec. 9 of this town, there is a ledge of dark, greenish, grayish and purplish, compact, minutely crystalline, eruptive rock, probably a diabase. It is traversed by numerous seams and veins of epidote rock, some of which are quite well defined. They are from a quarter of an inch to four inches wide, and contain, besides epidote, orthoclase and some calcite.

Three miles southeast of this, in the N. W. qr. of Sec. 24, on the southwest side of a creek, there is a low ledge of dark colored, fine grained, epidotic diabase amygdaloid (spec. 385), associated with diabase pseudo-amygdaloid. The latter is traversed by veins of epidote, and the amygdaloidal filling consists mainly of quartz, epidote and chlorite.

About one mile south of west, in the N. E. qr. of Sec. 26, is a low ledge of porphyritic pseudo-amygdaloid (spec. 383). Its porphyritic aspect is due to distinct crystals of gray and red feldspar. The ground-mass is greenish gray and rather hard. The false amygdules consist of epidote, chlorite and quartz.

In the N. E. qr. of the S. W. qr. of this section, the rock is of the same general type, but the specimen collected shows a more uniform grain, and the absence of the colored feldspar noted above.

In the adjoining S. E. qr. of Sec. 27, the porphyritic type is again exposed (spec. 382). Again, a little farther to the southeast, the granular form predominates (spec. 681).

About a mile and a half northwest, near a small lake, on the north line of Sec. 28, there is a very fine grained, hard, gray rock, belonging to the same group as the above, although differing considerably in texture and color (spec. 387). This, however, gives place to a coarser, darker rock of the same general class (spec. 389).

Less than two miles west of this, in the S. E. qr. of Sec. 19, there is a ridge about 50 feet high, which exhibits small and detached outcrops. The rock is a hard, dark, grayish and greenish black diabase, very rarely amygdaloidal. In a few places patches of epidote were seen, inclosing angular blocks of the country rock. At one point a large exposure of very hard, compact, dark red crystalline rock was observed.

The jointage system was mainly east and west and vertical.

T. 36, R. 18 W. Southwest from this, in the S. W. qr. of Sec. 2, T. 36, R. 18 W., there is exposed a large, flat area of trappean rock. It is hard, compact, dark grayish green, and very amygdaloidal, in places, and, in others, not so, there being no evident regularity in the distribution of the two varieties. The amygdules are of quartz, epidote and orthoclase. The bed contains veins of epidote rock, and also east and west seams, of 2 inches to 6 inches in width, of a softer, dark, broken, undetermined rock. A patch of rose colored quartz, containing epidote and malachite, was observed. In places the magnetic needle was reversed, indicating a large content of magnetite. The surface is much cut up by joints, which are in east and west, and in north and south systems, and are nearly vertical. There is noted also, as occurring in the same section, a similar flat exposure of rock, resembling in character that above described, but not amygdaloidal except in patches. It is dark greenish in color, and contains magnetite in small amygdules, and in large grains in the rock, which can be knocked out in sufficient size to influence the needle. It is smoothed and striated by glacial action in a direction due south.

In Secs. 11 and 12 of this town, there is an east and west ridge, about 250 feet high, whose top is quite level, and heavily timbered with oak and maple, and whose sides disclose trappean ledges all around. The rock is a hard, dark diabase, in part amygdaloidal and epidotic (sps. 373, 374, 375, 376). Veins of epidote traverse the formation, and, being much harder than the adjoining rock, stand forth in small ridges, often highly polished by glacial action. The dip is from 10° to 15° in a direction N. 50° W.

About two miles southwest of this, in the N. W. qr. of Sec. 22, the formation protrudes from beneath the drift in some very considerable ridges, which expose a dark, hard, compact, seldom amygdaloidal rock, containing frequent veins of epidote, quartz, and orthoclase. The rock has a very marked effect on the compass, causing the needle to dip to the ledge, to spin around when moved along it, or to stand in any direction.

Westward from this, less than three miles, near the centre of Sec. 18, T. 36, R. 18 W., there are two small outcrops of dark green, fine grained diabase, pseudo-amygdaloidal in portions (sps. 377 and 378), carrying mainly quartz and calcite in the false cavities.

Town 36, R. 17 W. Passing into the adjoining town on the east (T. 36, R. 17 W.), we find, near the middle of the line between Secs. 19 and 20, an amygdaloidal diabase, containing in cavities, quartz, feldspar, chlorite and epidote, the latter also occurring in seams. The chlorite amygdules frequently have a central filling of quartz. The groundmass is hard, compact, and dark colored; and causes a variation of the needle to the amount of 90°. It presents a flat, exposed area of about ten acres, on which are glaciated surfaces.

In the S. W. qr. of Sec. 12 of this town, there are low, flat ledges, in a windfall on both sides of the road. The rock is a dark greenish diabase amygdaloid. The amygdules consist of quartz, feldspar and epidote.

In passing southwestward, several outcrops of the formation under discussion are encountered, the more important being in Secs. 4, 9 and 31, as shown on the map. They are all described as being heavy, fine grained, dark, often nearly black, trappean rocks, and are probably diabase. The outcrop at the S. W. corner of the township is in part amygdaloidal, containing quartz, feldspar, and chlorite in the cavities, and traces of copper in the form of malachite, in small seams. This outcrop exhibits glacial smoothing and indistinct striæ having a course S. 40° E. At another point, fine hair lines were observed running east and west.

THE ST. CROIX FALLS DISTRICT.

At and in the vicinity of St. Croix Falls, and southward from there to the neighborhood of Osceola Mills, there are numerous and very fine exposures of the Copper-bearing series and of the overlying Potsdam sandstone. As these are in a settled region, and well known to the inhabitants, their several locations need not be described in detail, but may be seen by reference to the accompanying atlas plate XIX. For the greater part, they lie in the immediate valley of the St. Croix river, and owe their exposure to the erosive action of that stream. The valley here is some 400 feet (aneroid) below the higher plateaus that approach the streams within a mile or two on either hand. The copper-bearing rocks appear in the slopes of the valley, at heights ranging up to 200 feet or 300 feet. The lower 100 feet or more retain distinct evidences of the abrading action of the stream, in the form of worn channels, rounded bosses of rock, smoothed surfaces, and, most decisively, eddy-worn pot-holes, some of them of gigantic size. These have already been described.

Just below Taylor's falls, the river has cut a deep vertical gorge in trappean rock, forming the beautiful and picturesque Upper Dalles (see plate XXXVI). About two miles below this a similar cañon has been formed, constituting the Lower Dalles. The walls within these Dalles are almost absolutely vertical, and instead of showing worn faces, like the slopes above, present the regular rough surfaces common to fissure planes. It seems very probable that the original worn surface of the gorge has been riven and thrown down by the action of the frost and the undermining of the stream.

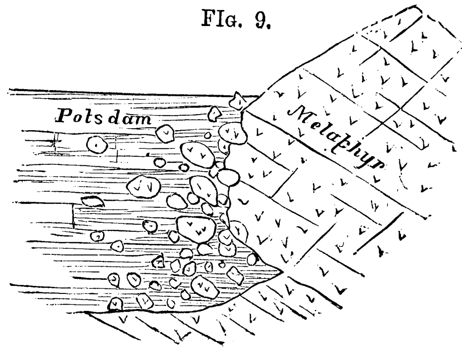
Mr. Strong suggested, with much reason, that the river, or more probably a branch of it, may formerly have followed the ravine running through the E. half of Secs. 30 and 31, T. 34, R. 18 W. This was abandoned when the present channel became deep enough, through erosion, to carry away all the water.

In this vicinity, the relation of the Potsdam sandstone to the copper-bearing rocks is most satisfactorily shown. The details relating to this subject pertain equally to the Potsdam formation, but will be here introduced. Some citations from the Minnesota side of the river will also be introduced to give completeness to the data, as it is important to geological science that the relative age of the two formations should be definitely and unequivocally settled, and nowhere else is the evidence so complete and conclusive as in the vicinity of the Dalles of the St. Croix.

T. 33, R. 19 W. On the N. W. qr. of Sec. 12, T. 33, R. 19 W., Osceola, there is an exposure of horizontally stratified sandstone in the side of a small ravine, and within a few feet is an exposure of melaphyr of the Keweenaw series. The sandstone is quite hard and compact, but the stratification is undisturbed, and there is no indication of metamorphism. A short distance farther north, the road passes over an exposure of melaphyr on which the sandstone is seen deposited in direct contact with it.

In the south part of the village of Taylor's Falls, near the summit of the ridge, is a remarkable exposure of the Potsdam in connection with the Keweenaw series. Its occurrence is illustrated in Fig. 9, but somewhat idealized. All that is seen is an outcrop of melaphyr, and, on the exposed face, a conglomerate formed of rounded and water-worn fragments of melaphyr. These fragments are of all sizes, and the cementing material is a ferruginous sandstone of Potsdam age, containing occasional Lingulepis shells. In the vicinity of the melaphyr the greater part of the conglomerate consists of its fragments. After inspecting the locality, it seems evident that the melaphyr was an exposed cliff in the Potsdam sea; about whose base large aud small water-worn fragments of the melaphyr were collected, and, the interstices being filled with sand, solidified into the conglomerate as it now appears. The junction of the two formations is not well exposed, as the sandstone graduates into the conglomerate, and the latter is banked up against the uneven surface of the melaphyr. The unconformability, however, cannot be doubted.

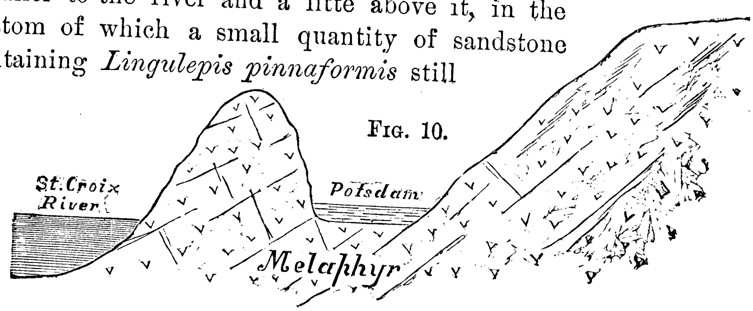
FIG. 9.



SHOWING THE RELATIONS OF THE KEWEENAW OR COPPER-BEARING MELAPHYR TO THE POTSDAM SANDSTONE AND CONGLOMERVTE AT TAYLOR'S FALLS.

On the east bank of the river, at the old mill, in St. Croix Falls, can be seen the junction of the Potsdam and the Keweenaw series, represented in Fig. 10. There is a small gorge in the melaphyr lying nearly parallel to the river and a litte above it, in the bottom of which a small quantity of sandstone containing *Lingulepis pinnaformis* still

FIG. 10.



SHOWING THE RELATIONS OF THE POTSDAM SANDSTONE TO THE CUPRIFEROUS MELAPHYR AT ST CROIX FALLS.

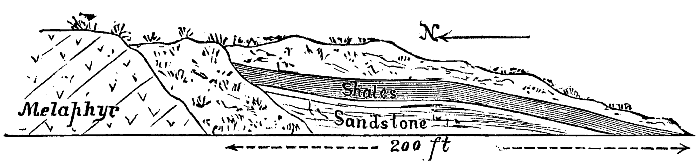
remains, being deposited horizontally on the inclined beds of the copper series. The thickness of sandstone is but a few inches.

About a quarter of a mile below the last exposure, and on the same side of the river, near the water's edge, is an exposure of sandstone and shale of the Potsdam, as shown in Fig. 11.

This exposure differs from the majority in this vicinity in that the layers are slightly undulat'ng, although the inclination nowhere exceeds 10°. The same beds are exposed down the river for nearly a quarter of a mile, and are quite horizontal. The junction of the sandstone and melaphyr is not exposed in this instance, as it is covered with a bank of clay and sand; the distance between the exposures, however, is only a few feet.

The sandstone is very fossiliferous, and affords fine specimens of *Lingulepis pinnæformis*. There are no cracks or breaks in the continuity of the strata, and it seems probable that it was originally

FIG. 11.



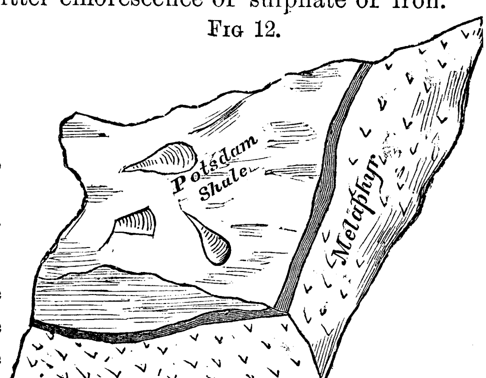
SHOWING UNDULATIONS OF THE POTSDAM SANDSTONE AND SHALE — ST. CROIX FALLS.

deposited in its present condition; since, if it were due to subsequent movement, other exposures would probably show similar irregularities.

Among the shales shown in Fig. 12, there is a bed of ferruginous matter about a foot thick, which, on being exposed to the air, forms a light colored and slightly bitter efflorescence of sulphate of iron.

On the opposite side of the river, about a quarter of a mile above the bridge, the shales are well exposed; they are soft and earthy, of a bluish color, and afford beautiful specimens of *Lingulepis pinnæformis*.

FIG 12.



HAND SPECIMEN SHOWING THE JUNCTION OF THE POTSDAM SHALE AND THE MELAPHYR.

On the west side of the river, about half a mile above Taylor's Falls, where the water is low, the junction of the Potsdam and Keweenaw formations may be found, and very good specimens obtained, one of which is shown in Fig. 12.

The fossiliferous blue shales of the Potsdam are horizontally deposited on a melaphyr, containing small specks of pyrites. The melaphyr breaks out in thin pieces, having the shales firmly attached. The junction is marked by a dark line about an eighth of an inch thick, which seems to cement the two formations. It is seldom that such fine specimens of the junction of two formations so widely differing can be obtained.

Small green seams and stains of malachite occasionally occur in the sandstone at Taylor's Falls. The copper in this instance has perhaps been derived from the adjacent Copper-bearing series, the melaphyrs having some copper disseminated through them.

The foregoing facts, corroborated as they are by much other data gathered from the vicinity and other parts of the district, and elsewhere, make it certain that the Copper-bearing series was subjected to much erosion during and previous to the formation of the Potsdam sandstone, by which valleys were cut into it to the depth of at least 300 feet. This, doubtless, represents but a small proportion of the total erosion which the series had suffered in the pre-Potsdam period.

This locality presents the most clear and unequivocal evidence that the Copper-bearing series is much older than the Potsdam sandstone of our state, so much older, indeed, that there was time for the very extensive wearing down of the former before the latter was deposited.

The crystalline rocks of the Copper-bearing series of this locality, while varying somewhat, possess a general similarity, and are not diversified by conspicuously distinct beds of different kinds of rock, as has been found to be usually the case in other extensive exposures of the formation. So true is this, that it is quite difficult to distinguish the true bedding planes. There are occasional amygdaloidal portions, but in many cases these have no evident layer-like arrangement, as is common where they mark the face of a true bed, which is the result of a distinct overflow of igneous matter. In some cases the amygdaloidal portion assumes a bed-like form, but then is seldom well defined, extensive or persistent. On the whole, however, these amygdaloidal layers show a tendency to parallelism, corresponding to what is confidently believed to be the true dip of the formation.

The massive rock varies somewhat in its crystallization, being in some portions very fine-grained, almost crypto-crystalline to the naked eye, and in others coarser, while in some it is distinctly porphyritic. It was not observed that the latter occupied distinct horizons, though more extended research might show that this was true. In color, the rock varies from grayish green to greenish black on the fresh fracture, and from gray to black on the weathered surfaces.

In physical structure it is quite massive. It has sometimes been described as presenting a columnar or basaltic structure, but this, we think, is a misconception. It is abundantly fissured in vertical planes, and, as is almost universally true, the vertical fissures arrange themselves in general systems which cross each other at large angles, dividing the rock into vertical columns. These, in the perpendicular cliffs of the Dalles, are conspicuously exposed, and give a picturesque columnar aspect to the formation, but it is not the true prismatic structure that often characterizes igneous rocks.

In addition to these vertical planes of division, which are generally quite smooth and uniform, but not persistent to great depths, there is another prominent set which are much less smooth, but much more persistent and constant in direction. The surface of the layers separated by these joints is nearly uniform to the general view, but in detail is slightly uneven and undulatory, as though the separation took place not through the fracture of a homogeneous rock, but by separation along a natural division plane. These planes are usually separated by several feet. They are confidently believed to represent the dip of the igneous beds. It is not presumed that *all* of the layers so formed represent separate overflows of molten material, much less distinct periods of eruption; but that in the flowage and outspreading of the igneous matter, a somewhat parallel arrangement of the not perfectly homogeneous substance took place, giving rise to an obscure pseudo-stratification, sufficient to influence the jointing that subsequently took place. At the same time, the fact that the beds at different horizons present different textures, and, in a subordinate degree, different mineralogical composition, would seem to favor the belief that the several hundred feet of the formation exposed in the vicinity of St. Croix Falls, represent a considerable number of distinct but closely successive overflows; all, perhaps, belonging to one great period of eruption. The latter statement seems to be demanded by the lithological similarity of the rock, the slight distinction between the beds, and the absence of detrital deposits between them. Notwithstanding their obscurity, however, the beds give to the outcrops the distinctive step-like or trappean contour that has been previously described and figured. This is best seen in the exposures about one mile east of St. Croix Falls (N. E. qr. of Sec. 29 and N. W. qr. of Sec. 28, T. 34, R. 18 W.), where the inclined ledges follow each other with much regularity and persistence, giving to the profile of a cross section a serrate outline, notwithstanding the fact that the glacial agencies acting from the northwest tended to plane down the edges of the beds.

It is upon the persistence of these inclined ledges, taken in connection with parallel lithological belts, that our determination of the dip, a matter of some theoretical interest at this extremity of the formation, is mainly based. The average of a large number of guarded observations gives a dip of about 15° W. by S. This inclination to the south of west is quite an interesting fact, however it may be interpreted. To the writer it seems to signify, taken in connection with other observations, that the trough of the Lake Superior synclinal, at this western extremity, curves rapidly southward, and is connected, over a sort of saddle-back anticlinal, with the broad stratigraphical basin that stretches southward into Minnesota; and that the igneous beds overlap this figurative saddle-back, so as, on their margin, to really lie in the southern or Mississippi basin. This low anticlinal is supposed to lie a little north of St. Croix falls, and to be the low, flattened extremity of the Laurentian and Huronian heights that lie to the eastward — the saddle-bow of our illustration.

This view is quite strongly supported by the fact that, while the dip in the northwestern part of the county, in the vicinity of Clam Falls, is decidedly to the northward, the strata on the Snake river in Minnesota, below Chengwatona lake, strike N. 10° to 15° E., and dip 50° to 60° south of east, which seems to show that the strata on the opposite side of the synclinal trough curve southward to conform to the Minnesota Archæan axis, which forms alike the western border of the Lake Superior and Mississippi stratigraphical basins.

The lithological characters of the crystalline rocks at this locality have been carefully examined and described by Professors Kloos and Streng, of Germany, and the results published in an article in the "Neues Jahrbuch für Mineralogie, Geologie and Palæontologie," for 1877.[1] The special description of the rocks is by the latter gentleman, and may be rendered substantially as follows:

Microscopically this rock generally appears throughout of a porphyritic nature, and sometimes, also, amygdaloidal. Here and there porphyritic layers are wanting, as *e. g.*, on the right shore of the St. Croix river, while on the opposite side decidedly porphyritic rock appears. The latter consists of a greenish gray, verging toward brownish, fine-grained, crystalline ground-mass, with numerous porphyritic plates of brown plagioclase. Besides there are also frequently light gray quartz aggregations, often provided with a dark green edge, so that this may be regarded as an amygdaloid. Further, there appears, also, scattered aggregations of a dark green, chlorite-like mineral. In the ground-mass, one sees, even with the naked eye, numerous small grains of a light yellow-green mineral distributed, which, as the microscopic examination shows, consists of epidote. This is particularly frequent in those varieties that are not porphyritic, so that owing to it the whole rock assumes a green color; even macroscopically, we may here recognize that the plagioclase has been changed into the dark green, chlorite-like mineral, so that it assumes a green color, even where the cleavage surfaces appear bright. Here, also, scattered sparks of pyrite present themselves.

The microscopic examination discloses the following composition:

1. Plagioclase, generally brown, colored by brown and gray granules. Besides that, it contains grains and flakes of the augitic constituent, changed into viridite or chlorite, which then sometimes so predominates, that it almost fills the whole plagioclase crystal; only small remnants of feldspar substance remain. But epidote crystals also fre-

[1] By G. Leonard and H. B. Geinitz, professors in Heidelberg and Dresden, Stuttgart, 1877.

quently appear distinctively in the feldspar. The plagioclase also here forms sometimes a component of the fundamental mass, and sometimes the greater part of the porphyritic layers.

2. The augitic component is here wholly changed into viridite. The larger aggregations of this mineral, which is here united with epidote and quartz also, appear more seldom; but the smaller aggregations, on the other hand, are very frequent, forming a part of the fundamental mass, which generally only fills the spaces between the feldspar particles. The mineral appears in polarized light, in granular, or radial, or confused texture.

3. One of the most frequent constituents is the epidote. This is found less frequently in large masses, but is common in small, irregular patches, and also sometimes in regular defined bounded crystals of a light yellow color. These are little dichroitic, but show very lively polarization colors. Generally, they are pretty pure. Sometimes they contain little particles of quartz. They are frequently cut through with little, irregular, brown veins. Rarely, also, the epidote is filled with viridite. In by far the majority of cases, it resists inundation by the viridite substances, even where the feldspar is wholly filled with it.

4. Greater and smaller collections of quartz present themselves in polarized light, as aggregates, which are covered with a green, granular substance, and therefore are to be regarded as amygdaloidal formations.

5. Also the white granular substance is here visible.

6. Magnetite,

7. And apatite appear here in slender needles.

From the foregoing it is evident that the melaphyr porphyry of St. Croix and Taylor's falls is generally distinctly porphyritic in formation. The porphyritic element consists of plagioclase, besides which there is a very little orthoclase present; of an aggregate chlorite-like, granular substance, which is to be regarded as a transformation product of the augite; of aggregates of epidote, of quartz amygdules, which, however, do not appear everywhere, and of small sparks of pyrite. The aggregates of two very much weathered ingredients could not be further discriminated; they probably form concretions of the two chief constituents.

The ground-mass consists predominatingly of plagioclase (perhaps also some orthoclase), augite, which, however, is very frequently changed into viridite, magnetite, epidote, often present in great masses, little quartz and a gray white, granular fissure product.

If the rock is developed in the manner of an amygdaloid, the quartz appears as the amygdule filling; likewise calcite and epidote.

From this it appears that the rock belongs to the melaphyrs; and since it is decidedly porphyritically developed, we may designate it melaphyr-porphyry.

Now in most of the varieties, except the freshest, the epidote plays a very important role. Hence it might also be designated as epidote-melaphyr; but since the epidote, as well as the viridite, is a secondary product, which, perhaps, has sprung from the transformation of the augite, the name could only apply to the changed melaphyr-porphyry. (For the original text, see the work cited above).

The outcrops in the N. W. qr. of Sec. 29, T. 34, R. 18 W., present rounded bosses fluted by glacial agency acting from N. 45° W.

The exposure on Close's creek in the N. W. qr. of Sec. 14, T. 33, R. 19 W., shows a small quantity of carbonate of copper in a group of broken, irregular seams, upon which a little prospecting has been done. Malachite also occurs in small quantities at several other points. On the Minnesota side, at Taylor's Falls, a shaft was sunk some years since, from which native copper was obtained. The amount was not sufficient to render the work remunerative, though the indications are said to have been considered encouraging.

Recently a vein has been disclosed by government employees engaged in quarrying at the foot of the Dalles. Mr. Caneday describes it as follows: "The vein is exposed but a short distance above the water level, has well defined walls only eighteen inches apart at the highest point of exposure, but with a perceptible increase in width as you descend on the line of dip. It apparently corresponds in dip and strike with the formation at large, dipping in a west southwesterly direction at an angle of twelve degrees. The ore streak at the point of examination was about four inches thick, consisting of bornite (better known as gray sulphuret of copper), which lies next to the hanging wall, under which is about a foot in thickness of snow white quartz. Upon the foot wall, and comprising the balance of the vein matrix, rests from two to six inches of rock so thoroughly decomposed as to bear a close resemblance to common earth. The walls have a striated or 'slickenside' appearance, and bear unmistakable evidence of continuity."

In the preceding pages we have traced the main belt of northward-sloping Keweenawan rocks from the vicinity of Nemakagon lake to St. Croix falls. It had been previously traced northeasterly to Keweenaw point.

There are some considerable intervals between exposures, but there is not the slightest ground for doubting the continuity of the terrane beneath the prevalent drift. The outcrops along this belt are almost wholly confined to the eruptive rocks that predominate in the lower portion of the Keweenaw series. Adjacent to the belt including these outcrops, there is a tract 15 miles and upwards in width which is exclusively covered by drift, and no rock of any kind in place appears at the surface. This barren belt doubtless conceals the sandstones and conglomerates that form the main constituent of the upper portion of the group. That these should have been more deeply eroded than the enduring crsytalline rocks is not strange, especially as they occupy the trough of the synclinal; and as the later glacial movement was across the trend of the ranges, it is all the more natural that the softer rocks of the valley should be concealed. Had the drift movement been parallel with the trend of the strata, doubtless exposures of the valley rock might have been more common.

As it is, we find none of the northward-dipping sandstones, shales and conglomerates, save at the two localities above described, and these, from their position in relation to the crystalline rocks, are believed to be interstratified with them. That the northward-dipping detrital beds are present, however, is not to be doubted, since we find a considerable development on the opposite side of the synclinal axis.

THE NORTH ST. CROIX DISTRICT.

To this southward-dipping series we now turn our attention. It has been described in its main features by Mr. Sweet in the preceding report, and our only labor here is to add the special observations of Mr. Strong, on the outcrops in the immediate St. Croix valley:

Pursuing the same order as heretofore, that of tracing the formation from the Lake Superior region, southwestward, we find between Chaquamegon bay and the head-waters of the St. Croix, a belt wholly covered by drift. In descending the St. Croix, the first exposed rock encountered occurs at Chase's dam, in Sec. 36, **T. 44, R. 13 W.** It consists of a red sandstone (sp. 395), approaching in its variations a fine conglomerate on the one hand, and an arenaceous shale on the other, and containing, imbedded in it, fragments and thin leaves of shale. An examination of the granular ingredients shows that it was derived mainly from the crystalline igneous beds of the series. Its dip appears to be 10° to the S. E. This sandstone forms the bed of the river from the dam to the rapids, near the mouth of Moose creek, and also immediately underlies the swamp on the north in Secs. 25 and 36. The preceding statement needs to be qualified, however, for about an eighth of a mile above the mouth of the Moose creek, in the midst of a series of short, swift, narrow rapids, there is a small ledge of crystalline rock, doubtless representing a comparatively thin intercalated stratum. From the description of Mr. Strong, it appears to be a dark colored, fine-grained, epidotic diabase.

Rocks of detrital origin seem to prevail for two or three miles back from the north side of the river. The central part of Sec. 34 (T. 44, R. 13 W.) is underlaid with sandstone and fine conglomerate, similar to that at Chase's dam. In the N. E. qr. of the N. W. qr. of Sec. 26 (T. 44, R. 13 W.), on the east bank of Moose creek and in the bed of the stream, there is a small exposure of the typical conglomerate of the series. The matrix is a finely comminuted material of a greenish, epidotic cast, in which are imbedded pebbles, from the size of shot to that of an egg, which are composed of the various crystalline members of the series. Little or no rock can be detected that might not have been derived from the lower members of the series, while the most of it very evidently had that origin. The pebbles are generally well rounded. Fragments or leaves of red shale, lying parallel to the strata, are also present.

In the S. W. qr. of the N. W. qr. of this section, on both sides of the creek, there are disclosures of coarse conglomerate of prevailing dark red color. It presents alternating beds of assorted, regularly stratified fine and coarse pebbles. Dip, S. E. 14°. The conglomerate again appears in the S. E. qr.of Sec. 27, in low ledges in the west bank of the stream, for about an eighth of a mile uninterruptedly. In the S. E. qr. of the N. W. qr. of this section, a small exposure of a conglomerate, similar to that on Moose creek, occurs, associated with a fine-grained, hard, light reddish and greenish gray sandstone (sp. 409). The highest point at which sedimentary rock is seen in ascending Moose creek, is in the S. W. qr. of the S. E. qr. of Sec. 14 (T. 44. R. 13 W.).

It consists of conglomerate of red color, for the greater part, and of similar composition to that above described. This and the preceding outcrop lie near the ledges of melaphyr which dip under them; and they may thus be regarded as lying on the margin of the great sandstone and conglomerate belt.

Returning to the St. Croix we find that from Sec. 4 (**T. 43, R. 13 W.**), to the southern line of the county (Sec. 33, **T. 43, R. 14 W.**), the bed of the stream is almost continuously composed of sandstone and conglomerate. The greater portion of this is the common red sandstone of the series. The lower mile and a half is conglomerate, and probably corresponds in stratigraphical equivalence to the conglomerates of Secs. 27 and 14, T. 44, R. 13 W. above described, as it lies in the line of strike, and bears a similar relation to the crystalline strata on the northwest. By consulting the map, it will be seen that from Chase's dam to the county line, a distance of about 11 miles, the river runs an almost direct course, and, with slight interruptions, is bedded on sandstones and conglomerates. A casual glance will show that the stream runs closely with the strike of the strata. A more careful study makes it appear that the river crosses the strata at a very small angle, passing from higher to lower beds. Near the county line, however, the river turns southward and pursues, for about three miles, a southerly course. This brings it over higher (geologically) strata. For a little more than a mile, however, it is bedded in drift, but near the north line of Sec. 9 (**T. 42, R. 14 W.**), the sandstone of the series reappears in the bed of the river and extends across it, causing rapids and forming occasional low exposures in the banks. The ledges show fine ripple marks and occasionally rain drop impressions. They are more indurated, and seem to contain more quartz and less argillaceous material than those previously described. This sandstone again becomes concealed at the south line of the section, but reappears in the bed of the river in the Indian village in the N. W. qr. of the N. W. qr. of Sec. 21 (**T. 42, R. 14 W.**), about a mile below. These are probably the highest beds of the Keweenaw group exposed in the district.

Next immediately underlying this sandstone and conglomerate series, so far as the outcrops show, there appears to be a diabase, little exposed, underlaid by a stratum of easily recognized melaphyr, forming at the surface outcrops along a belt lying parallel to the sandstones. This is the typical Keweenaw melaphyr described by Prof. Pumpelly on page 32, and identical with stratum 108 of the Eagle river section.[1] It is found in the N. E. qr. of Sec. 14 and the N. E. qr. of Sec. 27, T. 44, R. 13 W., the N. W. qr. of Sec. 29, T. 43, R. 14 W., and at the falls on Chase's brook, in the N. E. qr. of the N. W. qr. of Sec. 16, T. 42, R. 15 W.

The first three of these may be joined by a nearly straight line about 12 miles in length, whose course will be about N. 48° E., or nearly the average observed strike. If this line be projected, it will pass to the southeast of the melaphyr exposure on Chase's brook, and, if extended in the opposite direction, it will pass about an equal distance from an outcrop of precisely similar rock found on Moose creek, in the N. E. qr. of the N. W. qr. of Sec. 2, **T. 44, R. 13 W.** It would appear highly probable, then, that the first three exposures belong to the same stratum, and that the remaining two represent a lower bed. This is confirmed by the existence of a similar melaphyr near the center of the west line of the N. W. qr. of Sec. 21, **T. 43, R. 14 W.**, and also one in the S. W. qr. of Sec. 10, either of which might readily be referred to the lower bed, though it is not so apparent that both could. Entering more into detail, we observe that the outcrop of melaphyr (spec. 410) in the N. E. qr. of the N. E. qr. of Sec. 27, **T. 44, R. 13** W., rises only about 10 feet high and forms the bank of a creek. The rock agrees completely with the description of the typical Keweenaw rock previously referred to. The formation crops out quite continuously along the stream as far as the forks in the N. E. qr. of Sec. 23. Here it is found to be dark, coarse-grained, rather soft, containing much chlorite, and crumbling readily on weathering, and no longer possesses the distinctive melaphyr characters. On the line between Secs. 22 and 27, we, however, find the typical melaphyr again.

Following the line of strike into the S. E. qr. of N. E. qr. of Sec. 14 of this township (T. 44, R. 13 W.), we find on Moose creek the same melaphyr (spec. 406). Its dip here appears to be about 18° to S. 30° E. A few yards below, the ledges are traversed by veins of epidote, with some indications of copper. The rock is here very amygdaloidal,

[1] See Geol. Sur. of Mich., 1869-1873, Vol. I, part II, p. 136.

carrying chlorite as its cell-filling. Dip 20°. A few rods below we find a heavy, firm, fine grained, dark greenish, diabase-like rock. The surface of this presents very finely preserved glacial groves having a direction S. 13° W. Some are wide and shallow, while others are narrow, sharply defined hair lines. In the N. W. qr. of the S. E. qr. of this section there are also some small ledges of fine-grained diabasoid rock, and in the S. W. qr. of the S. E. qr. of the section we encountered the conglomerate before described. Following up Moose creek to Sec. 2, we find in the N. W. qr. of the S. E. qr. first a very hard, fine grained, nearly black diabase, above which, about 100 yards, there appears a coarser crystalline diabase (spec. 404), and diabase pseudo-amygdaloid (spec. 405), containing patches of epidote, quartz and considerable calcite, though the rock is not generally amygdaloidal. There are to be found occasionally specks of malachite. The dip measurements were 17° and 20° S. E. The ledges are much fissured and broken in all directions. Near the center of the section, low ledges, along the west side of the stream, exhibit a coarse-grained rock, somewhat resembling the melaphyr found further up the stream, presently to be described. Above this in the N. W. qr. of the section, there first appears a diabase of medium grain and greenish gray color, and about 100 yards farther up, on the left bank of the stream, a low outcrop of soft, very dark, diabase pseudo-amygdaloid (specs. 401 and 402) containing chlorite, quartz, orthoclase and prehnite. About an eighth of a mile above this, and only a short distance below the town line, the west bank of Moose creek exposes the typical melaphyr previously mentioned, characterized by a dark green color, fine grain, peculiar irregular fracture and large reflecting surfaces of satin-like luster.

Passing due southwestward about seven miles into the S. W. qr. of Sec. 6, we encounter a dark, fine-grained diabase, occasionally amygdaloidal, with calcite. A vein about two inches wide was observed, which carried considerable native copper in films and small particles, associated with calcite and epidote. In the rock there are also particles of epidote carrying copper. These are in the bed of the brook, and overflowed in high water. A short distance above, the rock becomes softer and contains large amygdules of chlorite, with frequently a core of calcite. These ledges extend along the stream for about half a mile. At the dam, near the town line, there is a ledge of highly altered diabase amygdaloid, containing calcite, chlorite and epidote. There also occurs here an interesting epidotic amygdaloid.

To the west of the center of Sec. 8, **T. 43, R. 13 W.**, there is a fine exposure of conglomerate, having a dip of about 14° in a direction S. 50° E. It is traversed by two regular systems of joints on courses N. 34° E. and N. 56° W., by reason of which it is cut into regular cubical blocks. Judging from the drift, the western portion of the S. E. qr. of the adjoining Sec. 5 is underlaid by conglomerate.

Passing over an interval of about five miles, in which no outcrops are known to exist, we find in the S. E. qr. of Sec. 6, **T. 43, R. 14 W.**, a wide, low, northeasterly trending ridge, presenting bared rock at one point, which appears to be a diabase (sp. 426) of very fine, close grain and dark color, coated with a thin, light colored crust due to weathering. In the N. E. qr. of Sec. 9 of this township, there is a ridge composed of a rather soft, fine-grained, dark, reddish brown diabase amygdaloid (sp. 425), weathering to a dirty lilac hue. It appears to be much altered. This ridge, in common with those of the vicinity, presents an abrupt declivity on the northwest and a gentle slope in the opposite direction, the same phenomena observed so frequently on the opposite side of the St. Croix valley, but reversed in direction. It is scarcely necessary to repeat that it is due to the inclination of the strata whose projecting edges form the ridges.

In the S. W. qr. of Sec. 10 (T. 43, R. 14 W.), there is a similar ridge composed of melaphyr and already referred to. A short distance south of this, in the adjoining section (N. W. qr. Sec. 15), there is a similar ridge, but of diabase, beyond which is still another, the rock of which is a dark brown and black, hard, fine-grained crystalline diabase (sp. 423), containing occasional amygdules of chlorite. It resists weathering well, and only shows a thin, light, dirty grayish coating of weathered substance. The trend of these ridges is northeasterly with the strike of the strata.

In the S. W. qr. of Sec. 15 (T. 43, R. 14 W.), in a large hill, there is a small denuded area of rock, of hard, close, minutely crystalline texture, reddish brown color, and rough, uneven fracture. It contains scattered aggregations of chlorite. It appears to be an altered melaphyr (sp. 427).

In the S. E. qr. of Sec. 17 (T. 43, R. 14 W.), there is a long ridge of melaphyr that appears to be a continuation of that above noted in Sec. 10, and is probably to be correlated with that in Sec. 2, T. 44, R. 13 W., and that at the falls on Chase's brook, Sec. 16 (T. 42, R. 15 W.). There is a like rock found near the centre of the west line of the N. W. qr. of Sec. 21.

In the S. W. qr. of Sec. 22 (T. 43, R. 14 W.), there is an outcrop of a fine-grained, hard, reddish brown, crystalline rock, probably a diabase. It forms the nucleus of a hill.

In the S. E. qr. of the N. W. qr. of Sec. 28, there is a small uncovered area of typical melaphyr, which probably belonged to the same stratum as those situated in Secs. 14 and 27, T. 44, R. 13 W., as already stated. From this point for a distance of about 30 miles down the St. Croix, no exhibitions of rock in place of any kind are known to exist.

In the vicinity of the mouth of Kettle river, **T. 39, R. 19 W.**, there are several denuded ledges of crystalline and sedimentary rock, but here, unfortunately, also, the high stage of water at the time of examination, concealed to a large extent the low, flat exposure of the river channel. At the head of the rapids, in the N. W. qr. of the N. W. qr. of Sec. 2 (T. 39, R. 19 W.), there is a ledge of dark colored melaphyr (spec. 432). The crystals of pyroxene enclosing minute feldspar crystals are smaller than is common to the melaphyrs above described, and the reflecting surfaces on the fractured face are less conspicuous. It is traversed by reddish bands, apparently due to oxidation of the ferruginous ingredients. On the Minnesota side, in the N. W. qr. of the S. E. qr. of Sec. 4, there is a low ledge of soft, crumbling, decomposed, igneous rock, in which are layers or veins of quite peculiar nature. Much of the latter substance has a flinty texture and composition, with which is associated green earth, considerable calcite, and a little malachite and pyrite.

In 1866 a shaft was sunk on the N. E. qr. of the N. E. qr. of Sec. 20, T. 39, R. 19 W. It is situated about 50 feet from the river, and was sunk 26 feet deep, to the level of the stream. The upper part penetrated a soft, light-colored crystalline rock, while the lower portion passed through a soft, dark brownish red amygdaloid, carrying a large amount of calcite and some quartz. The amygdules also consisted frequently of native copper, a considerable amount of which was obtained. The water proved a serious obstacle to the continuation of operations. The shaft was sunk upon a fissure vein about four feet wide, with well defined walls. Its general course is N. E. and S. W., and its inclination about 60°. The north wall showed striated surfaces, or slickensides.

A few rods northeast of the shaft, a cross cut has exposed the Potsdam sandstone at an elevation of about sixty feet above low water. It is the usual light colored, horizontally bedded, quartzose sandstone, and is without fossils, so far as observed. At the head of an island, in the river, in the N. E. qr. of the N. W. qr. of Sec. 29 (T. 39, R. 19 W.), there is a ledge of dark reddish brown, very hard, fine grained, crystalline rock, probably a diabase. It was mainly concealed beneath the water.

A short distance below this, in the S. E. bank of the stream, the horizontal Potsdam sandstone is again exposed. It here consists of alternate sandy shales of yellow and dark red color, some of the latter having an unctuous feel and being known as soapstone. It was entered about twenty years ago for mineral paint. In the N. W. qr. of

Sec. 7, **T. 38, R. 19 W.**, there are cliffs of Potsdam sandstone fifty feet high. The rock is light colored, generally nearly white, and consists of large grains of quartz very loosely cemented, so that the whole is very soft and crumbling. It resembles the formation as usually seen in the Mississippi valley. It appears again about a quarter of a mile below, in low ledges near the water's edge. It again crops out in the N. W. bank in the N. E. qr. of Sec. 4, **T. 37, R. 20 W.**; and in the N. W. qr. of the S. W. qr. of the same section, there are low ledges on each side of the river in the banks. This is known as the "Big Rock." These ledges of Potsdam sandstone probably represent a considerable development of that formation concealed by the drift, and lying in the synclinal trough of the Keweenaw series and in valleys in it formed by pre-Silurian erosion.

PART VII.

THE

GEOLOGY

OF

THE MENOMINEE IRON REGION

(EAST OF CENTER OF RANGE 17 E.)

OCONTO COUNTY, WISCONSIN.

BY THOMAS BENTON BROOKS.

NEWBURGH, N. Y., *July 15, 1879.*

PROF. T. C. CHAMBERLIN,

Chief Geologist of Wisconsin:

SIR: — I respectfully transmit, herewith, my Geological Report on the Menominee iron region of Oconto county. Gradually increasing illness, aggravated by this work (I have been more than once positively ordered to stop, by my physicians), has particularly unfitted me for composition, and has prevented my making this report what I had planned.

The results of the labors of Charles E. Wright, who assisted me in 1874, and afterwards worked independently in adjacent territory, but who has covered the whole as to economic questions, are given in his independent report to you, which follows. Dr. Arthur Wichmann's paper on Microscopic Lithology of the Huronian Rocks, constitutes chapter V of this Report.

Respectfully and obediently yours,

T. B. BROOKS.

NEWBURGH, N. Y., *July, 1879.*

INTRODUCTION.

This report covers only the northeastern portion of Oconto county, the most northeasterly sub-division of Wisconsin, and so much of the adjoining Michigan territory as was necessary to a full understanding of the geological structure. This was selected by the late Dr. Lapham, first director of the survey, as the area in which to begin work in this part of the state, because of its supposed exceptional geological interest and its promise of economic importance. The scientific results obtained, and recent developments of iron ore, have fully sustained the wisdom of this choice. My reconnoissance of the northeastern side of the Menominee, the results of which are given in the Geological Survey of Michigan, Vol. I, 1873, gave valuable data; but that work, on the whole, was incomplete and crude, and will be superseded by this report,[1] which is, however, also not complete in several directions.

The following geographical divisions of the Menominee Iron Region, based largely on the distribution of the iron ores, has been adopted, or rather extended from the Michigan side. See Atlas Plate No. XXVIII. The Menominee and Brulé rivers, constituting the state boundary, divide the mineral region, so far as its limits are now ascertained, quite unequally, by far the larger area being on the Michigan side. This I had formerly divided into the *Sturgeon* and *Paint River* districts. The Wisconsin side will be designated as the PINE RIVER DISTRICT. It would be premature to minutely subdivide it at present. The great *Commonwealth range* seems to run west and northwest through it, bringing Lake Eliza[2] near the center of the range. To the north is the Eagle-mine range, and about four miles south of the Commonwealth range is the Breitung iron location,

[1] In accordance with special instructions, no Wisconsin money was expended on the Michigan side, but, finding it impossible to complete the Wisconsin work without further studies in Michigan, I have made them at my own expense. — T. B. B.

[2] Also known as Keyes Lake and Loon Lake.

on Sec. 28, T. 39, R. 18 E. Mr. Wright has found strong magnetic attractions in the southeastern part of T. 40, R. 16 E., to which locality Geo. A. Wakefield has built a road. The STURGEON RIVER DISTRICT, Michigan, was further divided into the *north* and *south iron belts;* the latter was again divided into the *north* and *south ranges*, the two lakes Antoine and Fumee lying between them. It is in the south range of the south belt of the Sturgeon River District that the Quinnesec, Norway, Vulcan, Breen and adjacent mines have recently been opened, to which new ones are now being added. According to the newspapers, important discoveries are (July, 1879) being made almost daily.

Dr. Lapham's original view was to spend one season (1874) in the field and incorporate the results in a preliminary report. This was found impracticable, owing chiefly to the fact that about one-half of the first season's work was expended in re-surveys and correcting the topography of the U. S. Land Office maps as a basis for our work. The Federal maps of large portions of my territory are not only entirely inaccurate, but absolutely fraudulent and false.[1] The scarcity of rock exposures in the eastern part of the Pine river district was also a great drawback, and consumed much time in outcrop hunting, for which we have only negative results. Owing to these drawbacks, we were enabled in the two months spent in the field in 1874 to thoroughly survey only a part of the river boundary, and make a careful reconnoissance as far west as the middle of Range 17 E., beyond which there are but few outcrops.

I have spent parts of 1877 and 1878 in the same region and supplied, so far as the circumstances would allow, the wanting facts;[2] so that my report on the region east of the line above named is tolerably

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[1] A few of the grossest frauds are indicated on Plates V to VIII. That large irregular sheet of water, "Spread Eagle Lake," was not only never surveyed, but apparently was seen only in part by the deputy surveyor, who swore to his having traversed and mapped it according to his contract, and for which work he was paid, after it had been inspected (!) by the surveyor-general. Unless the country is re-surveyed by Federal authority, endless land litigation will ensue. Whether the U. S. government cannot be compelled to do this, and what hold it may have on the surveyor-general and his deputies, who were guilty of the fraud and neglect, is a question for lawyers. — T. B. B.

[2] At the urgent request of Dr. Lapham, an attempt was made to work the material collected in 1874 into a report, and it was only when that work was nearly completed that its palpable incompleteness became apparent. The facts gathered with the small appropriation for 1877 were wedged and patched into the original, which have the effect of localizing the incompleteness. The year 1878, found another small sum available, but sufficient to practically complete the field-work contemplated. At this period however, increasing ill health has rendered the writer unfit to rewrite the whole, and make most of the material accumulated. The effect in parts of the work, it is feared, is very much like that which results from putting new wine in old bottles.

complete as to the location and lithological character of the exposures of rock.

It being the desire of the state authorities to cover as much ground as possible,[1] Mr. Charles E. Wright, who had assisted me in 1874, took up the work in 1876, where I had left it, and carried a reconnoissance a considerable distance west, the results of which are given in this volume, part VIII. Mr. Wright has also examined microscopically and minutely described the specimens collected in 1874, duplicates of which are in Madison. He is to prepare the economic chapter on the whole Menominee region, all of which will be found in his report following this.

Dr. Arthur Wichmann, of Leipsic, has studied microscopically, not only most of the Wisconsin rocks collected by me, but, for comparison, the most interesting of my entire Huronian collection,[2] in which investigations he had the benefit of the suggestions and advice of Professor Zirkel, whose assistant he was. His results are given in Chapter V, and, as to clay slates, more fully in Quar. Jour. Geo. Soc., London, Feb., 1879.

Fred. J. Knight has rendered most valuable assistance in nearly every part of the field and office work, from the topographical surveys at the beginning, to the correction of the proof.

Geo. A. Fay, of Menasha, Wis., was of great assistance in the field work of 1878. F. H. Brotherton and Robert McKinlay were employed in topographical work and in locating outcrops.

The rocks represented in the Menominee Region are grouped as follows, from youngest to oldest. For their general geographical distribution, structural relations and folds, see sketch in Atlas Plate XXIX.

Superficial Deposits (Drift).	Sands and gravel, (Champlain?) Boulder clay (till) glacial.
Lower Silurian.	Calciferous sand rock and limestone. St. Mary's sandstone (Potsdam).
Keweenaw (Copper-series).	Wanting.

[1] I was in Europe at the time, but urged upon the then director, Dr. Wight, that a thorough survey of the Menominee region proper would be a better use of the money than to cover so much ground in a superficial way.

[2] Now deposited in the Amer. Museum of Nat. History, N. Y.

Huronian (Iron-bearing).	*Upper*	Granite (eruptive?), gneiss, hornblende, actinolite, mica, chlorite and quartz schists, iron ores, clay and carbonaceous slates, quartzite, and conglomerate.
	Middle	Clay-slate and quartzite.
	Lower	Dolomite, iron-ore and quartzite.
Laurentian (not subdivided.)		Granite, gneiss and crystalline schists.

It thus appears that within the small area surveyed, rocks of four, and possibly of seven, distinct periods are represented; but this report is almost entirely confined to the Iron-bearing series, believed to be the equivalent of the Huronian of Canada, and known here to rest non-conformably on granite and gneissic rocks, regarded as of Laurentian age, and to be non-conformably overlaid by horizontal lower Silurian sandstones. The *Keweenaw* (copper) series, belonging between the Huronian and Silurian, have not been found here. Spread over the whole region, and sometimes concealing the solid rocks for large areas, are superficial deposits of unstratified *glacial boulder-clay*, as well as of stratified sands and gravels, probably of the *Champlain* period. These superficial deposits have not been at all studied. The direction of the minor ridges and intervening swamps and smaller streams, as well as striations, show the course of the glacier to have been from the N. N. E., but the great valleys and higher ridges have a course at right angles, running W. N. W., and due entirely to the rock beds.

The presence of patches of *Lower Silurian* sandstone, capping the highest hills and in sheltered spots, supports Prof. Pumpelly's view that the leading topographical features of this region were formed in pre-Silurian times. The erosion of Silurian rocks, which must have been very great, since they must have covered the whole region attaining, in places, a thickness of several hundred feet. The two small patches discovered in Wisconsin, one four miles east and the other one mile northwest of Lake Eliza, have great interest in this connection, being the only points where this rock was seen in my Wisconsin territory. Eastward the Silurian covering rapidly increases, and beyond the Sturgeon river, Mich., entirely conceals the older rocks, which do not appear again, so far as I know, until we reach Canada.

Laurentian (granitic-gneiss series). Passing downward over the place of the wanting Keweenawan and the immense Huronian series to the oldest rocks known south of Lake Superior, we are not able to prove with certainty that they are anywhere exposed in Wisconsin within the limits surveyed. But to the eastward in Michigan, with the middle waters of the Sturgeon river as the east boundary, we find a large triangular Laurentian area, its base sinking away under the Silurian strata beyond the Sturgeon, and its rounded apex nearly touching the Menominee at the Bad Water Indian village. Away from this most ancient core, south, west and north, dip at high angles the non-conformably overlying Huronian beds, spreading themselves, with numerous short and irregular folds, beyond the limits of my survey.

The geological surveys heretofore made south of Lake Superior, having had for their main object the examination of the mineral regions from an economic standpoint, have given little attention to this system of rocks, which, south of Lake Superior, has not as yet been found to bear valuable ores, although in New York and Canada, the most extensive iron deposits are contained in it. The following necessarily fragmentary notes[1] will, however, it is hoped, convey such a general idea of these rocks as is necessary to the purpose of this report, the main point being to enable the explorer to distinguish the rocks of one system from those of the other, which is absolutely necessary in planning and conducting economic explorations and surveys. The necessity of attention to this point has become the more apparent, since the Oconto county explorations have demonstrated that gneisses and granites, heretofore believed to characterize the Laurentian system, are also found abundantly in the Huronian. About one-third of the whole area of Wisconsin is Azoic. To separate this area into the three or more great systems of rock which underlie it is one of the most important questions connected with the geology of the state, both from a scientific and economic standpoint. For further information regarding Laurentian rocks, see table I, chapter I, and appendix B.

The *difficulties* to be overcome in working out in the field the sequence, folds, distribution and age of the Huronian rocks of the Menominee region were, in part at least, common to all crystalline and highly contorted rocks, especially the older, and lie chiefly: (1.) In the entire absence of fossils.[2] (2.) In the often rapidly-changing mineral composition of the beds, as traced along their strike. (3.) In the fact that many fine-grained rocks could not be determined in the field. (4.) The beds are so plicated as to rarely present any other than vertical or nearly vertical dips, and the latter are often overturned so as to be only false lights. (5.) The frequent changes in the strike

[1] The Laurentian. See Appendix B, p. 661.

[2] Mr. Julien thinks he found organic forms in certain carbonaceous shales. See Mich. Geol. Report, 1873, Vol. II.

by which groups of beds wind and fold like a sluggish stream in a meadow. (6.) The superficial glacial drift-covering often concealed the rocks entirely for many square miles; and (7) lastly, the country is, or was when the greater part of the survey was made, a primeval forest, with numerous windfalls and swamps, only intersected with Indian trails and occasional canoe routes. Large areas were covered by swamps, in some of which were almost impenetrable cedar groves.

In Michigan, the Federal maps, based on land surveys, the lines of which cross the country at right angles every mile, were accurate; but in parts of Wisconsin they were almost worthless, as has already been noticed. These unfavorable conditions made it imperative that a large part of the time, energy and money be expended in packing supplies and utensils on the backs of men; making and correcting topographical maps on which to delineate the geology, and in searching the bush for exposures of rock, which were sometimes not seen for days. I venture the opinion that it would require more time and money to work out in detail the relative age of all the rocks occurring in Oconto Co., than to do the same work for the entire Paleozoic area of the state.

Fossils have been compared to the paging of the leaves of a book, rendering it comparatively easy to place them in their proper order wherever found, and however much injured. But the leaves of our book are not paged, besides being crumpled, soiled and torn. He must work long and well who would bring them into order.

My original plan, approved by Dr. Lapham (afterwards abandoned for various reasons), contemplated a full practical treatment of the subject of *mineral prospecting* and *exploration*, thus expanding and completing what was begun in chapters VII and VIII, Mich. Geol. Report, 1873, Vol. I. Much could be added under Prospecting, but the chapter on the *Magnetism of Rocks*, and use of magnetic instruments in searching for ore,[1] is quite complete save as to the use of the *dial compass*. Beginning with a rude home-made portable dial, in 1866, I gradually brought the instrument to the complete form made by F. Krœdel, N. Y.,[2] and extensively used in this survey. This instrument was exhibited and explained at the Hoboken meeting of the Am. Inst. of Mining Engrs., 1874. I regard it as indispensable in topographical and geological reconnoissance or mineral prospecting, where magnetite is present.

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[1] Extensive but not exhaustive research has led me to believe this was the first practical paper on this subject.

[2] Messrs. Gurley, Troy, N. Y., are now making a useful, cheap, hand form, like one of my earlier ones. They are also devising a tripod instrument, which bids fair to supersede the Burt solar compass for reconnoissance and some kinds of ordinary surveys.

TABLE I.

THE LITHOLOGICAL CHARACTER OF THE SYSTEMS OF ROCKS REPRESENTED IN THE MENOMINEE AND MARQUETTE REGIONS.

ILLUSTRATING THE REPORT OF T. B. BROOKS.

PERIODS.	KINDS OF ROCKS IN APPROXIMATE ORDER OF ABUNDANCE.	MINERAL COMPOSITION AND REMARKS.
LOWER SILURIAN.	Sandstone and associated	Occasionally contains excellent brown freestone for building.
	Conglomerate	Mostly white, black and red quartz, and granite pebbles.
	Limestone	Calcareous sand-rock overlying the sandstone.
KEWEENAW. (COPPER BEARING SERIES.*)	Conglomerates, sandstones and jasper rocks	Debris derived chiefly from the destruction of various porphyries and granitic rocks, and of the diabases and melaphyrs.
	Diabase { Upper portions of flows often true amygdaloids; the intermediate portions often amygdaloidal through mineral changes }	*Plagioclase* — chiefly *Oligoclase; Augite, Magnetite,* Prehnite, Quartz, Laumontite, Orthoclase, Chlorite, Datholite, Analcite, Apophyllite, Natrolite, Calcite, Epidote, Delessite, Greenearth, Native Copper, Native Silver.
	Melaphyr	*Plagioclase* — chiefly *Anorthite; Augite, Chrysolite, Magnetite.*
	Gabbro	*Plagioclase* — chiefly *Labradorite, Augite, Diallage, Hornblende, Uralite, Magnetite, Chlorite.*
	Augit-Diorite	*Plagioclase, Orthoclase, Augite, Hornblende.*
	Felsitic Porphyry?	*Orthoclase, Quartz, Glass basis.*
HURONIAN. (IRON BEARING SERIES.)	METAMORPHOSED SEDIMENTS.	
	Granite? (possibly eruptive)	*Quartz* (with fluid inclosures), *Orthoclase, Biotite, Plagioclase,* probably Oligoclase, Magnetite, Apatite.
	Greenstones (including possibly some that are eruptive): Diorite	*Hornblende, Plagioclase, Titanic iron, Magnetite,* Quartz, Apatite, Augite, Uralite, Calcite, Biotite, etc.
	Greenstones: Diabase	*Augite, Plagioclase, Magnetite, Titanic iron,* Quartz, Orthoclase, Epidote, Hematite, Hornblende, Apatite, Pyrite, etc.
	Greenstones: "Greenstone" Schist	Apparently altered and schistose forms of the massive Greenstones containing a chloritic mineral and biotite.
	Greenstones: Gabbro	*Diallege, Saussurite, Hornblende,* Tremolite? Biotite.
	Mica Schist	*Biotite, Muscovite, Quartz,* Staurolite, Andalusite, Garnet, Calcite, Tourmaline, Zircon, Hornblende, Feldspar, Magnetite.
	Quartzite, Quartz schist.. Conglomerate, Sandstone Jasper, Chert, Silicious Schist	*Quartz, Jasper, Chert, Lydianstone, Calcite, Mica, Chlorite, Magnetite,* Hematite, Feldspar, Garnet, Actinolite.
	Clay Slate	*Kaolin, Carbon, Mica, Chlorite, Pyrite,* Garnet, Tourmaline, Hematite, Feldspar, Clay slate needles.
	Crystalline Dolomite	*Dolomite, Calcite, Quartz,* Limonite, Carbon, Plagioclase.
	Crystalline Limestone	*Calcite, Quartz, Tremolite, Biotite, Dolomite,* Wollastonite, Titanic Iron, Magnetite, Plagioclase.
	Hornblende Schist	*Hornblende, Quartz, Plagioclase, Orthoclase, Biotite,* Calcite, Magnetite, Titanic Iron, Apatite, Sahlite, Titanite, Hematite.
	Ores of Iron. Magnetite	Hematite, *Martite, Chlorite, Quartz, Actinolite.*
	Ores of Iron. Hematite	*Martite, Magnetite, Jasper, Quartz, Chlorite, Turgite,* Goethite, Kaolin.
	Ores of Iron. Hydrated Oxides	*Limonite, Turgite, Goethite, Hematite, Martite, Quartz, Kaolin, Calcite, Pyrolusite.* Wad, Rhodochrosite, Actinolite, Magnetite?
	Chloritic Schist (including the Greenstone variety)	*Chlorite, Quartz, Garnet, Biotite, Orthoclase, Plagioclase, Magnetite,* Titanic Iron, Zircon, Tourmaline, Actinolite.
	Actinolite Schist	*Actinolite, Quartz, Magnetite, Hematite, Ochre, Chlorite, Garnets,* Authopolite? Zircon.
	Hydro-Mica (Sericite) Schists	*Sericite, Quartz, Ochre,* — pseudomorphs after Calcite?, Tourmaline.
	Carbonaceous Slate	Soft black *Clay Slate* rich in coal, *Quartz,* Mica?, Epidote?.
	Gneiss	*Quartz, Orthoclase, Plagioclase, Biotite, Muscovite, Magnetite, Rutite ?, Calcite.*
	Hornblende and Syenite Gneiss	*Hornblende, Quartz, Orthoclase, Plagioclase,* Biotite, Titanic Iron, Titanite, Ochre, Calcite.
	Syenite	*Hornblende, Orthoclase,* Plagioclase, Quartz, Biotite, Titanite, Apatite, Epidote, Hematite, Magnetite, Titanic Iron.
	Eklogite	*Garnet, Actinolite, Magnetite,* Biotite.
	Novaculite	Hard brittle yellowish green *Clay Slate,* containing *Garnets, Quartz, Tourmaline,* Hematite.
	Porphyrite	*Plagioclase,* altered *Hornblende, Ochre,* Chlorite, Quartz, Kaolin.
	Serpentine	An altered Greenstone, *Serpentine, Olivine,* Augite, Magnetite.
	Talc Schist	Very rare if it exists. The unctuous feeling, so called "Talcy Schists" are Hydromicaceous.
	ERUPTIVE.	
	Diabase (Dolerite)	In dykes in the Marquette Region in the Middle and Lower Huronian, but is rare. Is blacker, heavier, more massive and harder than the bedded kinds and possesses a distinctive microscopic character.
	Granite	In dykes in the Menominee Region. Rarely in the Lower, more frequent in the Upper Huronian.
	Diorite? Gabbro?	These rocks have never been seen in the form of dykes, but always as apparently conformable beds, and believed usually to be metamorphosed sediments.
LAURENTIAN. (GRANITIC-GNEISS SYSTEM.)	METAMORPHOSED SEDIMENTS.	
	Gray Granite	Rare, contains but little whitish Mica. Pegmatite and coarse graphic granite are varieties.
	Granitic Gneiss	A transition variety in which the large feldspar crystals have a general parallelism.
	Mica Gneiss	Abundant, often Chloritic.
	Mica Schist	Rare.
	Passing, through substitution of Hornblende for Mica, into	
	Hornblende Granite	Rare, often Chloritic.
	Hornblende Gneiss	Abundant.
	Hornblende Schist	Abundant.
	Passing, through alteration of the Hornblende, into	
	Chloritic Granite, Chloritic Gneiss	Common.
	Chloritic Schist	Very abundant.
	Garnetiferous Schist	Very rare.
	Magnetic Schist	Very rare.
	Granulite?	May exist.
	Quartzite?	May exist.
	ERUPTIVE.	
	Greenstone	(Dolerite) In numerous, regular and often thick dykes.
	Red Granite?	(Possibly Metamorphic) Rare, in large masses.
	Coarse gray Granite	In numerous small irregular dykes and veins.

[1] Privately communicated by R. Pumpelly.

THE MENOMINEE IRON REGION.

CHAPTER I.

THE HURONIAN SERIES IN GENERAL.

For the convenience of those who care only for conclusions, comparisons and general facts, the main results of my examination of the iron-bearing rocks of the Menominee region will be summarized in this chapter, and comparisons instituted with rocks regarded as their equivalents in other not distant regions.

1. The *kinds of rock*, their relative abundance and mineral composition, may properly be first noticed.

An inspection of the accompanying Table I, which presents a compact summary of the lithological characters of the several systems and series of rocks south of Lake Superior, shows the richness of the Huronian strata in *kinds*, embracing as it does about all the rocks occurring in the other series (save the melaphyrs of the Keweenawan), and more than a dozen distinct lithological families not found in either the older Laurentian, nor yet in the younger Keweenawan. This peculiarity seems to characterize the Huronian in Michigan, and in the adjacent Wisconsin territory, since the number of varieties diminishes to the southwest in Central Wisconsin, according to Prof. Irving, as well as to the west in the Penokee region. The poverty in kinds of rock of the Canadian Huronian is still more marked.

No one kind of rock is found in the four periods; only certain greenstones are common to the three older, while in the case of the older two, it may almost be said that every kind of rock found in the Laurentian occurs in the overlying Huronian. The lithological break at the line dividing the Huronian from the Keweenawan is further emphasized by the totally new accidental minerals enumerated by Prof. Pumpelly as occurring in the abundant "*amygdaloidal* traps" of the Copper series; i. e., the zeolite family and related minerals, the occurrence of which usually marks eruptive rocks, and which are not found in either of the older series, nor is the amygdaloidal structure. Those desiring fuller information regarding the microscopic character of the Huronian rocks are referred to Dr. Wichmann's report, chapter V, and for associations, transitions and graduations of the same, to chapters III and IV.

2. The *stratigraphical order*, or relative age and names of the various rock-beds constituting the series, has received more personal attention than any other question connected with these rocks. I first worked it out for the Middle Huronian, purely as an economic question connected with prospecting for iron ore in the Marquette region in 1865–7, Alexis A. Julien assisting me one season. The gist of my results was given by Dr. Credner, without credit, however, in his paper, already referred to, published in Berlin in 1869,[1] and copied in his Elements of Geology, 1872, p. 282. Subsequent studies, aided by extensive industrial developments, have placed the general correctness of this subdivision of the Marquette series beyond all question.[2]

The *numbering and designation* of the several beds which go to make up the Huronian series, came in this way:

In my economic work in the Marquette region, having in view the wants of explorers, prospectors and land-owners, it became necessary to designate certain strata, which I did by numbers from oldest to youngest, always writing them in Roman numerals. Thus, the great quartzite was called V, the great iron ore horizon XIII, and the staurolitic mica-schist of Lake Michigamme, the youngest rock then made out, XIX.

In my reconnoissance of the Menominee region,[3] a different series was employed, no attempt having then been made to equate them with the Marquette beds.[4]

Resuming work in the Menominee region in 1874, under the auspices of the Wisconsin survey, I soon became strongly impressed with the fact that there was a marked lithological similarity between certain beds here and corresponding ones in the Marquette series as developed 60 miles to the north. I have, therefore, attempted to equate the two series, using the Marquette numerical designations throughout. An inspection of the Table of Sequence and Equivalency at the end of this chapter, will indicate how far the attempt has been successful.

3. The *geographical distributions* of the three groups of beds

[1] Zeitschrift der Deutschen Geologischen Gesellschaft, Band XXI.

[2] See Mich. Geol. Rep., 1873, Vol. I.

[3] Results in Mich. Report, 1873, Vol. I.

[4] Dr. Credner had unsuccessfully attempted it in 1869. See his paper.

constituting the larger divisions of the Huronian series, can be best understood by consulting Atlas Plate No. XXIX. This map was constructed in order to separate what is hypothetical from what is known, and to simplify the broad structural problem by disregarding unessential facts. On it are represented only the main divisions of the Huronian in their hypothetical extension and folds so far as the facts would warrant conjecture. This plan leaves for the general map, Atlas Plate XXVIII, the representation only of known facts, and presents a white surface for the convenient addition of new facts which may be brought out in the future.

DESCRIPTION OF THE HURONIAN SERIES.

A. **The Lower Huronian** (Beds I to VII). See Atlas Plates Nos. XXVIII and XXIX, and Plate I, of this report.

Beds I to VII, inclusive, have their chief and, so far as positively known, only developments in Michigan, bordering the great Laurentian anticlinal on its S., S. W., W. and N. sides in all its various sinuosities, and are only in part made out.

The most conspicuous bed of this division, as well as of the entire Huronian series, is the Lower Quartzite, No. II, which, owing to its great thickness and resistance to weathering influence, is usually exposed in outcrops, sometimes, as where it crosses the lower Sturgeon river, becoming a bold topographical feature.

Omitting beds I, III and IV, about which little is known, we come to the great marble (dolomitic limestone) bed, V, which in the south belt of the Sturgeon river district, is almost as prominent as the quartzite. In one place on Sec. 35, T. 40, R. 30, there is exposed a thickness of over 1000 feet of this rock, and its course may be traced by a series of outcrops about N. 70° W. from near the Breen mine, for over 15 miles to a point S. W. of Lake Antoine, on the south side of which lake it is abundant. In the north belt it is seen at several points, but is less prominent and apparently, like the quartzite, much thinner.

Overlying the marble is the great iron-ore horizon (VI), in which, up to this time, the chief economic interest has centered. It may be said in general to be cöextensive with the marble last described, which it overlies, but is not so often seen in outcrops. The maps show this ore stratum as first emerging from under the Silurian rocks, which cover the entire area of the upper peninsula of Michigan east of this point, near the center of T. 39 N., R. 28 W., where the Breen and Emmet mines have been opened in it, and a good quality of brown and red iron ores found. From this point it is traceable by magnetic attractions, boulders, outcrops, explorations and now exploited mines, so numerous and well marked as to leave little doubt of its absolute continuity, nearly twenty miles in a general W. N. W. direction, to and across the Menominee river into Sec. 22, T. 39, R. 19 E., Wisconsin. One or two minor folds are known to exist within this distance; others will probably be found.

Like nearly all the rocks in this part of the valley of the Menominee and Pine rivers, the iron-ore bed is here eroded to a great depth, and so covered with sand and earth that it is not seen; but its position is put beyond all question by the deviations in the magnetic needle to be observed about one mile north of the mouth of Pine river, which continue with diminishing intensity for a mile into Wisconsin. The bed at this last point seems to lose the greater part of its magnetite — nowhere abundant — which renders it impossible to follow it farther with the compass needle. This phenomenon often occurs in other parts of the Menominee region, and in a still more marked degree in the Marquette region; for it must be borne in mind that the two most abundant ores, the specular and soft hematites, are not in themselves magnetic. They usually, but not always, contain a slight mixture of magnetite. For example, there is no magnetic attraction whatever at the Jackson, New York, Cleveland, Lake Superior and Barnum mines, of the Marquette region, which produce in the aggregate one-half of all the first-class ore mined in Michigan. It is possible that the place of the ore beds could be determined farther west by more delicate and expensive magnetic observations than we were enabled to make; but digging must be resorted to in all probability.

The magnetic attractions and shows of iron, so abundant in the vicinity of Lake Eliza and on the Pine river, as is elsewhere explained, belong to younger beds.

The ore range which passes just north of Lake Antoine and under Lake Fumee (see map), and which also loses its magnetism going west before it reaches the Wisconsin line, is believed to belong to the same horizon of ore last described, being the north wing of an anticlinal which sinks toward the west, and spreading out in a more or less undulating bed, undoubtedly underlies the entire region surveyed in Wisconsin, at a depth possibly accessible near the river, but, over a considerable area, beyond the reach of mining, according to present ideas and methods.

This ore horizon again appears in the North Belt of the Sturgeon river district, as shown on the map, but no reliable indications have been found of a connection between the two, which, on the hypothesis assumed, must exist, probably for the most part, on the Michigan side of the river. The facts point toward the existence of considerable faults in this vicinity.

Exposures of quartzite and limestone beyond the limits of my survey in the S. W. part of T. 41 N., R. 16 E., Wis., suggest the possibility of the presence of the Lower Huronian on that portion of the Brulé.

B. **Middle Huronian.** To attempt a general description of the Middle Huronian (beds VIII to XIII) quartzites, clay slates and obscure soft schists, would be to repeat the little that is known about them contained in the detailed description of the Huronian beds given in the following chapter. We therefore proceed at once to consider the better known and far more important Upper Huronian Beds XIV to XX.

C. **Upper Huronian** (Beds XIV to XX). The uppermost members of this division, and therefore the youngest rocks of the Huronian series (the mica schists, gneisses and granites), were not recognized by Dr. Credner,[1] and are only partially made out and described in my Michigan Reports, although extensively developed in Michigan as well as on the Wisconsin side of the river. Their barrenness in iron ores was one reason for this neglect. These beds possess much interest from the aid derived from the mica schist in establishing the equivalency of the Menominee with the Marquette series, elsewhere considered, and because granite is a heretofore unrecognized rock in the Huronian.

Taking up this division at its most easterly large exposure, and not far from where it emerges from under the Silurian (see Atlas Map, No. XXVIII), we have, at the Sturgeon Falls of the Menominee river, a fine section of the lower portion of this division, in which the great gabbro bed, XVI, is conspicuous, forming the barrier rock of the fall. North and south are softer and more schistose rocks, all of which are described in the following chapter. (See Plate I.)

The facts regarding the distribution of the youngest beds southwest of Sturgeon Falls are shown on Atlas Plate XXVIII, and my hypothesis of folding on Atlas Plate XXIX. From Sturgeon Falls, the general course of the series is parallel with the great iron ore and limestone beds of the lower divisions, that is, about W. N. W., which determines the course of the Menominee river here, as well as that of the Lower Pine, farther to the west, which is but a continuation of the same great valley.

[1] See first published description of these rocks in Zeitschrift der Deutschen Geologischen Gesellschaft, Band XXI, p. 516.

Four miles, for which distance only a few exposures can be seen on the river, brings us to the Devil's Gut and Sand Portage series, where there is a large development of the softer schistose beds overlying the great gabbro, here only seen north of the river.

Between Sand Portage and Little Quinnesec falls, there is an almost continuous high mural exposure of the great gabbro (XVI) on the north side of the river, which here attains a thickness of over 750 feet.

At the Little Fall, the river again breaks through the barrier at a point where considerable disturbance in the strata, probably due to a fault, seems to have taken place. The facts bearing on this are noted on Plate No. II, Chapter II, which see, with description.

Above this fall we have several miles of still water and littoral deposits, indicating a lake bottom at no very remote period, to the basin of the Great Quinnesec fall, in which are rocky islands. Here begin a succession of falls and rapids which extend for two miles, in which most of the beds of the upper division, that is, from XV to XVIII, are crossed and uncovered in the river banks. This great exposure, and the proximity of the overlying granite to the south, render this locality one of the best in the whole region in which to study this division of the Huronian. Plate III, with description, chapter II, covers the most interesting facts.

From this locality but little is known of these beds for eight miles, when they reappear in strength at the various falls in the Pine river, where they become more quartzose and more highly ferruginous, promising to bear workable beds of ore.

By the general map, it will be observed, that immediately west of the Great Quinnesec falls the rocks bend to the west and even south of west, while at the same time the iron range (VI) bends more to the north, thus forming a topographical and probably geological basin, about which little is known, owing to deep erosion, which has made room for the sand terraces which conceal the rocks.

It is believed that the clay slates and associated rocks forming the middle division of the Huronian, are spread out here, through one or more undulations, the presence of which is rendered probable by the Lake Hanbury fold. (See Section DD., Atlas Plate XXVIII.) The rock exposures near the mouth of the Pine are believed to belong to the middle division.

One of the most interesting and yet puzzling facts in this basin, is the presence of the seven immense marble boulders in the Menominee river, about two miles below the mouth of the Pine, and the one, still larger, just above.

Assuming the boulders to belong to No. V (they may be simply drift, which, however, seems improbable from there being seven together and only one seen at any other point), it may very probably be brought near the surface here by folds. On this hypothesis, we should find the iron ore bed VI near. No iron boulders were seen, and only slight magnetic attractions exist, but nothing was made out of them. Mr. Desor (Foster & Whitney, L. S., Part II, page 24) is reported to have seen marble boulders on the surfaces of the adjacent drift hills.

Taking up again the known members of the upper division, we find at the several falls and rapids of the lower Pine, between the Great Bend and the mouth of the Poplar, numerous exposures of its beds, the lithological character of which has somewhat changed. The rocks here contain more quartz and more iron ore, the character of which last will be discussed hereafter. The great gabbro has disappeared and its place is occupied by various schists. The conglomerate-quartzite bed, XIV., forming the key-rock of the Pine river district, here makes its appearance.

The series were not traced to any considerable distance west of the north-and-south reach of the Pine, in T. 39 N., R. 17 E., but a species of hornblende schist procured by Mr. Halsey from the west line of Sec. 7 of this town, indicates that the series continues to follow the general west-northwest direction, probably again crossing the Pine on the line between towns 39 and 40 N., range 16 E.[1]

So far, the superficial distribution and structure of these rocks has been very regular and easily understood, for they have followed a narrow belt one to three miles wide, running with slight variations about N. 70° W., and having a length of over 25 miles. The whole series, like the iron of the lower division, dipping at a high angle to the south, away from the Michigan Laurentian, and apparently underlying the granite and granitic-gneiss observed south of the Quinnesec falls. Crossing now the great Laurentian wedge which, coming from the eastward, divides the Huronian series, to the north wing of the anticlinal, we find in T. 42 N., ranges 28, 29 and 30 W., Mich., numerous outcrops of hornblende and mica schist, with occasional beds of gneiss and veins of granite, just as was observed in the corresponding geological position south of the Quinnesec falls.

Not being in Wisconsin, nor essential to a general comprehension

[1] Since the above was written, Mr. Wright took up this series at the western edge of my especial area, that is, west of the N.-S. center line of range 17, and followed it W. and N., obtaining results fully confirming this view, which are shown in part on the accompanying maps, and fully in his report, part VIII of this volume.

of the subject, no attempt was here made to work out the equivalency of the several members of the upper division of the Huronian, as was done in the south belt. Nor, indeed, has the lower division, embracing the iron and marble, been as fully worked out in the north belt, owing to few outcrops, less magnetite in ore, and the greater prevalence of the capping Potsdam sandstone. For a brief description of this north belt, Sturgeon river district, see my Michigan Geological Report, Vol. I, page 173.

Following the upper division of the Huronian of the North Belt, we find its general bearing (not regarding for the present its numerous great sinuosities), to be south of west, as if to unite with the South Belt, which, it will be remembered, bore north of west.

One striking difference between these north and south wings is obvious, and needs to be referred to here; that is, the far greater breadth, at least three times, of the south as compared with the north. This is probably due in part to a thinning out of the beds in this direction, but I am of the opinion that the major part of the discrepancy is owing to the greater number of folds and undulations (as shown on atlas plates), in the series as developed south of the axis, and that Dr. Credner's[1] estimated thickness of 20,000 feet is much too great, even perhaps with the addition of the younger members, which he did not recognize.

All the numerous exposures of rock, dipping and striking as they do at all angles and at all points of the compass, near the junction of the Brulè, Paint, and Michigamme rivers, and along the Menominee down to and including the Twin Falls, are believed to belong to this upper division of the Huronian, as are also the many exposures of quartzite, clay slate, greenstone and iron ores, east, north, and west of Lake Eliza.

To have followed out the various colored stripes in this crumpled, torn and cut pile would have been impossible with the means at our disposal, had it been exposed to view through the hundreds of miles which the length of its various members aggregate. With many square miles covered from view by drift, and in the absence of magnetite in portions of the area, it is simply impossible to completely solve the structural problem.

The facts collected and the general hypothesis formed are given on the atlas maps in the belief that they will aid the future investigator. No explanation of the map is necessary except to state that considerable uncertainty as to their age has existed with reference to the magnetic actinolite schists, greenstones and plumbaginous clay slates so

[1] See Zeitschrift der Deutschen Geol. Gesellschaft, Band XXI.

extensively developed west of Lake Eliza. They are now believed to be younger than the great quartzite (XIV), which is shown to dip under them.

It will be observed that over a considerable portion of the upper Huronian area, I have not even ventured to draw hypothetical structural lines on the map. In a region where sharp folds with inclined axes, sudden changes in the trend of the beds, overturned dips, and immense erosion is the rule, one is liable to pass from one bed to another in going a very short distance in any direction.

The absence of fossils forces one to depend entirely on the lithological character of the different horizons for their identification; but this character is not at all constant. Different beds are almost exactly identical, so far as can be observed in the field, as, for example, II and XIV, and the same bed changes its character almost entirely in a few miles, as in the case of XIV and XV, described in chapter II.

With these drawbacks the task would be simply one of time and labor, if there were more outcrops; but large areas, as, for example, the valley of the Menominee, north side, and the valley of the Lower Pine, are almost entirely covered with drift, affording no clue to what is beneath. Only magnetic rocks can be followed here unless we resort to the pick and shovel.

When facts are so scarce, one is so rejoiced in finding them, that he almost forgets that he has perhaps waded swamps or clambered through windfalls, at the rate, with intense labor, of not to exceed five miles a day, maybe for one or several days, and found only a single outcrop. He may have passed within a few rods of others and not observed them, because of trees and brush and fallen timber. The same labor and time would have carried him a hundred miles comfortably on horseback in the far west, with a boundless view and uncovered rocks constantly before him, enabling him to select the points to visit, thus utilizing time and labor to the utmost.

4. With regard to the *thickness* of the different beds, and of the total Huronian series of the Menominee region, my results are not very satisfactory, owing largely to the inherent difficulties of the problem. It is true that these rocks generally expose their upturned edges, which makes it often apparently easy to measure the thickness of one or several beds. The difficulty lies in the fact that the number of sharp folds where thick beds double back upon themselves, often renders it doubtful whether what is exposed on the surface represents the true thickness of the bed, or double the thickness when a single axis exists, or three times the thickness where both an anticlinal and

synclinal are present. This is especially true of quartzites, clay-slates and greenstones, whose bedding planes are usually very obscure.[1]

The following table presents all the material which I consider at all reliable, bearing on the subject. It will be observed that the minimum thickness, say 5,000 feet, which was obtained in the northeast portion of the Menominee region, is one-fourth the apparent thickness found in the south and west portions of the region, within a distance of 25 miles. A part, and perhaps the greater part, of this difference is very likely due to a difference in the original thickness of the beds. A part I conceive may have been produced by a lateral pressure, the same perhaps as that which produces cleavage in rocks, which we may suppose to have squeezed the thin series within a space considerably less than its normal thickness. A third cause of discrepancy has already been referred to, *i. e.*, the sharp plications of the beds themselves. From year to year more such folds are being found, and it is quite improbable that all are yet known.[2]

Not including the overlying granite, bed XX, which is very likely eruptive, and which has been but little studied, but is apparently very thick, I think we may, on present information, speak generally of the Huronian series of the Menominee region as from 10,000 to 15,000 feet thick. While this is undoubtedly about double the thickness of the Marquette series, it is quite insignificant when compared with Prof. Irving's estimate of the thickness of the Huronian in Central Wisconsin, supposing the Black river and Baraboo series described by him to be Huronian. (See Geol. of Wis., Vol. II.) Lying geographically between these points of minimum and maximum thickness, the facts seem to point unmistakably to a rapid thickening as we go south from the shore of Lake Superior. To the west, approximately parallel with the border of the lake, a thickness approximating that found in the Marquette series seems to maintain between Lake Gogebic and Montreal river, and which I do not believe is greatly increased in the Penokee series. But as I have only made a reconnaissance of that region, we must look to the results of Messrs. Wright and Irving's detailed surveys for the facts.[3]

Turning eastward, the Canadian geologists (Report of 1863, p. 67) make out a thickness of about 18,000 feet.

[1] So able an observer as Dr. H. Credner in this way counted bed IX three times in his much too great estimate of the thickness of the middle and lower Huronian.

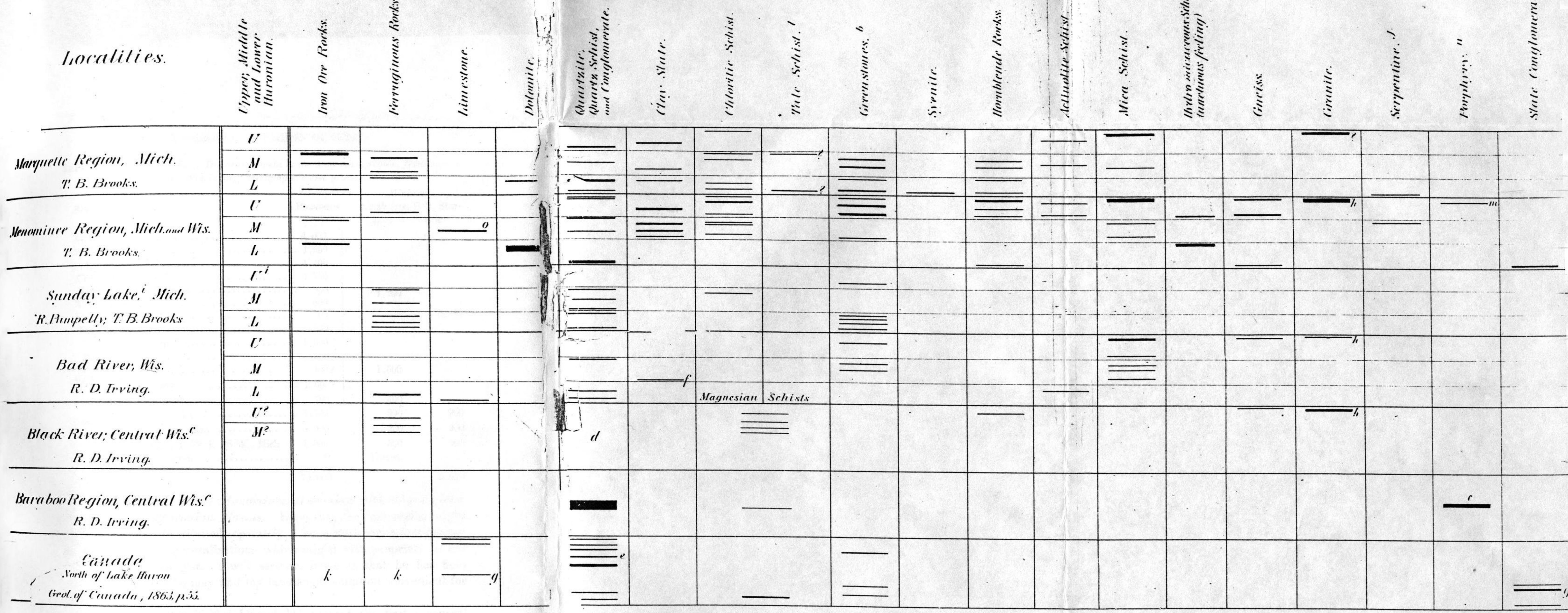
[2] More than one unknown fold has since been developed by recent mining operations.

[3] Prof. Irving, in the Amer. Jour. Sci. May, 1879, has published the thickness of the Penokee series as 12,800 feet. On his forthcoming official map of the Bad river region, I observe that his general sections show no folds. It will be surprising if such do not exist — all of which will undoubtedly be made clear in his text, which I have not seen.

Approximate Stratigraphical Position an[d] Relative Abundance of the Rocks of Huronian Age at Several Points South of Lake Superior.

Note.– The thickness of the horizontal lines representing the rocks is ap[pro]ximately proportional to the thickness of the corresponding beds.

Illustrating T. B. Brooks Report Chapter I



a. Mostly quartzose and amphibolic, may contain merchantable ores.
b. In Michigan, Diabase, Diorite & Gabbro in order of abundance grad... ing through schistose varieties into a Kind of Chloritic Schist.
c. It is not determined which is the older rock of this series, nor posit... whether this and the Baraboo series are Huronian.
d. The absence of pure quartzite here must be considered in con... tion with the presence of ferruginous quartz schists, and extensive covered areas.
e. Red jasper conglomerate, abundant in Canada but not observed ... of Lake Superior.
f. "Feldspathic slate"
g. On page 53, Geol. of Canada, 1863, is described a series of 1200 ft., w... is mostly slate conglomerate, and on page 5? is a second limestone, quartzite, and slate conglomerate series.
h. This granite may always be eruptive and is certainly so in the ... d River Region according to Irving.
i. The upper division of the Huronian in this series is believed to b... ncealed by the non conformably overlying Keweenaw rocks. The Section is incomplete.
j. Seems to be altered Greenstone.
k. Contains Iron ores & ferruginous rocks position unknown.
l. Dr. Wichmann determined only one specimen to be a true talc schist, s... hydromica schists may be included here.
m. Porphyrite rocks (Julien) associated with greenstones believed to be ... per Huronian age.
n. Porphyry probably exists in the Huronian of Minnesota.
o. A small local bed holding tremolite crystals.

APPROXIMATE THICKNESS *of Huronian strata in the Menominee region, from base to (but not including) overlying eruptive granite.*

Bed.		*Maximum.*	*Minimum.* North Iron Belt,	Sturgeon R. District.
XIX	Michigamme R	4,000		
XVIII	Brulé R	1,900		
XVII	Pine R	1,400		
XVI	Sturgeon Falls	1,700		
XV	Sturgeon Falls	900		
XIV	Pine River	800	1,700	
XIII	Four feet Falls	700		3,400
XII	Four feet Falls	200		
XI	Four feet Falls	1,000		
X		300?		
IX		400?	1,500	
VIII, VII	Lake Hanbury	1,000?		
VI	Iron, South Belt	700	400	
V	Marble, South Belt	1,700	900	900
IV, III	Pine Creek, Michigan	1,000?	200	200
II	Secs. 7 and 8, T. 39, R. 28 W., Mich	1,000?	500	500
I	Falls of Sturgeon	300	Absent.	....
		19,000		5,000

5. *Comparison of the Menominee Huronian with other regions. Extent of the Huronian Basins.* Expecting that my report might be published or distributed separately, I have made some few general comparisons and generalizations which might with propriety be left to the Chief Geologist. I will assume, however, that he has field enough, and trust he may find my tabular presentation convenient for reference.

The accompanying Tables II and III present, the first, a general and approximate; the second, in considerable detail, a summary of the kinds, sequence, and relative abundance of the Huronian rocks at the several points south of Lake Superior. The most obvious facts shown by table II are worthy of note.

The richness of the Huronian period in kinds of rock has been already mentioned, and compared with other adjacent terrains of different age. But this great variety is confined to Michigan and adjacent Wisconsin territory, *i. e.*, to the Marquette and Menominee regions, in which are found about eighteen distinct kinds of rock, including probably all found in the Huronian of the Lake Superior basin, except, perhaps, true quartz-porphyries. At 160 miles west of Marquette the Penokee series yields nine kinds of rock. At about the same distance in the opposite direction, we find on the north side of Lake Huron, where the series was first studied, only six kinds mentioned by the Canadian geologists. Nearly the same paucity in kinds seems to prevail on the east and northeast shore of Lake Superior. To the northwest, however, on the Minnesota shore, according to Owen, are quite possibly more kinds, including porphyry. Passing to the southwest in Central Wisconsin, at a distance of about 240 miles from Marquette, Prof. Irving names but seven kinds of rock. The extensive mining operations in the Marquette and Menominee regions have probably already exposed all the rocks that exist, but the same cannot be said of the other regions mentioned, hence the wide difference now apparent may be somewhat diminished by future developments.

Quartzose rocks are found everywhere in the Huronian, and are nearly everywhere the most abundant kind. *Greenstones* are nearly as wide-spread, and are conspicuous, as are *limestones*, by their absence from central Wisconsin. *Magnesian schists* (which may sometimes include hydro-mica schists) mostly, if not wholly, chloritic, are probably as widely distributed as the *greenstones*, to which they are intimately related, through one variety. *Merchantable iron ores*, so far as actually developed, are confined to the Marquette and Menominee regions, but *ferruginous rocks*[1] (quartzose and amphibolic), are far more widely distributed. *Clay-slates* and *mica-schists* (including *hydro-mica* schist) are naturally found together, but do not seem to be as widely distributed as might be expected.[2] The distribution of the *limestone* and *dolomites* is interesting in the small number of different but tolerably thick beds, and their wide distribution. They decrease rapidly to the west, and disappear to the southwest.

Amphibole rocks are almost entirely confined to the Marquette and Menominee regions, where they are abundant, mostly in the form of schists. They seem to follow the rich iron ores, and are themselves, especially actinolite, often ferruginous.

Gneiss and *granite* are most abundant in the Menominee region. The beds are not numerous. These rocks have not been found in the Baraboo series, nor in the Huronian of Canada.

Unless it exists in Minnesota, *quartz-porphyry* is a very rare Huronian rock, our table showing it only in Central Wisconsin, with a related rock, porphyrite, in the Menominee region.

Schistose conglomerates of various kinds, but in small beds, have been observed by me, but I have not included under slate-conglomerate a class of rocks, as has been done in Canada.

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[1] Future explorations may very probably find rich ores among these rocks.

[2] The soft character of certain slates and shales would cause them to weather down and be covered with soil, and thus be concealed from superficial exposure.

The question of over how wide an area of the Huronian sea lie conditions of sedimentation and metamorphism prevailed as indicated by the known lithological character of the resulting rocks, is a subject of great interest. The points of resemblance between the Marquette, Menominee, Sunday Lake, and Penokee series, are so numerous as to point, I think, unmistakably, to their having been formed in one basin and under essentially like conditions.[1]

They may be summarized:

(*a*.) The iron ore rocks which characterize the series, are confined, I believe, entirely to the middle and upper portion of the lower divisions, but are not found in the lowest; while (*b*.) staurolitic mica-schists, gneisses and granites characterize the upper division. (*c*.) Dolomitic marble, graduating into quartzite, is confined, with perhaps one local exception, to the lower beds. Other less general, but nevertheless interesting facts of the same kind are given in the following scheme of equivalency (Table III). By reversing the order of sequence of the Black river series in central Wisconsin,[2] as studied by Prof. Irving, to which he sees no serious objection, and which has been done in the table of equivalency, these rocks would be brought approximately into harmony with those above described, and would immensely increase the geographical area of the supposed Huronian basin. This basin must have had a minimum east and west length of 175 miles, and a breadth to the east of at least 75 miles, or if we embrace central Wisconsin, three times as far north and south. Its possible area may have been at least 20,000 square miles.

I have not been able to find in the literature of the survey of Canada, any evidence that a like sequence prevails in the Huronian series eastward of Lake Superior; hence conclude that region was not embraced in the same basin. This might be expected, however, since the causes which led to the existence of this mighty lake may be supposed to have had their beginning as early as, or before, the Huronian period.

Those who are not disposed to admit that lithology affords much assistance in identifying rock beds over even small areas, should have in mind that the lower Silurian sandstone can now be seen quite uniform in character over a much greater area in the same region. Almost the same remark may be made of the underlying Keweenawan rocks. Cannot, approximately, as favorable conditions have existed for the formation of a particular kind of rock over a smaller

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[1] I pointed this out in Am. Jour. Sci., March, 1875. See, also, in same, Irving, May, 1879.

[2] Vol. II, p. 493.

area at the earlier period. Prof. Irving has well remarked that it is a waste of time to attempt to establish stratigraphical equivalency, bed for bed, in non-fossiliferous rocks of the same age formed in different basins.

How far this idea is applicable to those rocks formed by the ordinary processes of sedimentation in widely separated portions of the same continental basin, is an important question which Dr. Hunt, who has given the subject much attention, has briefly discussed in Appendix A. Certainly the more widely separated the areas of deposition, the less probable that any given bed should maintain a constant lithological character.

TABLE III.

Sequence of the Huronian Strata at several points south of Lake Superior, with Hypotheses of Equivalency.

NORTH OF LAKE HURON, CANADA.

GEOLOGY OF CANADA, 1863.

1. White quartzite.

2. Yellowish chert and limestone.

White quartzite.

Yellowish chert and limestone.

White quartzite, with intercalated beds of greenstone.

Red jasper conglomerate.

Red quartzite interstratified with masses of greenstone.

Slate conglomerate, with beds of greenstone.

Limestone, some beds dolomitic and ribbed.

Slate-conglomerate, with heavy interstratified beds of greenstone.

White quartzite, sometimes conglomeritic, with considerable greenstone.

Chloritic and epidotic slates.

Quartzite, strong and solid and resisting well the influence of the weather.

Slate conglomerate.

LAURENTIAN.

MARQUETTE IRON REGION, MICHIGAN.

T. B. BROOKS.

LOWER SILURIAN.

KEWEENAWAN SERIES wanting, permitting the horizontal St. Mary's sandstone to rest directly on the upturned edges of the Huronian.

XX. The "granites" S. W. of Lake Michigamme probably belong to this horizon.

XIX. Grayish-black *mica schist*, often staurolitic and holding andalusite and garnets; rarely *chloritic schist*. Quartz in bunches and veins, and hornblende seams, rare. No. (61.)

Covered.

XVII. *Actinolitic (anthophyllitic?) schist*, usually magnetic and containing manganese. Gray and black, banded, abundant on north shore of Lake Michigamme. (58, 69.)

Banded ochrey porous *quartzose schist*. (57). Decomposed *limonitic schists*.

XV. Blackish *argillaceous slate*, with imperfect cleavage, rarely micaceous, and sometimes holding garnets. (56.)

(Note. The beds above XIV have only been observed in the Michigamme District.)

XIV. Gray arenaceous *quartzite*, often semi-schistose, and sometimes micaceous and ferruginous; *quartz conglomerate*. (50), (51), (145).

XIII. Pure specular *hematite* and *magnetite* ores; ferruginous banded *jaspery schist*, with interstratified beds of chloritic and hydromicaceous schists. "*Trap dykes*" at Washington mine. (36) to (49), (52) to (55), (79), (89), (94).

XII. Red arenaceous *quartz-schist* banded with micaceous iron; quartzose *limonitic ores*. (32), (33), (34), (35).

XI. *Diorite, hornblende schist, chloritic schist*, chloritic-looking *mica-schist;* rarely *hornblende gneiss*. (118), (29), (30), (107).

X. Siliceous *hematitic* (west) and *limonitic* schistose ores, often manganiferous (east); siliceous schists; garnetiferous actinolitic (eklogite) schists; obscure compact chloritic (?) magnetic schist, with conchoidal fracture (Lake Fairbanks). (23) to (28), (131).

IX. *Hornblende rock* and related *diorite* and *diabase*, often micaceous. (22), (88), (31).

VIII. *Clay-slate* with oblique cleavage and associated arenaceous *quartz rock*. *Ferruginous* and *chloritic schists* (20, 21), near Negaunee. *Magnetic quartz schist* (19), Republic mine.

VII. *Hornblendic rocks* with related *greenstones*. (18).

VI. *Ferruginous quartzose schist; clay* and *chloritic slates*. (15), (16), (17).

V. Gray *quartzite*, massive to schistose, graduating westward into *protogine* (*sericite?*). Near Lake Superior *dolomitic marble* and *clay-slate* with oblique cleavage (*novaculite*) occurs in the upper portions of and overlying the quartzite; rarely micaceous and chloritic varieties. (8, 9, 10, 11, 12, 13.)

I did not attempt to subdivide the lowest Huronian rocks. About Marquette are quartzless *syenites, diorites, diabases, hornblende schists*, and obscure *chloritic slates*. Also typical unctuous-feeling, soft (talc?) schist. (74.)

The Cascade iron series, consisting of quartzose *hematite schist* ("flag-ore"), conglomeritic *quartzites*, and soft slates (see Mich. Geol. Rep. 1873, Vol. 1, p. 147), although entirely unlike the above, seem to occupy nearly the same stratigraphical position. Dr. Rominger has recently thoroughly examined them.

Non-conformable with

LAURENTIAN.

MENOMINEE IRON REGION — MICHIGAN AND WISCONSIN.

T. B. BROOKS.

Divisions: MICHIGAMME AND PINE RIVERS. (WEST.) | QUINNESEC. | STURGEON RIVER. (EAST.)

THE LOWER SILURIAN (St. Mary's) SANDSTONE horizontally caps the highest hills, resting non-conformably on the Huronian and Laurentian.

THE KEWEENAWAN (COPPER) SERIES have not been observed in this region.

MICHIGAMME AND PINE RIVERS. (WEST.)

XX. Granite (101) [2463, 3340], gneiss and porphyrite [3359].

This granite mass (possibly eruptive), is in places gneissic, and overlies the youngest Huronian rock yet observed; apparently conformable. Peculiar amphibole [tremolite?] schists in the S. one-half of T. 42 N., R. 31 W., Mich., belong in or near this bed [2385, 2462]. The same may be said of the Peminee Falls series, including porphyrite [3200 to 3206].

XIX.

Near Michigamme River. Brownish (biotite) *mica-schist*, sometimes staurolitic, often corrugated. *Micaceous quartz schist* [2162, 2163] (90). *Gneiss* [2454, 2381].

Near Pine River. *Hornblende schist* and *gneiss*, rarely *chloritic schist* (128, 134, 117, 108). *Mica schist* [3359].

Actinolite-schist, sometimes altered to chloritic schist, forms a heavy bed [2676 to 2712], often ferruginous (magnetitic, hematitic, and ochrey), in places banded with saccharoidal quartz laminæ, which are highly contorted and broken [2702 to 2705]; chloritic and micaceous quartz schists [2158, 2222]; chloritic schist [2094].

Black *carbonaceous* slate and schist, sometimes porous and holding quartz veins [2662 to 2664]. Associated are *clay-slate* and *chloritic schists* [2656 to 2658, 2665, 2190].—(L. Eliza.)

XVII. Typical gray *gneiss*, with small crystals of triclinic feldspar, and large rare ones of orthoclase [2875 to 2880, 2908 to 2914]. A variety contains mica in lenticular, parallel seams (146), and is associated with gray *hornblende schist*. "*Augen*" *gneiss* (157). Interstratified are beds of *chloritic schist*. *Micaceous quartz schist*.

Very tough, fine-grained, green *diabase* (127).—Brule.

Light to dark-green, almost black, highly crystalline, massive to schistose, fine to coarse-grained *greenstone* [2608 to 2631, 2638 to 2646], and *hornblendic mica schist* (106).

Coarse gray *clay slate*, with oblique cleavage [2564 to 2579], graduating into obscure and rare, hard, schistose varieties, bordering on fine-grained greenstone-schists [2585 to 2587]. Associated are ferruginous *actinolite schists* [2560 to 2563, 2595 to 2602], the iron probably pseudomorphic after actinolite. Minor beds of greenstone are associated [2550 to 2553].

Light olive-green, very coarse-grained *actinolite schist* (129).

The Commonwealth iron horizon. Prevailing rock, *clay-slate*, several varieties, usually without oblique cleavage, graduating into soft carbonaceous and graphitic varieties [2153, 3410] on one hand, and into chloritic schists on the other [2183, 2185]. Unctuous feeling, gray schists (hydromicaceous) occur perhaps in large quantities [2404, 3452, 3453, and 2731 to 2733?]. Interlaminated are seams of gray and ochrey saccharoidal quartz. Workable masses of earthy to semi-specular red *iron-ore*, sometimes more or less hydrated (135). Associated are harder quartzose ferruginous schists ("flag-ore") [2411]. Massive, rich, specular ore (martite) (154).

XIV. Light-gray, specular, conglomeritic, *quartz schist*, containing mica and magnetite [2224]. The quartz is often saccharoidal.

In the vicinity of Lake Eliza is a semi-schistose gray *quartzite*, often "aventurine" [2213], and sometimes conglomeritic [2187].

On the S. E. ¼ of Sec. 13, T. 39 N., R. 17 E., Wis., the following rocks in thin beds lie north of (under?) the quartzite.

Magnetic quartzose *conglomerate schist* [2820]; *eklogite* [2819], *siliceous schist* with hornblende [2818], *hornblende schist* [2817], pyritiferous *magnetitic slate*, containing biotite [2816], black *hornblende schist* [2814].

GENERAL REMARK. The middle and lower Huronian rocks, as made out to the eastward in Michigan, have not been identified in Wisconsin, being either concealed under extensive drift areas (true undoubtedly of a part at least of the middle Huronian), or covered by younger members of the series, as must be the case of the lower Huronian, including the lower quartzite, great dolomite (marble) formation, and the overlying Breen-Quinnesec iron series. The latter economically important bed has been traced by magnetic attraction (see atlas map) to the Menominee river. It must cross it, and become the surface rock for a small area at least on the Wisconsin side, but is concealed by the deep drift of the river valley. For general distribution and folds of the various Huronian rocks, see Plate XXIX.

Non-conformable with

LAURENTIAN.

QUINNESEC.

XX. Reddish granite, rarely gneissic [2129].

XIX. Grayish-green, fine-grained, crystalline *hornblende schist*, with dykes of granite (125), [2120].

Covered.

Massive gabbro-like *greenstone*, from fine to very coarse-grained, with whitish feldspar [2350, 2933 to 2937]. Like XVI. Has the appearance of being eruptive, and surrounds an irregular mass of red micaceous feldspathic rock [2349] related to the gneiss XVII.

XVI. At the Big Quinnesec falls forming the barrier rock, is a heavy bed of more or less schistose *greenstone*, with numerous *micaceous, chloritic* and *quartzose* varieties [2070, 2850 to 2855, 2863 to 2872]. At the foot of the fall is a massive *gabbro-like greenstone* [2070] like that described above.

This rock is extensively developed on the north side of the river, below the Little Quinnesec Falls.

Light gray *sericite-schist*, holding grains of quartz, and partly decomposed feldspar [2071].

Chloritic and *greenstone schists*.

Covered about 1½ miles by the sand terraces of the Menominee Valley.

STURGEON RIVER. (EAST.)

XX. Granite.

XIX. *Hornblende schist*, dark-green, fine-grained, massive (resembling greenstone), [2261]. Greenstone [2484]. Tremolite (?) schist [2480].

Covered ¾ mile.

Light grayish-green, highly jointed, massive *diabase* [2262].

Sericite gneiss (147).

XVI. Massive, medium to coarse-grained, greenish-gray *diorite* (*gabbro?*) [2098, 2268]. A similar associated rock has been called *diabase* [2266]. *Magnesian schist.*

Magnesian schist, with *greenstone schist* and *serpentine* [2263].

In the north iron belt of the Sturgeon river district, Mich., a bed of marble, containing large crystals of tremolite occupies the place of bed X (?).

Covered about one mile by sand and alluvial land at the mouth of the Sturgeon river.

Banded, somewhat fissile, *clay-slate*, in places chloritic.

Grayish-green, medium-grained *greenstone*, with veins of quartz.

Fissile, *clay slate*.

Bluish-gray, obliquely-cleavable *clay slate*. [2253].

Dark-gray, arenaceous, deep-weathering *quartzite*, [2257, 2258, 2259] (139), and chloritic-looking *mica-schist*.

Gray-green, fine-grained, massive, jointed, highly-crystalline *greenstone* (?).

QUINNESEC AND STURGEON RIVER.

VII. Gray and red, soft, unctuous, *hydromicaceous schist* [2942 to 2945], graduating into *clay slate*.

VI. IRON ORE. VI. IRON ORE.

A banded quartzose ferruginous schist ("flag-ore") prevails [2066, 2946 to 2950]. Altered portions produce a rich, soft, purplish, specular hematite schist (67, 68, 136), and limonite. Beds of argillaceous and arenaceous schists and slates are interlaminated [2065, 2067]. The Breen-Quinnesec range of mines have been opened on this bed.

V. DOLOMITE MARBLE. V. DOLOMITE MARBLE.

Grayish to white, crystalline, with quartz or cherty laminæ, presenting often a ribbed surface; with rare beds of gray quartzite and hydrous magnesian schist (66) (143).

Strong magnetic attractions, and boulders of very siliceous ore.

Covered (Pine Creek Valley, Mich.).

II. QUARTZITE. II. QUARTZITE.

White to gray, compact, massive to semi-schistose, arenaceous, in places micaceous and actinolitic, holding occasionally specular ore, and is sometimes banded and weathered (137), [1629]. The Felch Iron Mt. is believed to be a highly ferruginous portion of this bed.

I. *Chloritic* (protogine) *gneiss; hydrous magnesian schist; slate-conglomerate; quartzite*, and perhaps *diorite* (65), (102), [1636, 1656]. (May possibly belong to the Laurentian.)

Non-conformable with

LAURENTIAN.

SUNDAY LAKE SERIES.

Between Lake Gogebic and Montreal river, Michigan.

PUMPELLY AND BROOKS.

LOWER SILURIAN.

Non-conformable with the

KEWEENAWAN SERIES.

The Upper Huronian is here believed to be non-conformably overlaid and concealed by the Keweenawan.

Compact *greenstone* with green cherty (?) layers. Bright-red specks of jasper and crystals of pyrite.

Greenstone; holds grains of glassy quartz and appears chloritic.

Hematitic and *magnetic quartzose flags*. (Like Marquette flag ores.)

Gray, green, and brown, banded, ferruginous *siliceous slate*, strong rhombohedral cleavage.

Grayish and greenish banded schist, weathering brown, apparently *chloritic* with *jaspery layers*. Contains pyrites. In places apparently felsitic and again aphanitic.

Covered.

Ferruginous banded (purple and green) *cherty schist* (magnetic).

Banded ferruginous *jasper schist*.

Ferruginous *siliceous flags* (not magnetic.)

Arenaceous *quartzose schist*.

Reddish *quartzite*.

Hydrous magnesian or *argillaceous schist*.

Greenstone.

Banded *cherty schist* and schistose *cherty breccia*, more or less ferruginous. (84, 85).

Compact hard *greenstone*.

Very soft, apparently chloritic *greenstone*.

Gray banded slaty schist.

Covered 100 steps.

Greenstone.

Banded, *ferruginous, siliceous schist*, strongly magnetic.

Greenstone.

Banded, *ferruginous slate*.

Massive *greenstone*, apparently chloritic.

Banded ferruginous *jasper schist*.

Non-conformable with

LAURENTIAN.

BAD RIVER AND PENOKEE GAP, WISCONSIN.

R. D. IRVING.

(See Amer. Jour. Sci., 1879, p. 393.)

LOWER SILURIAN.

KEWEENAWAN SERIES.

Certain uralitic diabases and gabbros are observed here, but their age is not fully determined.

XXII. Mostly blank, but showing at several points *mica schist*, like the coarser kinds of XXI, including also many red granite veins and masses like XXI. In the uppermost part, like the quartzose layers of the uppermost part of XXI. Containing possibly some greenstone layers, but probably largely taken up with mica schist.

XXI. *Mica schist;* from dark-gray, aphanitic and slaty, to brownish or blackish, medium grained, and highly micaceous. Near the summit it is light-gray, fine granular, highly quartzose, like a fine-grained gneiss. The uppermost portions include veins and masses of very coarse red and pink orthoclase *granite*.

XX. Blank.

XIX. *Greenstone-schist;* very close grained, heavy, imperfectly schistose, chloritic. It forms a rock bluff, 170 feet high.

XVIII. Blank. *Slate* like XIV a.?

XVII. *Quartzite* like XV.

XVI. *Mica-slate* like XIV a.

XV. Dark-gray *quartzite*.

XIV. a. Dark-gray and black *mica-slate*, like X, but some layers are filled with long slender crystals of chiastolite. The black portions are close to XII, which they almost exactly resemble in general appearance.

b. Blank.

c. Black magnetic *mica-slate* like XII.

XIII. *Diorite-schist*, fine-grained, chloritic,—not well exposed.

XII. Black aphanitic magnetitic *mica-slate;* appears like VII, but not so regularly slaty; at times chiastolitic.

XI. Blank (supposed to cover rocks like X and XII).

X. Black, aphanitic *mica slate*, like VII.

IX. Chloritic pyritiferous *diorite*, tough, highly crystalline; forms falls in Bad river.

VIII. Blank.

VII. Dark-gray to nearly black aphanitic *mica-slate*, having a wholly crystalline base of quartz and orthoclase, with disseminated biotite scales.

VI. Blank.

V. Black *feldspathic slate;* forms layers down to one-sixteenth inch in thickness; comes out in large, smooth slabs, nearly aphanitic; consisting of orthoclase grains imbedded in a paste of biotite, pyrite, limonite and carbon.

IV. *Magnetic belt;* including (a) banded magnetic quartzite, banded with seams of pure black, granular magnetite; (b) magnetic quartzite, the magnetite in varying proportions, pretty well scattered throughout; (c) magnetitic quartz slate; (d) slate like (c) but largely charged with tremolite or actinolite; (e) arenaceous to compact and flaky quartzite, free or nearly so from iron oxides; (f) thin, laminated, soft, black magnetitic slate; (g) hematitic quartzite; (h) garnetiferous actinolitic schist, or eklogite; (i) diorite. These varieties have no persistent stratigraphical arrangement, and are named here in order of relative abundance.

III. *Siliceous schist;* straw colored to green (chloritic), slaty.

II. a. Magnetic *quartzite*.

b. White granular (arenaceous) *quartzite*, with vitreous coating on surface.

I. Tremolitic crystalline *limestone;* white to straw-colored, siliceous.

Non-conformable with

LAURENTIAN.

The Roman numerals in this column are Irving's.

CENTRAL WISCONSIN.

R. D. IRVING.

LOWER SILURIAN.

Covers nearly the whole region.

KEWEENAWAN SERIES have not been observed here.

BLACK RIVER VALLEY, JACKSON COUNTY. (Geol. of Wis., Vol. II, p. 493.)

I. *Gneiss*, rather fine-grained, plainly laminated, pink and gray banded.

I *a*. *Granite*, medium-grained, pinkish, with but little gneissoid structure, and apparently conformable with rocks below.

II. *Hornblende rock;* fine-grained, crystalline texture, dark-colored to black, breaking with conchoidal fracture.

III. *Magnesian slate;* pale-gray, light greenish gray, dark-green, occasionally pink or even bright brick-red; sometimes quite soft, at others hard and gritty, from the presence of quartz, which appears never to be entirely absent. The magnesian mineral appears to be talc and chlorite, the former predominating.

IV. Covered.

V. *Ferruginous quartz-schist*, finely laminated, varying from a light-gray, somewhat ferruginous, quartz-schist to a dark colored highly magnetic rock.

VI. *Magnesian schist*, similar to III.

VII. Covered.

VIII. *Magnesian schist*, light-colored, siliceous, similar to VI.

IX. *Ferruginous quartz-schist*, fine-grained, dark-gray, very quartzose, non-magnetic.

X. *Magnesian schist;* In the upper or most southern portions, quite soft, light greenish-gray, and without indication of any quartzose ingredient; towards the lower part becoming more quartzose, losing its softness and greenish tinge.

XI. Covered.

XII. *Magnesian schist*, greenish-gray.

XIII. *Ferruginous quartz-schist*, very much weathered.

XIV. *Magnesian schist.*

Covered, 3,500 feet, after which follow ferruginous quartz-schists and covered spaces. The whole series below the magnesian slate are closely related to the middle Huronian of Michigan, hence are placed as the equivalents here. The series are the reverse here of the order given by Mr. Irving, to which he sees no objection.

SAUK, COLUMBIA, MARQUETTE AND WAUSHARA COUNTIES.

Prof. IRVING finds in Sauk, Columbia, Marquette and Waushara counties, Central Wisconsin (See Geol. of Wis. Vol. II), the following described rocks, which he regards as of Huronian age, but has not made out their position in the series: *Quartz-porphyry* and *granite*, many thousand feet thick [illegible] See Vol. II, p. 515. Gray to red quartzite with some aluminous schists and specular iron in seams and nests, 20,000 feet thick. (NOTE.— In the U. P. of Mich., the quartzites are far more abundant in the lower and middle divisions, but true porphyries are absent from the Michigan Huronian, so far as my observations extend. I have an impression that these rocks will be found to belong to the lower half of the series.—T. B. B.)

CHAPTER II.

LOCAL DETAILS.

This chapter comprises descriptions of the rocks at localities where the outcrops are sufficiently numerous to afford a tolerably complete sequence.

The Roman numerals, indicating the supposed sequence of the beds from oldest to youngest, are here freely, perhaps too freely, used. It is very probable that future investigations may develop folds and faults unknown to me, whereby these numerical designations of beds will be modified. I find it, however, a convenient way of expressing the hypothesis of structure and sequence, towards which my facts point. The following descriptions were originally prepared in tabular form, giving the approximate width of the outcrops and breadth of the intervening covered spaces, the latter amounting on the average to say 9-10 of the length of the sections described. Since the natural exposures usually display only a part and sometimes a very small part of the stratum, and concealed and sometimes unsuspected folds are passed over, this plan has been abandoned except where the exposures were approximately continuous. A glance at the plans and accompanying sections will give the reader the best idea of the nature of the data on which the approximate magnitude of the beds given in the preceding chapter was based.

The collection numbers enclosed in angular brackets [] are employed in referring to specimens, except in the case of the 162 numbers constituting the typical suite of Huronian rocks, which are enclosed in curved brackets ( ).

All the collection numbers occurring in this work are arranged in order at the end, with descriptive names and page where the rock is described.

The specimens are all deposited in the American Museum of Natural History, New York, and duplicates of Nos. 2051 to 2284, collected in 1874, in the state survey collection at Madison, Wis.

1. Sturgeon River Section, *crossing the Breen-Vulcan Iron Range.* See Plate I, T. 38 N., R. 21 E., Wis., and T. 39 N., R. 28 and 29 W., Mich.

Beginning at the S. W. end, in the S. W. part of Sec. 32, T. 38, R. 21 E., Wis., with the uppermost Huronian granite and gneiss, the series will be followed N. W. from youngest to oldest. Along this broken section and in its vicinity, the entire Iron-bearing series are more completely developed than on either of the following sections.

In order to bring together in one place the complete series, occasional notes will be interpolated along this section, supplying its deficiencies and blanks, thus anticipating facts elsewhere recorded.

The following may, therefore, be regarded as the most complete stratigraphical enumeration of the Menominee rocks, and may be conveniently examined in connection with the general sections on the Atlas Map XXVIII, or with the Table of Sequence and Equivalency, in chapter I.

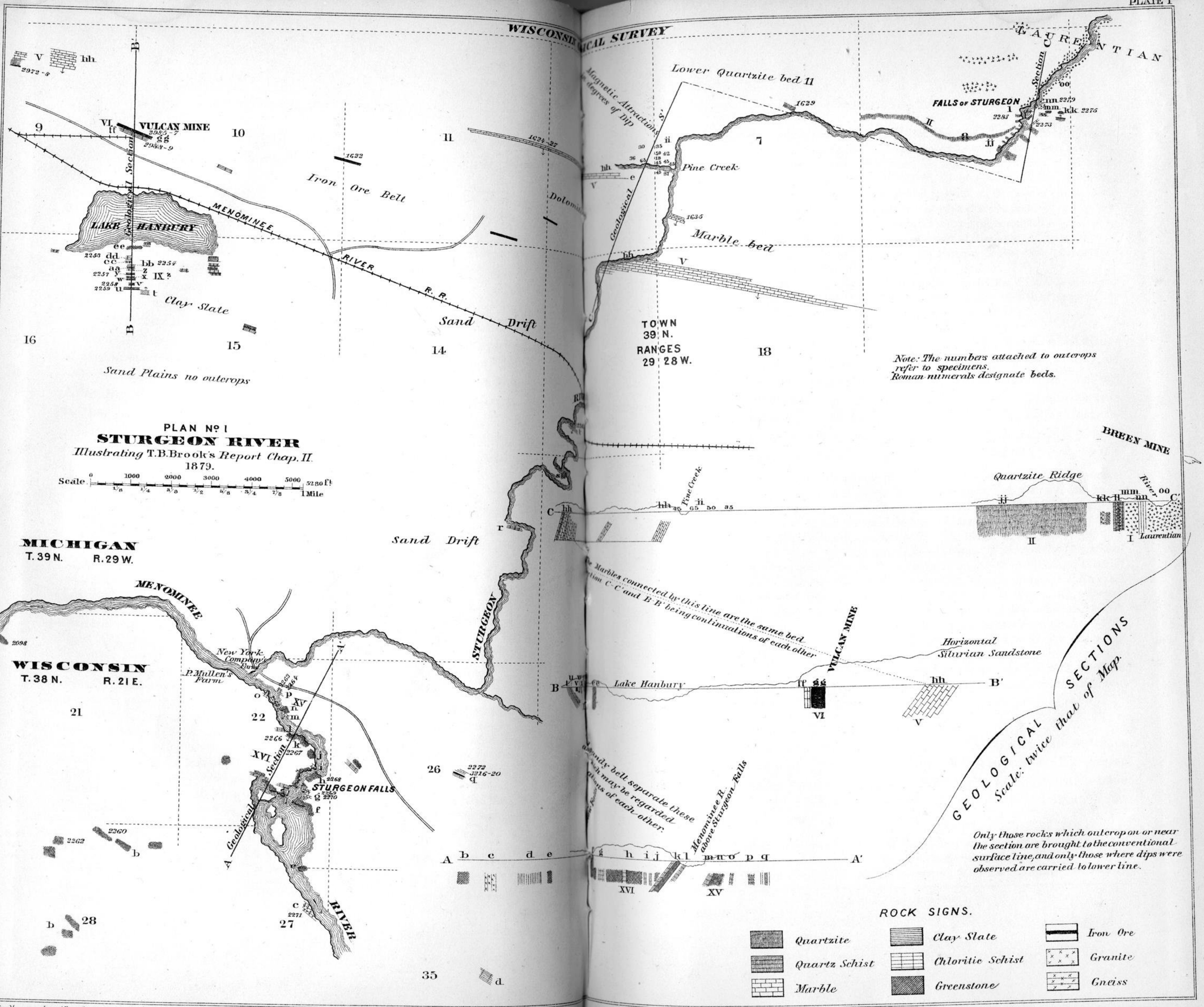
The following description of the granite applies more particularly to the rock south of Big Quinnesec, where it was more closely studied.

Bed XX. *Granite,* medium to coarse-grained, with large crystals of feldspar, often showing rectangular facets. Mica occurs in small, black scales, and is not abundant. Quartz is "veiny," or like a paste in which the other minerals are bedded.

Distribution and general character of this bed. In my Mich. Geol. Rep., 1873, Vol. I, p. 161, there is mentioned as extending east and west through the center of T. 42 N., R. 28 to 30 W., a belt of outcrops of hornblende and mica schists and gneiss, traversed in places by dykes and perhaps by beds of granite. On p. 175, attention is called to the lithological resemblance of these to certain Laurentian rocks, as well as to the fact that gneiss and granite had not at that time been observed in the Marquette Huronian. This belt has since been traced westerly across the Michigamme river, where there are large exposures of granite near the center of T. 42, R. 32. On the Michigamme it is well exposed between Norway and Long Portages. South of the Menominee river, on the opposite side of the great anticlinal, is the undoubted equivalent of this series, differing, however, in containing a large proportion of granite, especially toward the east, and scarcely any typical mica schist. The granite area lying S. W. of that portion of the Menominee, embraced between the mouth of the Sturgeon and the mouth of the Pine, apparently conforms with the underlying hornblende schist, into which it gives off dykes.[1] At the few points where gneissic structure can be made out, it conforms with the schist. To this rock and its granite and gneissic equivalents in the north belt, where the structure is, however, more complicated, we have provisionally assigned the number XX, and regarded it, whatever its origin, as the youngest Huronian rock in the region.

In the Amer. Jour. Sci., Mar., 1875, I conjectured that a belt of granite, syenite, and hornblende rocks, mapped by Col. Whittlesey, and dividing the iron from the copper-

[1] Granite dykes are rare in the Menominee Huronian, and have never been observed in the Marquette series.


WISCONSIN GEOLOGICAL SURVEY
PLAN No. 1
STURGEON RIVER
Illustrating T. B. Brook's Report Chap. II.
1879.
Scale 0 1000 2000 3000 4000 5000 5280 ft.
1/8 1/4 3/8 1/2 5/8 3/4 7/8 1 Mile
MICHIGAN
T. 39 N. R. 29 W.
WISCONSIN
T. 38 N. R. 21 E.
TOWN 39 N.
RANGES 29 28 W.
VULCAN MINE
LAKE HANBURY
Geological Section
MENOMINEE RIVER R. R.
Iron Ore Belt
Clay Slate
Sand Drift
Sand Plains no outcrops
Dolomite
Magnetic Attractions in degrees of Dip
Lower Quartzite bed II
Pine Creek
Marble bed
LAURENTIAN
FALLS OF STURGEON
Note: The numbers attached to outcrops refer to specimens.
Roman numerals designate beds.
BREEN MINE
Quartzite Ridge
Laurentian
The Marbles connected by this line are the same bed
Section C-C' and B-B' being continuations of each other
Horizontal Silurian Sandstone
Lake Hanbury
MENOMINEE
New York Company's Farm
P. Mullen's Farm
STURGEON
STURGEON FALLS
RIVER
Menominee R. above Sturgeon Falls
GEOLOGICAL SECTIONS
Scale: twice that of Map.
Only those rocks which outcrop on or near the section are brought to the conventional surface line, and only those where dips were observed are carried to lower line.
ROCK SIGNS.
Quartzite
Quartz Schist
Marble
Clay Slate
Chloritic Schist
Greenstone
Iron Ore
Granite
Gneiss

bearing series of the Penokee range, was probably the equivalent of these youngest Menominee rocks. Mr. Irving claims to have proven that the granites are eruptive, and the rocks in part belong to the Copper series. It is possible that some of our rocks embraced in Bed XX, e. g., those in Secs. 21, 22, 28, 29, of T. 42 N., R. 31 W., Mich., may also be Keweenawan, but I see no good reason to think so. It is quite possible that the granite may be eruptive, and the conformability above noted the result of an overflow and local, which possibility should prevent us from attaching too much importance to the presence of the granite in determining the sequence of the series. The porphyrite mentioned in Chap. III as having been found at Peminee Falls, may probably be embraced in this bed.

No younger Huronian rock than the staurolitic mica schist (Bed XIX) was made out in the Huronian of the Marquette region, but it is very probable that the "granite" S. W. of Michigamme lake may be equivalent to our Menominee Bed XX.

a. **Bed XIX.** In Sec. 32, T. 38, R. 21 E., two miles S. W. of Sturgeon Falls, there are numerous outcrops, not shown on Plate I, of dark-green, fine to coarse-grained, massive *hornblendic schist*, having in places the character of a greenstone [2261]. About two miles farther S. W., on Secs. 1 and 12, T. 37, R. 21 E., Wis., are related obscure hornblendic rocks, apparently greenstones [2475 to 2478]. One variety was designated by Mr. Julien a *tremolite schist* [2480].

Distribution and general character of this bed. The youngest bed clearly made out in the Marquette region[1] is a mica schist (61), often containing staurolite and andalusite, and occasionally garnets, which we numbered XIX. Finding an identical rock at one intermediate locality, and on the Lower Michigamme and Paint (that is to say, in the north part of the Menominee region), occupying about the same stratigraphical position, I have given it the same numerical designation. Where this bed is exposed at Long and Cedar Portages, on the Michigamme and on the Lower Paint, it is decidedly more gneissic in character than its equivalent in the Marquette region. No exact lithological equivalent of this rock has been found south of the Menominee, either on the Sturgeon or Quinnesec sections, but in its place, it is believed, is a hornblende schist, which becomes more micaceous and gneissic as it is followed west-northwest. To the eastward, near the section we are describing, it partakes more of the nature of a greenstone. An almost exact equivalent of this southern hornblende-schist range is, however, found in a broad east and west belt through the southern portion of T. 42 N., R. 28 and 29 W., Mich., where it contains beds of gneiss and dykes of granite which usually characterize it.

Covered, so far as known, about 4,000 feet.

b. In center and north half of Sec. 28, T. 38, R. 21 E., are outcrops of a rock having the physical character of obscure aphanitic *greenstone.* The specimens have most resemblance to those which have been classified as chlorite and hornblende schists and diabase [2260, 2262].

Along the Menominee river between the Badwater Indian village and the mouth of the Michigamme, is a chloritic quartzose schist, perhaps in places micaceous, varying from a soft, dull-green schist to a massive quartzite. The observed facts as to strike,

[1] Mich. Geol. Rep., 1873, Vol. I.

dip and lithological character of this work, suggest the hypothesis of folding, shown on the atlas map of the Menominee region. An unctuous-feeling quartz schist was found on the opposite side of the great anticlinal along the Pine river.

This bed is designated No. XVIII, but no equivalent for it has been made out on the Sturgeon river section. At the head of the Big Quinnesec Falls, a mass of gabbro, perhaps eruptive, is in or near this horizon.

Covered about 500 feet.

c. **Bed XVII?.** In the right bank of the Menominee river, below the Sturgeon Falls basin, is an outcrop of a peculiar, unctuous-feeling feldspathic, schistose rock, provisionally called red gneissic *protogine*, but which Dr. Wichmann determined to be *sericite gneiss* (147).

A related rock occurs at the falls of Sturgeon river (102), in bed I. A similar rock is associated with granite in Sec. 13, T. 42, R. 30 W., Mich. [1748 to 1751]. Pumpelly and Credner saw the same rock in the N. part of T. 42, R. 28 and 29 W., Mich., and the latter regarded it as of Laurentian age, to which system its lithological character inclines. I consider it, however, on structural grounds, to be of Huronian age in all these localities, as it certainly is on this section.

A somewhat similar rock occurs in the Laurentian (?) of the Marquette region, Sec. 16, T. 49 N., R. 33 W., described by Mr. Julien, pp. 153, 154, Vol. II, Mich. Geol. Rep. [1398, 1400, 1402, 1456].

Along the north side of the upper portion of the Big Quinnesec rapids, and in a broad east and west belt through Sec. 24, T. 39 N., R. 17 E., Wis., are conspicuous outcrops of a well characterized gray gneiss, which undoubtedly belongs to the same horizon, numbered XVII. Whether outcrop *(c)* of this section, which differs considerably in lithological character, is precisely the same age, is not asserted; but it is near it.

Along the upper Menominee, neither variety has been seen in corresponding stratigraphical position; but apparently occupying the same place are important beds of greenstone.

d. Dr. Credner describes the rock exposed on the E. half of Sec. 35, T. 39, R. 29 W., Michigan, as a series of grayish-green, quartzitic, *talcose slates*, extending to a width of quarter of a mile. Segregations and flat lenticular masses of white quartz, red laumonite, light-red and white orthoclase, with cubes of iron pyrites, are frequently intercalated between the slates. He regarded it as a variety of the gneissic protogine *c*.

e. **Bed XVI.** Light-gray, medium grained, massive *greenstone*. Nearly in the strike of *d* but more like *f* in character.

Covered about 1,200 feet.

f. A massive, coarse-grained, light greenish-gray *diorite*, similar to *h* [2268], forms the foot of the rapids, bounding the Sturgeon Falls basin on the up-stream side. A schistose layer was observed in this bed on the west side of the river. From this point the rocks are continuous to the head of the fall.

g. Light greenish-gray *chloritic schist*, having somewhat of a talcy character, and splitting into quite regular rhombohedral prisms, the planes of which bear N. 60° W. (general direction of bedding planes) and E.-W. The axes of these prisms dip south about 45°, which is the probable dip of the bedding planes. In one place the structure was almost slaty. A less schistose variety, containing what seems to be reddish decomposed feldspar, has somewhat the character of a gneiss. The soft character of this schist has permitted the widening of the river at this point, which is, however, abruptly narrowed above and below by the more resisting greenstones. Specimens [2269, 2270] of this rock have been named, "talcose schist," "clay slate," "phyllite," "chloro-quartzose schist," and "decomposed gneiss."

h. The barrier rock at Sturgeon Falls is a rare variety of *greenstone*, being light greenish-gray in color, medium to coarse-grained, massive and jointed, and made up essentially of a green amphibole mineral and a whitish compact feldspar, giving the fresh fracture a porphyritic or mottled appearance [2268]. Mr. Rutley determined another specimen from the same locality to be, probably, gabbro (69), and Herr Wapler pronounced still another to closely resemble the typical German gabbros in physical characters.

Near the N. W. corner of Sec. 21, T. 38, R. 21, the same rock appears in the south shore of the river [2098]. On the west side of the river, and near the middle of this bed, is a schistose layer which was not examined. Except along this portion of the Menominee, I have not observed gabbro (or gabbro-like greenstone) in the Huronian, south of Lake Superior. Mr. Irving finds it in the lower portion of the Keweenawan series of the Bad river region. Besides the great lithological interest attached to this rock, it is the heaviest bed of greenstone observed in the Menominee region, and has, in consequence, much influence on the topography, forming the barrier rock at the Big Quinnesec and probably at the Little Quinnesec falls, as well as the striking perpendicular wall on the left bank of the river above Sand Portage. In the Pine river district, Wis., an actinolite schist appears to be the equivalent of this bed, and has been numbered XVI. At the Lower Twin falls certain chloritic rocks seem to belong here, which harmonizes with the Sturgeon falls rocks if we regard the gabbro as local.

i. On the right bank of the river, at the head of the falls and underlying the greenstone bed *h*, or else forming its lowest portion, are several thin beds of *chloritic* and *greenstone (?) schist*, which were not examined, as they did not appear on the left bank, where the studies were chiefly made. They possess interest in connection with the puzzling fact that where Bed XVI crosses the river at the Little Quinnesec, the whole formation partakes more or less of this schistose character.

j. A dark green, fine-grained massive, rock, having decided affinities with the greenstones, from which it may be altered, in places, into a chloritic variety. There are indications that this rock passes, by almost insensible gradations, into:

k. Gray-green, massive, jointed, porphyritic, *gabbro-like greenstone*, similar to *h*, and regarded as belonging to the same bed, XVI [2266]. It contains semi-schistose layers, which strike N. 70° W., and dip 45° southerly.

l. An unctuous-feeling schist, with chlorite in joints, similar to *p*. With it occurs a massive greenstone resembling *n*. The vertical schistose planes strike N. 70° W. This outcrop is believed to belong to Bed XV.

m. An unctuous-feeling *magnesian schist*, resembling *p*, but more fissile and less contorted. Schist planes, supposed to be bedding, strike northwesterly and dip S. W. 55°. This rock contains considerable magnetite, which is interesting in connection with the fact that its supposed equivalent in the Pine River series (XV) also contains iron. See Plate V. About 800 steps S. E. are outcrops, apparently belonging to beds *m* and *n*, although the greenstone is coarser grained.

n. Underlying *m*, and in contact with it, is a gray-green, medium-grained *greenstone*, with minute veins of reddish feldspar, and containing some calcite [2265].

o. Like *p*, but less schistose. The strike and dip of the splitting planes are very irregular at both outcrops, but a southwesterly dip prevails, making the strike parallel with the trend of the river at this point, the bed of which is undoubtedly excavated in these soft schists.

p. Two hundred and fifty steps below the mouth of the Sturgeon river, and on the left bank of the Menominee, occurs the most northerly exposure of the Sturgeon Falls series, an unctuous-feeling schist, varying from light-gray to dark-green, and presenting a contorted or warped schistose structure which Dr. Wichmann calls serpentine [2263]. Associated with this rock, in a vein-like mass, is a fine-grained, green, magnesian schist, which differs from the containing rock in not being foliaceous and apparently more chloritic. Dr. Wichmann pronounced a specimen *indeterminable* [2264]. I surmise this may be a dyke filled by material from the adjacent rock, when in a semi-plastic state, therefore perhaps identical in composition, and differing only in being more crystalline.

q. About one mile southeasterly from *p*, and near the center of Sec. 26, T. 39, R. 29 W., Mich., on top of a hill, is an outcrop of an *argillaceous* rock, in places quite siliceous, which contains considerable iron, but does not promise to be workable so far as could be seen [2272, 3216 to 3220]. At one point the dip needle was deflected 90°. This rock has considerable resemblance to the Keyes & Fisher ferruginous slate on Sec. 20, T. 40 N., R. 18 E., Wis., as also to that on Sec. 12, T. 40, R. 17 E., and probably belongs to the same bed, XV.

The same bed has been recognized at several points in Wisconsin, and everywhere contains iron, but, so far as seen, only in small quantities. No exploration has been made on this stratum so far as I know. Since the above was written, in the winter of 1874–75, the Commonwealth mine has been opened in this bed, and its character as bearing valuable ores fully established.

This completes the enumeration of the rock outcrops seen at, or in vicinity of, Sturgeon Falls. Omitting the first described outcrops, (*a* and *b*), about which comparatively little is known, and which may belong to the same bed, although *a* agrees in lithological character with XIX, we have here a thickness of about 5000 feet, embracing beds XV to XVII, both inclusive.

This interesting Sturgeon Falls series was first studied in 1874, and had time permitted, would have been reëxamined in order to have instituted more valuable comparisons with the rocks further west.

Between the Sturgeon Falls series and the Vulcan Mine series, to be described below, is a low, sandy plain with occasional hills, and farther west, sand terraces, in which there are very few exposures of rock and no magnetic attractions. This broad, barren belt, trends parallel with the general strike, W. N. W., maintaining the same general character to Lake Eliza, Wisconsin.

It is undoubtedly underlaid by some soft, easily eroded, little known schists, which rarely outcrop, and for which I have left the numbers XIV to X. Again it is possible that the whole of this concealed belt may be underlaid by beds VII to IX, due to plications such as can be seen south of Lake Hanbury.

The great quartzite and conglomerate schist bed, XIV, which is the most conspicuous rock in the Pine River district (fully described below), entirely disappears long before reaching this point. We leave its number, but have no rock to represent it.

At the Four Foot Falls are certain chloritic schists and clay slates, believed to belong to the Middle Huronian, and to be the best representatives of these beds, about which little is known and which may not exist as distinct formations, the series, as may already be inferred, being nowhere complete. A peculiar tremolitic limestone bed occurring in the north belt of the Sturgeon district, is believed to be the equivalent of one of the unknown series. I would again remark that our stratigraphical numbers employed broadly are provisional, and may express my present hypothesis of equivalency. While a few leading beds can be readily traced by their mineral composition, many of the intermediate ones cannot be, as I have practically ascertained at great cost and sorrow.

On the Sturgeon river are three outcrops, respectively, on Secs. 23, 24, and 13, T. 39, R. 29 W., Mich.

r. *Clay slate*, with very perfect cleavage, the vertical planes of which strike N. 75° W. Bedding obscure, but is believed to be indicated by certain joint-like planes which form a high angle with the cleavage planes.

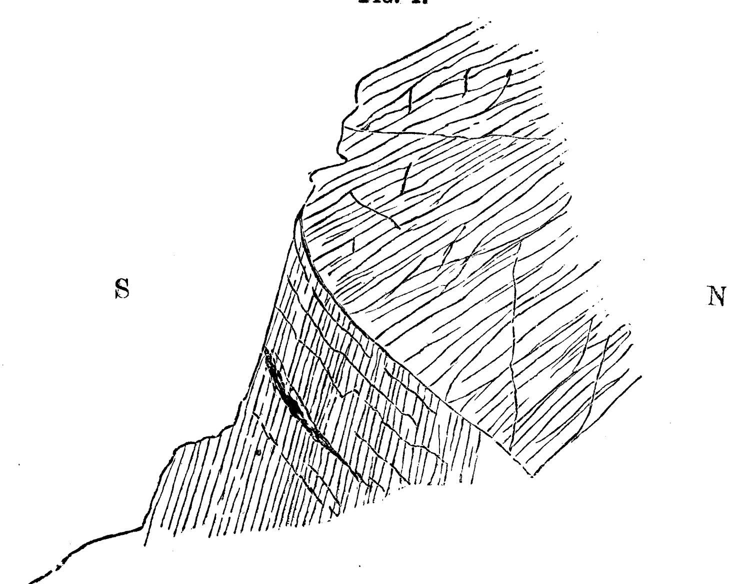
s. Greyish-green, medium-grained *greenstone*, holding veins of quartz. The surface shows glacial groovings, bearing N. 80° W., which is parallel with the leading stratigraphical and topograpical features of the district.

t. Similar to *r*, the cleavage planes of the two outcrops being approximately parallel. The same obscure appearance of bedding planes before mentioned can be here observed. They appear to strike N. W. and dip N. E., which is quite probable taken in connection with the Lake Hanbury synclinal now to be described, and of which this outcrop may be supposed to represent the south upturned edge [2282].

The observations of the rocks at Lake Hanbury began about 500 steps south of the lake, and on the north edge of the great sand plain already mentioned, which is here terminated by an abrupt ledge of slate and quartzose rocks. The geological section B—B, Plate I, nearly follows the line between Secs. 15 and 16, T. 39, R. 29 W., Michigan.

t. Bluish-black, possibly chloritic clay slate, which is regarded as the equivalent of *t* already described. Cleavage planes, more or less perfect; dip 80° S. S. W.; bedding planes are tolerably distinct, and in places contorted, and marked by striping at various points along the ridge for a distance of say 500 feet, the dip being from 40° to 80° to the N. N. W. See remarks on cleavage in Chapter III, under Clay Slate.

FIG. 1.



VERTICAL SECTION LOOKING WEST.

Clay-slate, with cleavage planes dipping at high angle to south, and bedding planes to north overlaid conformably by quartzite, holding numerous minute quartz veins perpendicular to stratification.

u. Gray and, on splitting planes, brownish-gray, arenaceous *quartzite.* It contains numerous small (one-eighth to two inches thick) veins and bunches of white quartz, which have a direction perpendicular to the bedding planes [2259]. Dr. Wichmann calls this rock a sandstone. The quartzite, conforming with the underlying clay-slate (*t*), dips N. N. W. at an angle of 40° to 50°.

The junction of clay-slate and quartzite can be observed near the line between Secs. 15 and 16, and about 500 steps south of the lake. The veins of white quartz in the quartzite were here very fine, and acutely reticulated, but the direction, perpendicular to the bedding, is preserved. This fact, which I have not noted elsewhere, has interest in connection with the origin of these minute quartz veins. About one-half mile easterly, I observed a junction of the clay-slate and quartzite, with northerly dip. Pumpelly and Credner mark "clay-slate and quartzite, strike N. 72° W.," on the N. E. qr. of Sec. 17, or 1¼ miles westerly from this point, and undoubtedly the same bed.

v. The crest of the north lobe of the ridge is formed of a bluish-gray, arenaceous *quartzite,* holding considerable calcite; also containing the numerous minute irregular projecting veins of white quartz. The surface of the Huronian marbles is often finely ridged by projecting quartz seams, presenting an appearance not unlike the above, except as to reticulations; an important difference being, however, that in the marble the quartz seams are always parallel with the bedding planes.

w. Light gray, glassy variety, like *x.*

x. On north face of a small rise of ground is a bluish-gray *quartzite,* the brown, friable weather coating being in this instance one inch deep [2257]. See Wichmann's chapter, § 176.

y. About 35 steps south of the crest of the ridge is a *quartzite* similar to *aa,* but less affected by the weather. It may be the south outcrop of the synclinal of which *aa* is the north outcrop. It contains numerous scales of a chloritic-looking mineral. The banded and reticulated surface due to quartz veins, already described, is here present [2256].

z. In the crest of the ridge, from which an extended prospect, especially to the south, may be had, a *clay-slate* like *dd* was found. The vertical cleavage planes are very strong and strike N. 85° W. by dial.

aa. Next north comes an apparently thin bed (say ten steps) of gray arenaceous *quartzite,* with a thick weathering coat, in places one-half inch, much resembling that already mentioned as covering the clay-slate *dd.* Scales of what appears to be chlorite can be seen, in the decomposed outer portions. Adjoining the above was a variety holding bunches and seams of white glassy quartz.

bb. One half way up the ridge on the north face, is a small exposure of *clay-slate*, identical with *dd.* Cleavage as before, bedding contorted, averaging nearly horizontal.

cc. At about 265 steps south of the lake, being at foot of the north slope of the main E. W. ridge, is an outcrop of a dark greenish-gray, faintly banded, soft schist, apparently chloritic, the nearly vertical schistose planes of which strike E. W., *i. e.*, parallel with the clay slate [2254].

In another variety whitish grains took the place of the whitish soft bands, and was more slaty in structure, and although having many of the physical characters of chloritic schist, was determined by Dr. Wichmann to be a mica schist [2254].

About 700 steps westerly is an outcrop of a similar schist, but holding the white grains in still greater abundance [2255].

About 200 steps northeasterly is a high bluff overlooking the lake, composed of clay slate similar to the above, and believed to be the same bed; for although the bedding is likewise much plicated, yet the prevailing direction was S. W., which would carry it to outcrop *cc.* The dip of this slate, although very irregular, was in the main plainly to the west, *i. e.*, towards and possibly under the greenstone *ee.*

dd. Two hundred and twenty steps south of the lake is a small knoll of dark colored *clay-slate*, with imperfect cleavage, the vertical planes of which strike E. to W. The bedding planes, as indicated by faint striping and banding, are much plicated and folded, dipping in all directions and at various, but usually low, angles. The following dips were observed: South 50° and 25°; east 20°; horizontal; west, and again so plicated as to make it impossible to decide the angle. Iron pyrites occasionally occurred. Veins of quartz, some conforming with the cleavage planes, and others not, were observed, one of which was 2½ inches thick. A brown, iron-stained weather-coating, in places one-half inch thick, was common.

ee. Eighty-five steps south of the lake, and west of the line between Secs. 15 and 16, is a large exposure of a gray-green, fine-grained, massive, jointed, highly crystalline *greenstone*, in places semi-schistose. No bedding planes could be found.

About one-third of a mile east of this section are large exposures of the same series of rocks (excepting the greenstones), which are described above. On the crest of the ridge, about 200 steps south of the lake at this locality, is to be seen (1) a small outcrop of the soft, green schistose rock (chloritic ?), described under *cc.* In its western extension this bed becomes heavier and nearly excludes the accompanying rocks. (2) *Clay-slate.* (3) Bluish-gray *quartzite*, with vitreous grains. (4) *Clay-slate* with contorted bedding; prevailing dip S. E. (5) Like (1). (6) Light-gray, massive *quartzite*, near lake.

Near the center of the N. half of Sec. 8, being 1½ miles west of the line of our section, and on the north edge of the low ground, is a low, rounded knob of *clay slate* with vertical E. to W. cleavage and obscure bedding. It is in all probability the western extension of the clay-slates described above.

ff. Regarding the next member of the series, we have but little light. It is a soft, hence easily eroded, unctuous-feeling, *argillaceous schist*, and has been seen (1) as clay-slate by Prof. Pumpelly in the N. E. corner of Sec. 15; (2) Dr. Credner found, while exploring for the Portage Lake Ship Canal Co., on Sec. 11, south of the iron ore series, "fifty feet of ferruginous clay-slates, of light reddish color," and a similar rock in corresponding position in other places [1623]; (3) the explorations of the Milwaukee Iron Co., on Sec. 10, revealed a bed of soft, reddish-brown, unctuous-feeling schist or shale, with irregular thin seams of a white mineral. A very similar rock was observed, in a corresponding geological position, near the N. quarter post of Sec. 36, T. 40, R. 31 W., which Dr. Wichmann calls sericite schist [2077]. No outcrops occur on the N., W. or E. shores of Lake Hanbury, nor in the valley in which the lake is situated, which can be traced several miles W. N. W. and E. S. E. It is undoubtedly occupied by soft slates, like those just described, and it may quite probably be the upturned edges of the same series. Observations made four years later, point toward the possibility of this valley being occupied by a hydromicaceous schist like *ff*. These several exposures of rock are believed to belong to the same horizon of unctuous-feeling, argillitic schists (No. VII), varying, probably, from a true sericite-schist through argillaceous varieties to clay-slate [2942 to 2945]. Since the above was written, the R. R. cuts at the Vulcan and the extensive explorations of Mr. Davis on the S. half of Sec. 31, T. 40, R. 30, have placed beyond all question the existence of a heavy bed of this rock, which is No. VII, and directly overlies the iron series.

gg. We now arrive, in descending order, at the great *iron-ore* horizon (Bed VI) of the Huronian series, as developed in the Menominee region, which possesses more economic importance and not less scientific interest than any other bed. It is topographically conspicuous, forming, as it often does, a comparatively high ridge, having, of course, the same trend as the ore stratum, N. 72° W.

The elevation is sometimes considerably increased by a covering of horizontal Silurian sandstone, which often caps the ridge, as is the case on the section under consideration, and which is much in the way of the miner and explorer. This ore range has another fortunate character to which not enough attention has been paid, to wit, its magnetism.

Although the ore is almost entirely specular (red) and limonite (brown), yet there is usually enough of the magnetic (black) oxide intermixed to cause deviations in the needle, thus enabling the prospector to approximately mark its position with little cost in places where it would be otherwise exceedingly difficult and expensive.

This iron ore horizon having been somewhat fully described by me under South Iron Belt, Michigan Geological Survey, Vol. I, pp. 158 to 180, need not be further noticed here, than to add a very interesting and detailed section, showing the internal structure of the ore mass, made by Dr. Credner for the Portage Lake Canal Co., on Sec. 11, T. 39, R. 29 W.

A part of the iron series exposed by open trenches is from south to north as follows:

6 feet clayish red iron ore.
13 " clayish soft red iron ore.
47 " ferruginous clay-slates, soft, blood-red.
29 " poor quartzose ores, with narrow streaks of rich ore.
14 " quartzose ores, a little richer than the last, frequently with bands of good ore, especially in the northernmost four feet.
6 " fine grained, steel-gray iron ore, supposed to be rich; in narrow streaks a little jaspery.
10 " same; a little more siliceous.
5 " iron ore, supposed to be rich.
3 inches quartzite ore.
3 feet iron ore, supposed to be very rich.
1¾ " middling ore.
1½ " rich ore.
6½ " poor quartzose banded ore.
5½ " iron ore, supposed to be very rich.
1½ " banded siliceous ore.
4 " banded rich and siliceous ore.
47 " siliceous iron ore.
12 " dark-red ferruginous clay-slates.
Outcrop of 30 paces showing ferruginous clay slates.
50 " ferruginous clay-slates of light reddish color.
20 paces poor ferruginous clay-slates, and very poor siliceous ore.
26 feet siliceous iron ore of poor quality.
6 " iron ore, supposed to be very rich.
6½ " siliceous ore.
28½ " good fine-grained steel-gray iron ore, here and there with a narrow streak of siliceous ore, but in such a small proportion as not to spoil the good quality of the whole. The whole series gives a dark red streak.
5 " poor siliceous ore, banded with better ore.
26 " fine-grained, steel-gray, iron ore; shipping ores prevail.

15 feet jaspery banded ore, consisting of layers of poor siliceous and rich steel-gray ore.
5 " fine-grained, steel-gray ore, in streaks a little siliceous.
13 " jaspery banded ore.
3 " poor siliceous ore.
14 " alternating layers of slaty rich ore, some jaspery, poor and siliceous middling ore.
4 " poorer class of banded ores.
2½ " slaty ore, supposed to be good.
9½ " alternating layers of richer and poor siliceous ore, the former prevailing.
39 " slaty ore, supposed to be workable, with some narrow streaks of jaspery ore.
2 " poorer class of siliceous ores.
6 " fine-grained steel-gray iron ore, very rich looking and very hard, therefore siliceous.
19 " turning by and by into more and more siliceous and poorer ores.
High drift and Potsdam sandstone.

According to the above given series of iron strata, S. 11, T. 39, R. 29, contains iron-strata which are supposed to be workable, of an aggregate thickness of 139 feet.

The ores regarded by Dr. Credner as merchantable, are below the present standard of shipment, but this does not detract from the interest that attaches to his very full descriptions of the alternation of more or less quartzose and argillaceous, thick and thin, ferruginous layers. It is a typical section of the so-called "flag ores," which constitute probably more than 90 per cent. of the material of this formation.

On the same range, but more than a mile west, at the quarter-post between Secs. 9 and 10, where the Vulcan mine is now located, I found, in the summer of 1872, the first merchantable ore in place, so far as I know, seen and proven in the south range of the Menominee region. It is thus described in Mich. Geol. Rep., Vol. I, p. 179:

"At the quarter-post between Secs. 9 and 10, north of Lake Hanbury, are to be seen several boulders of a black, porous, earthy ore, resembling somewhat varieties of the Negaunee manganiferous hematites; the same ore was found in place in a pit near by, and a large boulder of it near the center of S. half of N. W. qr. of Sec. 6, and at other points. A hand-specimen gave Mr. Jenny 56.44 per cent. of metallic iron, less than 16 per cent. of insoluble siliceous matter, and nearly 1 per cent. of manganese. It is unlike the Breen mine hematite, and, in fact, unlike any Lake Superior ore I have seen. It is not improbable that workable deposits of it may exist, which, being soft, would not be likely to produce outcrops or boulders. I think it is well worth investigation."

This show of ore has since been thoroughly prospected by Capt. Whitehead, under the direction of Mr. Hulst, whose explorations have developed a lenticular shaped mass conforming with the bedding, having a maximum thickness of 75 feet, and apparently wedging out toward the west, where in one pit it is but two feet thick. Neither its eastern nor downward extension have been determined.

A strictly average sample, obtained by collecting indiscriminately small portions from all parts of the stock pile, analyzed by Mr. E. T. Sweet, under direction of Prof. W. W. Daniells, of the Wisconsin State University, Madison, gave the following constituents: Sesquioxide of iron, 84.98; peroxide of iron, 1.17; silicic acid, 10.56; alumina, 1.43; lime, .62; magnesia, .28; oxide of manganese, .18; phosphoric acid, a trace; sulphur, .07; water, 1.22; total, 100.51. Metallic iron, 60.4. Sp. gr. 4.414.

Associated with this ore are several interesting rocks [2985 to 2989]

On these facts, we are warranted in saying that this ore is first-class as to quality, although not identical in character with the high-grade Marquette ores; and that there is a large workable deposit of it, with every probability of more being found.

The above was written in 1874, since which time extensive developments have been made on this iron range, and several mines are now shipping large products by rail. As the region is rapidly developing through mining and exploration works, it is not worth while to attempt, in its present transition state, to further describe its geological structure, than to say that the ores seem to have the same origin as the soft hematite ores of the Marquette region, which, I conceive, are altered forms of the quartzose ores, the siliceous matter having been dissolved out. This leaves them soft and porous, more or less hydrous oxides in the Marquette region; but, except at the Breen and Emmet mines, anhydrous here, so far as developed. This supposed origin produces essentially a more or less irregular, pocket-like form, the ore sometimes giving out suddenly in the direction of the strike; and, on the other hand, the "flag-ores" as suddenly passing into the altered form. It seems not improbable that more than one distinct iron bed may be found in this horizon, separated by some quartzose, argillaceous or chloritic schist. The ores are characterized by being very low in phosphorus, and easily reduced on account of their porosity. Just what place they will take in the iron trade of the west, it is not safe yet to predict, but certainly an important one.

Although not belonging to this part of the subject, it may be interesting to note that this Breen-Quinnesec iron range, constituting bed VI, has not been seen within the limits of my survey on the Wisconsin side of the Menominee river, although it undoubtedly exists under the drift, just north of the mouth of the Pine river, where its rapidly diminishing magnetism enables us to barely follow it across the river. See general atlas map. That it is widely distributed at great depth under the Pine river district, there can be no doubt.

hh. Underlying the iron horizon, and not less conspicuous, is the great *dolomitic marble* bed of the Menominee region, which appears to be coëxtensive with the iron, one being seldom seen without some indications of the other. On the south side of Sec. 35, T. 40, R. 30 W., it can be proven by measurement that this stratum has a minimum thickness of not less than 1000 feet, making it one of the thickest beds of the series, and excepting one comparatively small and little known bed (X) of the north belt, Sturgeon river district, the only bed composed essentially of crystalline dolomite, yet made out in the Huronian — one may say in the Eozoic, for no limestone has yet been found in the underlying Laurentian south of Lake Superior, or in the overlying Copper series. It is true that the lower quartzite (bed V) of the Marquette series contains considerable lime in places, but it is essentially a quartzite, and is only locally or probably in its upper portion, dolomitic, as it is in other places argillaceous. See page 148, Vol. 1, Mich. Geol. Rep. This subject will be further considered when discussing the equivalency of the Marquette and Menominee series.

The marble, as will be seen on Plate I, outcrops in N. half of N. half of Sec. 9, and in N. half of S. half of Sec. 12, T. 39, R. 29 W., as well as in N. half of N. half of Sec. 18, T. 39, R. 28 W. The observed dips were from 25° to 80° to south — the former being the lowest regular dip I have observed (in 1874) in the Menominee region, and occurs in the S. E. qr. of Sec. 12. In many places the rock is massive, and the dip cannot be made out, but it is often banded with siliceous layers, which are made to project on exposed surfaces from the effects of weathering. These are usually true seams and mark the stratification, otherwise they have much resemblance to the quartz veins in the quartzite described under *v.* The marble is usually compact, fine-grained, and bluish, purplish, or light greenish-gray (2068). See Mich. Geol. Report, Vol. I, pp. 167 and 171.

In the fall of 1878, four years after the above was written, I had an opportunity to examine a quartzite which Prof. Pumpelly imformed me he had seen in the N. E. qr. of the N. W. qr. of Sec. 9, T. 39, R. 29, which seemed to divide the iron from the marble. A careful study of the peculiar jaspery quartzite, and of a similar one immediately north of the Norway mine, leads me to regard them both as secondary forms of the Silurian sandstone [2965, 2966, 2971]. At one place I found angular pebbles of Huronian limestone bedded in the jaspery quartzite. I therefore determined to omit from my section a partially conjectured bed of quartzite and clay slate which I had formerly placed here.

We have now arrived at the valley of Pine creek (Michigan), which forms the topographical separation between the marble and lower quartzite to be described. This valley shows few outcrops and has been little explored. It is in all probability mostly underlaid by soft schistose, easily eroded, rocks.

ii. That a ferruginous bed immediately underlies the marble, is rendered almost certain by the magnetic attractions, amounting in places to 60° of the dip needle, which can be observed on the north side of Pine creek, near its junction with the Sturgeon. Pumpelly and Credner saw sharp angular boulders of iron ore about one mile further west, which, in all probability, came from the same bed. The local variations of the compass marked on U. S. plats near N. qr. post, Sec. 17, T. 39, R. 28 W., are undoubtedly due to the same cause, and those observed also by the federal surveyors, at or near the corner of Secs. 19, 20, 29, 30, T. 40, R. 29 W., point toward its being continuous to the N. W.

jj. We now reach the great *quartzite* of the Menominee Huronian, which, owing to its hardness, has resisted eroding influences to that extent that it presents more aggregate length of outcrop than any other formation, and its character is, therefore, well known.

It is well exposed on the Sturgeon river, where its most southerly outcrop is on the S. W. qr. of the N. E. qr. of Sec. 7, T. 39, R. 28 W., where it is purplish-gray, fine-grained, massive, breaking into irregular fragments, with occasional fine striping which probably marks the bedding. One mile above and near the falls, the quartzite rises to an elevation of over 200 feet on the east side of the river, maintaining the character given above, but lighter colored, in places nearly white, and often in such instances not unlike vein quartz.

Fine banding, or stripping, due undoubtedly to a stratification, bore at different points N. 60° to 75° W., and dipped nearly vertically, in one place 72° to the north.

Peculiar forms, not unlike Gothic roofs, covered with moss, are common, the crest lines being parallel with the banding. A thickness of 330 steps was measured, and the whole mass cannot be less than about 1,000 feet.

Near the river and west of the most northerly exposure of the quartzite, in the direction of the strike — hence, perhaps, a variety of it — is a quartzose rock holding much feldspar and having somewhat the appearance of granulite. Its weathered surface resembles some varieties of gneiss, the schistose structure of which bears N. 80° W.

North of the quartzite, and beyond a small valley, is a hornblendic schist [2275 and 1636]. (Wichmann's Report, § 128.) Next north are several beds of greenstone or hornblende schist, or both, alternating with layers of what has been called a talcy, or protogine gneiss.

At one point, the division plane between two of these beds was very plain, dipping 72° S. by W.

These beds, underlying the quartzite, are not represented on the plan and section, being too far east, and not having been precisely located. They may cross the river under the basin which bounds the quartzite on the north, and hence be concealed, or may represent in part the conglomerate-schist series now to be described. They are small in extent, and are chiefly interesting because Dr. Credner pronounces them to be of Laurentian age, and bases some lithological generalizations on such view, which seem to me to be erroneous. See "Die Vorsilurischen Gebilde der Oberen Halbinsel von Michigan. Zeitschrift der Deutschen Geologischen Gesellschaft," XXI Band, p. 521, and following.

This series is exposed on a projecting point on the east side of the river, a short distance above the foot of the Falls of Sturgeon, portage trail, being about 500 steps S. W. of the center of Sec. 9, T. 39, R. 28 W.

1. On the south side of this point, hence forming the north shore of the basin, is a considerable bed of a soft, fine-grained rock, apparently a chloro-argillaceous, *arenaceous schist* [2277]. The strong cleavage planes strike N. 80° W., dip 60° S. A somewhat distinct banding had a strike N. 75° W., and vertical dip. As no rock is exposed for some distance south, this schist may have considerable thickness, and in part underlie the basin.

2. North of the schist is eight feet in thickness of a reddish-gray quartzite.

3. A thin bed of a schistose *conglomerate*, holding pebbles of what appear to be Laurentian granite and gneiss and white quartz, loosely bedded in a matrix resembling 1 [2278]. Prof. Pumpelly called the rock provisionally *protogine conglomerate*.

4. Five feet of *schist* similar to 1.

5. Eight feet of *conglomerate* similar to 3.

6. Three feet of *schist* similar to 1, which brings us to a narrow part of the river and ends the series, for on the opposite side is Laurentian granitic-gneiss. On the east side where the character of the rock could be observed, it was reddish and coarse-grained, bedding obscure, but apparently N. 60° W., and dip 70° to N., which seemed to be the strike and dip of the division plane between the two series.

The bedding of the conglomerate and schistose beds 1 to 6, above described, was unmistakable, being N. 80° W., with vertical dip, hence essentially parallel with the great Huronian quartzite which overlies them on the south. The bedding of the granitic-gneiss series (Laurentian), which here presents several varieties, as has been remarked, was obscure; in one place, however, about one-third of a mile farther up the river, it was distinctly N. 45° E., and in another place N. 20° E., with dip 35° to 50° southeasterly. About fifty steps up stream from the conglomerate-schist series, is an exposure of a dark-green schistose rock, apparently a hornblendic chloritic schist, and containing much lime [2279], which strikes N. 45° E., and dips 45° to S. E. As this rock has somewhat the character of a dyke, we are not warranted in saying that it marks the bedding of the Laurentian.

The structural facts, in connection with the strong lithological affinities which the schist-conglomerate series bear to the Huronian, and the still more important fact that the pebbles contained in the conglomerate are unmistakably Laurentian, leave no question in my own mind but that the rocks under consideration are Huronian, and form the base of the series at this point. I have therefore marked them I, indicating the first formed strata of the Huronian age.

This number is intended to embrace all the Huronian beds older than the great quartzite.

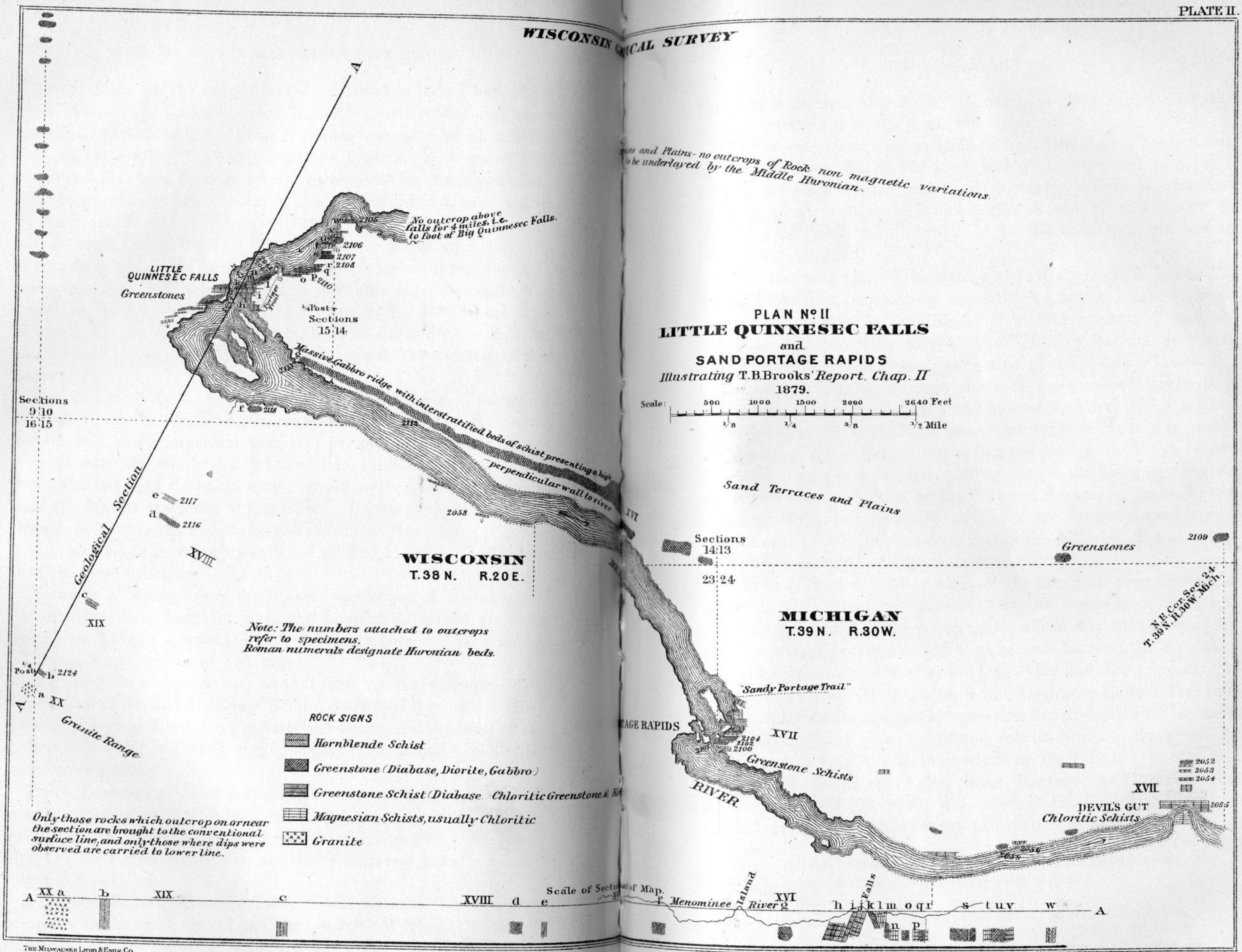
No rocks affording to me the slighest suggestion of a conglomeritic structure have been found in the Laurentian system, its rocks being always highly metamorphosed, and often so much so as to destroy all traces or suggestions of bedding.

Nor have we a right to assume that these rocks are simply local, for in Towns 40 and 41, Range 30 W., there is everywhere a valley between the great Huronian quartzite and the nearest exposure of the Laurentian, which may, and very probably is, underlaid by a similar conglomerate-schist series.

There is another class of rocks at this interesting locality which may be properly mentioned here, which, apparently conforming with neither system, present rather the structural phenomena of dykes, although their material is softer and more schistose than is usually found in true dykes.

1. 1125 paces N. and 400 W. from the S. E. corner of Sec. 8, which brings us on the south side of the amphitheater of which the before mentioned basin is the center, there is a thin, vertical bed of a schistose rock, gneissic in appearance and rich in mica. It is soft and brittle, of purplish-green color, and altogether an uncommon variety [2273].

PLATE II.



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Its strike is unmistakably N. 60° E., nearly at right angles with the great quartzite which cuts it off each way.

2. Northwest from 1 about 75 steps, and forming the barrier rock of the small lower fall at the lower end of Portage trail, is a light-reddish and greenish-gray, and apparently talcy, variety of quartzose rock, the schistose planes of which strike N. 45° E., and dip 60° S. E., or approximately parallel with No. 1. No other rock was seen in contact with it [2276].

3. On the west side of the river, and just above (2), is a peculiar metalliferous rock, exposed by some digging, which I have observed in no other place. It is a highly crystalline mixture of reddish, orthoclase feldspar, with many cubes of iron pyrites, and in places thickly sprinkled with crystalline grains of magnetite. It may not improbably be a vein, although the rock has some affinity with a feldspathic rock observed on the east side of the river, which is illustrated by Spec. 65, Mich. State suite, where it is called talcose gneiss.

Regarding the schistose, dyke-like masses (1) and (2), above described, I have seen precisely similar ones in the Marquette region, and regard them as formed by the filling of fissures in rocks by the inflowing, if flowing it may be called, of the nearest adjacent rock which has the requisite plasticity, just as the galleries of coal mines are filled by creeping of adjacent slates.

The two N. E. and S. W. reaches of the Sturgeon river above and below the falls, which are parallel with the direction of the dykes, point toward some such general cause, which may also account for the river having broken through the quartzite barrier at this point.

While displacements (faults) and true dykes and veins are rare in the Huronian area, I think there is much evidence to show that such small displacements and partial squeezing out of beds, such as must have accompanied great plications, are common. Such will be pointed out at the Little Quinnesec and on the Pine.

2. Little Quinnesec Falls, Sand Portage, and Devil's Gut Section. T. 38 N., R. 20 E., Wis. (See PLATE II.) From south to north, beginning with the youngest formation, as in No. 1.

No. of bed.			*Thickness in feet.*
XX.	*a.*	*Granite.* Supposed to be the youngest bed of the Huronian series. See description, under *a* of preceding section. Covered..........	100
XIX.	*b.*	*Hornblende schist.* Dark, grayish-green, fine-grained, crystalline, very jointed, and feels rough to the touch [2124 [1]]. Dykes of granite course through the bed in every direction. The dip is nearly vertical, but farther west it is southerly, and under the granite; and in every case where the dip could be made out, the hornblendic schist dipped toward the granite at a high angle..	250

[1] See Dr. Wichmann, Chap. V, § 130.

No. of bed.			*Thickness in feet.*
		Covered	850
	c.	*Hornblende schist*, resembling *b*	200
		Covered	1,100
XVIII.	d.	A high bluff of coarse-grained *gabbro* or *gabbro-like greenstone*, somewhat porphyritic in texture [2116], resembling the barrier rock at Sturgeon falls. This rock is lithologically identical with that of the great greenstone ridge north of the river, described below (XVI), and it may possibly be that formation brought to the surface by a fold, or, if both are eruptive, then its presence is still easier to account for. I regard it, however, as the equivalent of the gabbro, occurring at the head of the Big Quinnesec (see Plate III), therefore forming a distinct, thinner, and younger bed, whatever its origin	100
		Covered	50
	e.	Unctuous-feeling, apparently chloritic, schist [2117]	50
		Covered. Probably the Sand Portage and Devil's Gut series belong here. See detailed description of those rocks which follow this section.	1100
XVI.	f.	On the south shore of the river is a dark green, fine-grained *greenstone*, with thin seams of chlorite [2118]. A specimen was named by Dr. Wichmann diabase, and later chlorite schist, and one by Mr. Wright, chloritic diorite, based on a microscopic study of thin sections	100
		Covered by river	550
	g.	This locality is at the N. W. end of one of the most conspicuous ridges of rock on the Menominee river, suggesting as it does the palisades of the Hudson on a small scale. It forms a continuous crag extending for a mile below the Little Quinnesec falls, in one place 700 feet wide. The rock, which has been variously called gabbro, gabbro-like diorite, porphyritic diorite, and diabase [2112, 2113, 2114] (69), is usually very coarse-grained. The green hornblende crystals sometimes ½ inch long, and whitish feldspar facets nearly as large, are at once striking and beautiful	200
		Mr. Rutley first applied the name gabbro, based on a careful microscopic study of a specimen of the Michigan state suite (69). Those interested in its mineral composition are referred to chapters III and IV.	
		Intercalated beds of soft green schist, striking with the trend of the ridge and having vertical dip, occur.	
		Covered	100
XV.	h.	*Chloritic schist*, splitting into flat prisms, with acute edges	200
	i.	*Chloritic schist*	10
	j.	Unctuous-feeling schist, light gray-green, with irregular branches and seams of quartz and a thin dark gray-brown weather coat,	40
	k.	A mass of greenish-gray, fine-grained, massive *greenstone?* presenting a rectangular surface and surrounded on three sides with chloritic schist, having a trappean structure [2063]	20
	l.	*Chloritic schist*, from typical to unctuous-feeling and quartzose	40
	m.	Fine-grained *greenstone*	10
	n.	Unctuous-feeling *chloritic schist*, with seams of quartz and lime,	24

No. of bed.		*Thickness in feet.*
	Covered	10
o.	Medium-grained, green, highly crystalline, *hornblendic diorite and hornblende schist*	40
p.	Dark *chloritic schist*, with veins of quartz and calcite [2110]	10
q.	Light-green *diorite*	33
r.	Dark-green *chloritic schist* with narrow seams and veins of quartz [2108]	10
	Covered	113
s.	Light-green, massive *diorite* [2107], with a 10 foot bed of very dark-green chloritic *greenstone* schist, containing occasionally reddish specks	95
	Covered	20
t.	Soft, dark-green *chloritic schist* [2106]	30
u.	Massive *greenstone*	40
v.	*Chloritic schist*, containing considerable magnetite, and somewhat warty on cleavage planes	C5
	Covered	175
w.	*Chloritic hornblendic schist*, with grains of glassy quartz [2105] (or, Wichmann, porphyritic hornblende gneiss)	25
		5760

Our inability to identify the beds on opposite sides of the river, together with the facts recorded above, and certain topographical features of the locality, render it not improbable that there may have been a cross fracture and small right hand throw at the locality, along which the river has broken through the series. This might easily, I conceive, have produced the phenomena suggestixe of eruptive agency recorded under *k* above.

It was remarked above that the considerable covered space between *e* and *f* (Plate II), was likely to be underlaid by the rocks to be seen at the head of Sand Portage Rapids and at Devil's Gut. These will now be described (the former from Mr. Wright's notes) from south to north, in supposed descending order, beginning with Sand Portage.

No. of bed.		*Thickness in feet.*
XVII.	*Chloritic schist*	20
	Chloritic hornblende rock, often dioritic	100
	Near foot of first rapids. Light greenish, tolerably soft, *chloritic schist*, on weathered edge somewhat shaly [2100]	40
	Chloritic diorite; somewhat schistose, with reddish spots on fresh fracture that have the appearance of garnets [2101]	40
	Chloritic schist, with thin seams of quartz; ash-green color, with reddish specks, possibly feldspar [2102]	25
	Chloritic diorite, similar to 4th outcrop above, with seams of calcite	35
	Three beds of *diorite* [2104] and *chloritic schist*	35
	Massive *hornblende rock*	35
	Alternating beds of *chloritic schist* and *chloritic diorite*	60
	Chloritic schist, occasionally somewhat talcose in character	180
		570

Half way between Sand Portage and Little Quinnesec is a light greenish-gray, micaceous slate, slightly unctuous-feeling, with quartzose laminæ; weathered surface is brown [2058].

The following beds, believed to be the equivalents of the above series, can be seen at Devil's Gut (Plate II), and are enumerated from south to north:

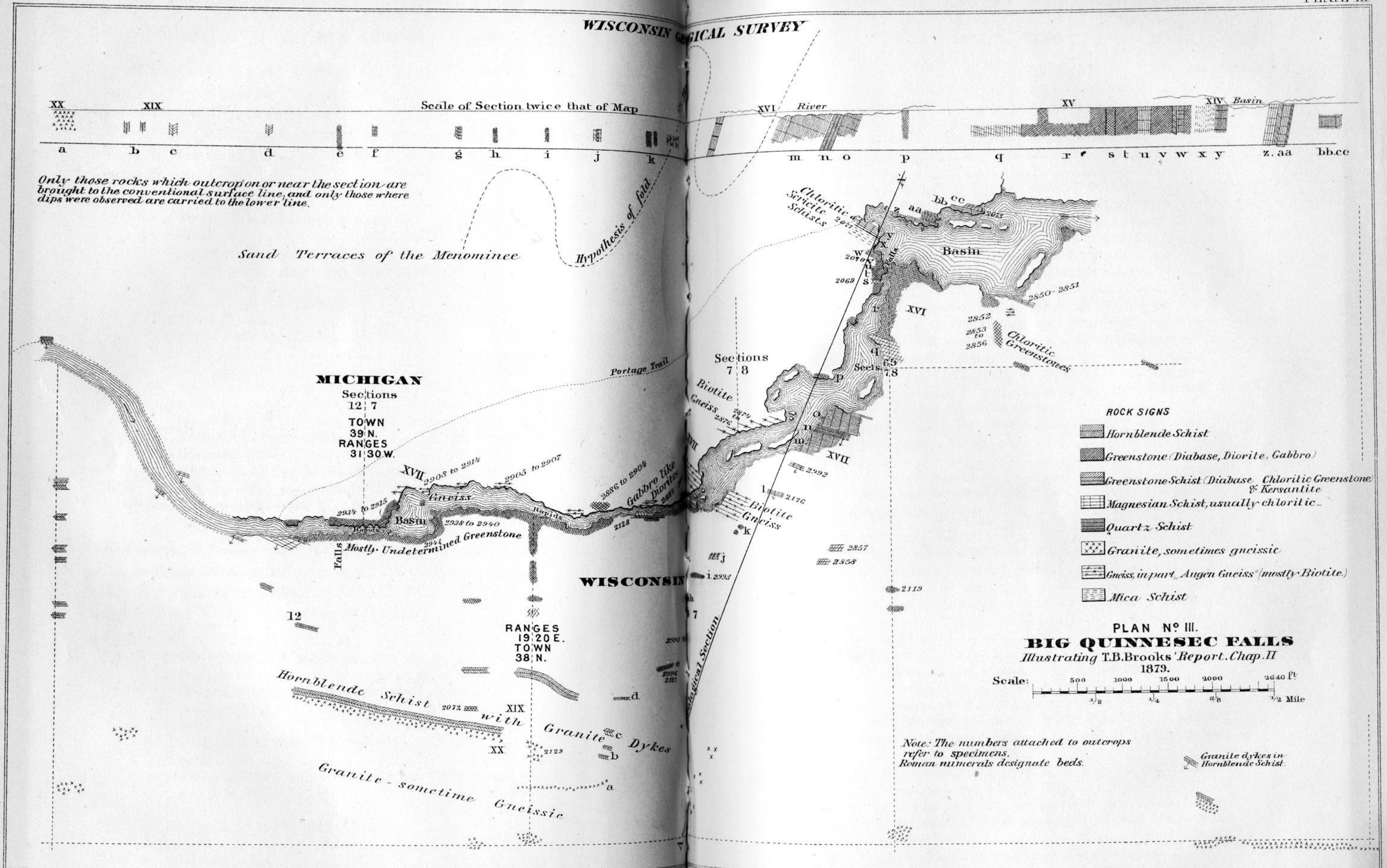
No. of bed.		*Thickness in feet.*
XVII.	*Chloritic schist* (south bank of river).	
	River	90
	Gray-green *chloritic* or *clay slate*, effervescing slightly with acids, and containing occasional quartz seams [2055]	30
	Covered	120
	Magnesian slate, like 2054 below	10
	Covered	15
	Chloritic schist, like 2053 below	60
	Covered	30
	Thinly laminated, gray and brownish, soft, *magnesian slate*, with thin seams of quartz in cleavage planes [2054]	50
	Covered	20
	Chloritic schist or slate, with greenish gray, irregularly pitted weathered surface, and thin seams of calcite; weathers greenish-brown [2053]	40
	Fine-grained, light-green, *chloritic greenstone* schist; weathered surface greenish-gray, studded with crystals of feldspar brought out by weathering [2052]	30
		465

The unctuous feeling which belongs to the hydro-micaceous schists exists in the above so-called magnesian schists in some degree.

3. Big Quinnesec Falls. Sec. 12, T. 38 N., R. 19 E., and Secs. 7 and 5, T. 38 N., R. 20 E. (See PLATE III.)

No. of bed.			*Thickness in feet.*
XX.	*a.*	*Granite*[1] [2129]. See (*a*) Sturgeon river section. In a few places evidences of bedding, indicated by gneissoid structure, were observed, dipping to the south and conforming with the adjacent hornblende schists.	
		Covered	250
	b.	*Hornblende schist* with dykes of granite	50
		Covered	50
		Hornblende schist. Farther west is a very tough diabase, with crystals of feldspar [2072]	50
		Covered	125
	c.	*Hornblende schist*, ledge 100 feet high	200
		Covered	300
	d.	*Hornblende schist*	25
		Covered	350
	e.	Coarse-grained, gray-green *diorite*, with beds of chlorite [2127]. Mr. Julien applied the name *kersantite* or *mica trap* to a specimen from this outcrop [2996], probably altered from a greenstone	50

[1] These notes are largely Mr. Wright's.



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No. of bed.			Thickness in feet.
	Covered		150
f.	*Chloritic schist*		50
	Covered		300
g.	*Chloritic schist* with quartz dykes and *diorite*		100
	Covered		100
h.	*Diorite*	25	
	Covered	200	
i.	Massive *diorite*	50	
	Covered	200	
j.	*Chloritic* and *dioritic schists* with dykes of quartz	100	
	Covered	250	
k.	Coarse-grained massive *diorite*, with *chloritic schist*	150	
	Covered	400	
	On the northwest side of the river, opposite the outcrops from *k* to *n*, are numerous exposures of a schistose, chloritic-looking rock which Mr. Julien designates *biotite-gneiss* [2874 to 2883]. It is not improbable there may be a single and perhaps double fold here. These differ from the prevailing varieties ¾ miles farther up the river, which are gray, harder, and less micaceous.		
l.	*Talcose, chloritic* and *dioritic schists*, passing into each other [2126]	50	
	Covered	500	
m.	*Chloritic schist*	265	
n.	*Quartz schist* with seams of chlorite	50	
o.	*Chloritic schist*	250	
		2,490	
	On the hypothesis of a double fold the true thickness would be one-third of this amount, equal to		830
	Covered		250
p.	Light-gray, medium-grained *greenstone*, resembling kersantite		50
	Covered		300
q.	*Greenstone schist*		250
r.	*Greenstone*		550
	Different varieties of greenstone occupy the east bank of the river continuously to the basin. Subsequent observations ¼ mile east on the strike of these rocks, afforded numerous varieties of altered greenstone, apparently chloritic [2852 to 2856]. At the extreme south corner of the basin is a related gneissic variety [2850].		
s.	*Diorite*, porphyritic with grains of glassy quartz [2069]		13
t.	Light-gray, medium-grained *greenstone*		75
u.	Siliceous, unctuous-feeling *chloritic schist*		25
v.	Light-gray *gabbro* ("diorite porphyry") with large white crystals of feldspar [2070]		230
w.	*Greenstone schist*, with a ten foot bed of *chloritic schist*		40
	Covered		60
x.	Light-gray *sericite schist*, holding grains of quartz and partially decomposed feldspar [2071[1]], often slaty and showing on cleav-		

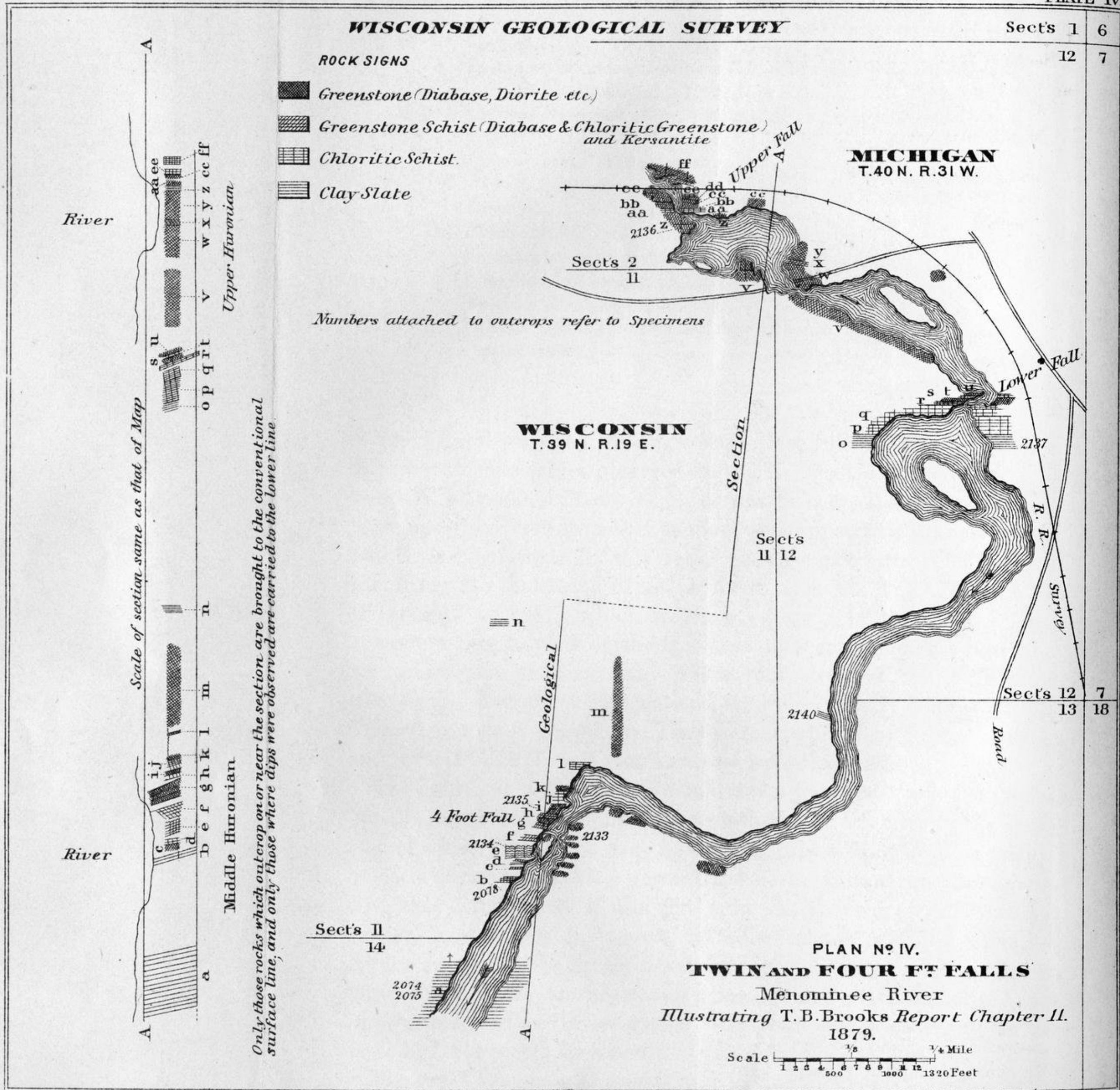
[1] Dr. Wichmann, chapter V, § 118.

No. of bed.		Thickness in feet.
	age planes pinkish spots and uneven surface	115
y.	*Chloritic schist*	85
	Covered	225
z.	Light grayish-green *chloritic schist*, with seams of quartz (slight magnetic attractions)	30
aa.	*Chloritic greenstone schist*, with pinkish grains of feldspar (schalstein?)	25
	Chloritic schist, with seams of calcite	25
	Chloritic greenstone schist	25
	Covered	130
bb.	*Chloritic schist*, with seams of calcite and veins of quartz	20
	Siliceous, unctuous-feeling *chloritic schist*, with seams of calcite. Appears to be a dyke [2073]	3
	Chloritic schist	40
cc.	*Chloritic greenstone schist* and light-greenish, fine-grained *greenstone schist*	54
		5,600

The typical gray gneisses with plagioclase [2905 to 2914] associated with hornblende schist, observed on the N. W. side of the basin, 1,500 paces N. and 500 W. from S. E. corner Sec. 12, T. 38 N., R. 19 E., were not discovered near this section, and apparently do not cross it, and their exact place in this series is not made out. The gneiss is identical with that north of the Pine in Sec. 24, T. 39 N., R. 17 E. [2234, 2839 to 2847], which we now embrace in bed XVII. They are interesting in view of the fact that they are the oldest Huronian typical gneisses yet observed. These rocks were missed in 1874, because under our strict instructions, we were strictly confined to the Wisconsin side of the river. They were examined by Prof. Pumpelly and myself in 1877, and afterwards by myself in 1878.

The gabbro is found both up and down the river from the gneiss, but the latter was not found on the south side of the river in the direction of its strike. This may be explained by a fault or by a narrow gneissic anticlinal, sinking toward the east. Comparing this gneiss with that described as biotite gneiss in the above description, this is grayer, harder, less micaceous, affording almost granitic varieties. At the same time its chloritic beds and intermediate varieties have so much resemblance to the biotite gneiss of the section that it is not improbable further investigation may prove them belonging to the same bed, connected by a series of folds.

The great thickness of gneiss, and in fact of the whole series, to be explained here, would be most easily accounted for on this hypothesis. See Plate III.



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4. Four Foot and Twin Falls Section. Menominee river, T. 39 N., R. 19 E., Wis. See PLATE IV.

Section from south to north, beginning with the supposed oldest bed of the series.

		Thickness in feet.
	Middle Huronian.	
a.	Light bluish-gray, shining, *clay-slate*, with strong cleavage and no distinguishable bedding planes [2075]. Dr. Wichmann called this specimen *phyllite.* Quartzose laminæ or seams ⅛ to 2 inches thick conform with cleavage and mark bedding [2074]. The strike is N. 85 E. and dip 70° to 80° to the north. The bed where it crosses the river produces a ripple, and is exposed in the bottom of the banks for a thickness of 200 steps. No more typical clay-slate, and perhaps no thicker bed of this rock, has anywhere been found. It has been nowhere seen in place in the direction of its strike. Numerous fragments of a similar rock found in the S. W. portion of Sec. 6, T. 39, R. 18, indicate that it probably extends westerly under the heavy drift region, and may very likely graduate into the hydro-micaceous slate found on the north side of Pine river in Sec. 34, T. 40, R. 17 E. The clay-slate at the mouth of the Pine river is similar and probably the same bed. The prevalence of carbonaceous or ferruginous material in the clay-slate of the Upper Huronian and their absence from similar slates of the Middle Huronian, as developed in Michigan, together with other considerations, leads me to place this in the latter division, perhaps bed XI	550
	Covered	600
b.	Tough, hard, irregularly-splitting, *micaceous chloritic schist* [2078]	50
	Covered	50
c.	*Greenstone schist*	25
	Covered	10
d.	Chloritic? slaty schist	50
e.	Ochrey, carbonaceous (magnesian?) contorted schist [2134]. It is often black and stained reddish and yellowish from the decomposition of iron pyrites. Found only on the west side of the river, suggesting the possibility of a fault	135
	This bed has more characteristics in common with the Commonwealth formation XV, which apparently should be found in this series, than with any other which is exposed. I do not, however, believe they are equivalent.	
f.	*Greenstone schist*	
g.	*Massive greenstone*	265
i.	Massive fine-grained *greenstone*	
	Beds *b* to *i* inclusive seem to be chiefly represented on the east side of the river by greenstone.	
j.	An obscure, apparently *magnesian, schist,* which Dr. Wichmann calls *calcareous hornblende* schist [2135]	80
k.	*Greenstone*	25
	Covered, probably a soft schist or slate	120
l.	Soft *chloritic schist*	25
	Covered	65

The remainder of the section is from Mr. Wright's notes.

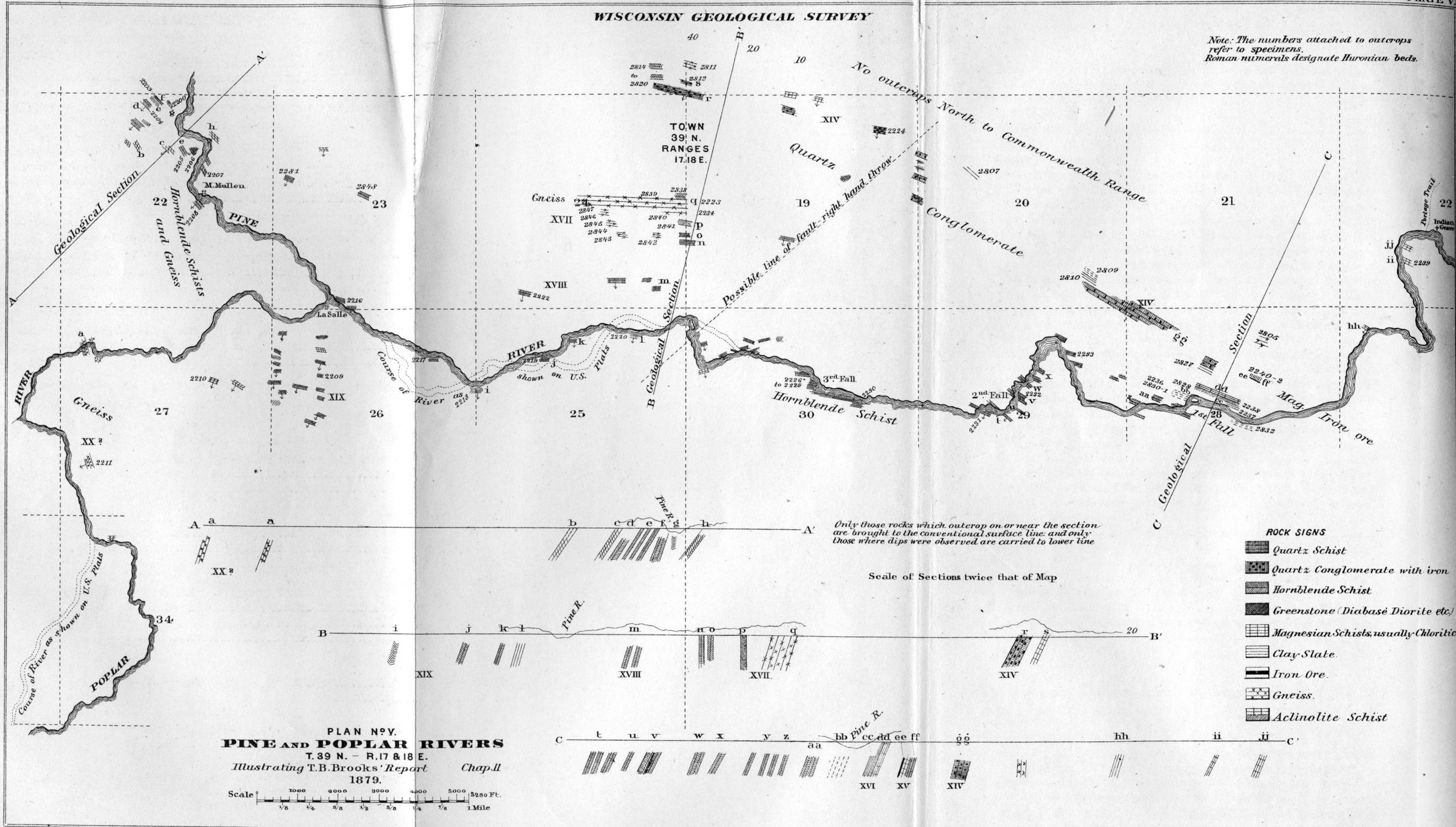
		Thickness in feet,
m.	A very heavy bed of light greenish-gray, massive, fine to medium-grained, *diorite;* varies only in size of grain, and in places somewhat schistose. The same rock was found to the westward	725
	Covered	300
n.	*Chloritic slate,* like outcrop on river bank [2140]	50
	Covered	1,600
	Upper Huronian.	
o.	Dark grayish-green on fresh fracture *chloritic slate* [2137]	50
p.	Earthy ash-gray *dioro-chloritic schist,* very jointed, and splitting into spear-head like slabs	75
q.	Ash-gray-bronze, soft and very jointed, slaty *chloritic schist*	100
r.	*Dioro-chloritic schist,* light to grayish to ash-green color, soft, jointed, with yellowish or brownish specks, and containing quartz and calcite	30
s.	Massive *chloritic diorite,* sometimes schistose and jointed, with seams of calcite and veins of quartz. This rock forms the barrier at the Lower Twin Fall	65
t.	Soft, ash-green, *chloritic schist*	25
u.	Dark grayish-green, medium-grained, massive *diorite,* with chlorite	40
	Covered	265
v.	Grayish-green, fine-grained, massive *diorite,* somewhat chloritic	460
	Covered, by river	125
w.	Massive *diorite* similar to *y,* with seams of chlorite and often jointed	200
x.	Grayish-green *chloro-dioritic schist,* with reddish specks, probably feldspar	20
y.	Light greenish-gray, fine-grained, massive *diorite;* contains seams of calcite and irregular veins of quartz	50
	Covered	100
z.	Very fine-grained (aphanitic) grayish-green *amphibole* rock, very jointed and hard, and rings when struck with a hammer, like a piece of steel [2136]. Disseminated through it are irregular patches of light-colored pyrites	50
aa.	Grayish-green, soft, typical, *dioro-chloritic schist*	15
bb.	*Diorite,* similar to *v*	15
cc.	" " " *z*	60
dd.	" " " *u*	15
ee.	*Dioro-chloritic schist* similar to *aa*	25
	Covered	40
ff.	Light grayish-green, fine and even-grained, *chloro-dioritic schist,* with little seams of calcite	150
		6,700

On the opposite side of the river, the equivalents of Mr. Wright's *o* to *u,* I find from south to north.

Choritic schist [2357].

A fissile, lustrous, hard, dark-green *slate,* with cleavage apparently parallel with bedding. It suggests hydromicaceous slate and phyllite [2359].

The barrier rock of the fall could not be reached. The sharp ridge south of the basin is a dark, olive-green *chloritic schist,* with sparkling facets of quartz [2361]. Strike, N. 80° E., dip to the N. 60°. Contains a layer of massive, fine-grained, hard *greenstone.*



PLAN No. V.
PINE AND POPLAR RIVERS
T. 39 N. – R. 17 & 18 E.
Illustrating T. B. Brooks' Report Chap. II
1879.

In 1877, Prof. Pumpelly and myself examined the rocks at the Upper Twin Fall, embraced under Mr. Wright's description under *z* to *cc*.

The prevailing greenstone is crypto-crystalline, compact, hard, somewhat brittle, ringing under the hammer and breaking into angular forms [2362 to 2364]. Intercalated slaty beds, four feet and less in thickness, striking S. 75° to 80° E., appear to mark the bedding. In places the greenstone is irregularly broken into polygonal masses, the minute fissures being filled with the slaty material, giving the rock a coarse, brecciated appearance. In other places it suggests a concretionary or semi-nodular structure. The same phenomena can be seen on the shore of Lake Superior, in front of the Northwestern Hotel, Marquette. This slaty material may be simply a compacted form of the pulverized greenstone, produced at the time of fissuring.

The full and interesting series of rocks mentioned above as occurring at the Four Foot and Twin Falls, can be traced by occasional outcrops about 3½ miles east, and nearly twice that distance west from the river. Beyond this they cannot be followed, nor have I been able to make out with absolute certainty their sequence and place in the series. An inspection of the general map, in connection with what has been said above, will indicate my hypothesis that the whole series ascend from the clay-slate on the south, which belongs to the Middle Huronian, and may be bed XI, to the massive greenstone which is spread out to the north by a double fold occupying the belt to the Badwater Indian village, where it is supposed to pass under the chloritic quartzite bed, XVIII, and is provisionally numbered XVII.

5. Pine and Poplar rivers section. T. 38 N., R. 17 and 18 E. *Description of Geological Section A–A.* See PLATE V. From the south, northeasterly, in descending order.

Some distance to the right of this section on the Poplar river is:

a. A grayish-black or very dark-green *hornblendic gneiss*, with dykes of granite. In seams are layers of mica, which are porphyritic with crystals of hornblende. Very heavy, highly crystalline, and feels rough to the touch.

About one mile N. W. of the mouth of the Poplar is the following series:

	Thickness in feet.
b. Dark-green, medium-grained, *greenstone? schist*, holding veins of feldspar. Fifty steps east it is more hornblendic, if not a hornblende schist	150
Covered	400
c. Grayish-green *greenstone? schist* and coarse-grained *hornblendic schist* — a schistose variety of *g*	150
Covered	80

		Thickness in feet.
d.	*Hornblendic schist* with calcite laminæ, similar to *f*. A variety contains crystals of black mica [2204]	200
	Covered	20
e.	Banded *quartzose schist*, the laminæ from one-fourth to several inches thick, much broken up and giving the rock a brecciated appearance. The light gray, reddish, and yellowish layers, are arenaceous on weathered surface, and apparently jaspery within, and in places micaceous. The dark colored layers are mostly chloritic, being dark-green on fresh fracture. At another point the rock is a banded gray and yellowish cherty schist [2203]. One-quarter mile S. E. in direction of the strike, they become micaceous quartz schists	150
	Covered	20
f.	Finely banded, medium to dark greenish-gray, *hornblende schist*, with numerous laminæ of calcite, the weathering out of which produces in places a corrugated weathered surface [2201]	100
	Covered	80
g.	Blackish-green, very coarse-grained, massive, jointed *hornblende rock* [2200]. In places it is finer-grained and of a greenish-gray color, suggesting greenstone	75
	Covered	100
h.	Gray-green *chloro-dioritic schist*	50

Description of Geological Section B–B. See PLATE V. From south to north in descending order.

No. of bed.			Thickness in feet.
XIX.	i.	Massive *hornblende rock* (Wright), consisting of black hornblende and white quartz in about equal proportions [2218]. Herr Wapler calls this rock a diorite	50
		Covered	800
	j.	*Hornblende schist* [2219]	50
		Covered	400
	k.	*Hornblendic schist*	75
		Covered	300
	l.	Grayish-green, gneissic-looking rock, containing garnets, which vary up to ⅓ inch in diameter, [2220]. In places suggests chloritic and again hornblendic schist	75
		Covered	1150
XVIII.	m.	Unctuous-feeling *quartz schist*, probably chloritic [2222]	300
		Covered	900

Mr. Wright describes the outcrops *n* to *q* inclusive thus:

XVIII.	n.	*Micaceous feldspathic quartzose schist*	50
		Chloro-hornblendic rock	50
		Covered	400
	o.	Gray *hornblendic schist*, passing into:	
	p.	Light greenish-gray, massive *hornblendic* or *quartz schist* with hornblende crystals plainly visible on weathered surface, rendering it porphyritic, and containing some black mica. No. 2234 has mica in minute lenticular parallel seams; several varieties were observed	100

No. of bed.			Thickness in feet.
		Covered	200
	q.	Semi-schistose, gray, *micaceous quartzite* with seams of hornblende [2223]	100
		Massive gray *micaceous feldspathic quartzite*. The ledge is exposed for ½ mile west. (Subsequent observations prove that a broad E. and W. belt of gray, compact gneiss, embracing outcrops *n* to *q* inclusive, containing layers resembling greenstone, exists here; possibly locally folded, but undoubtedly the equivalents of the gneiss already described as occurring near the head of the Big Quinnesec rapids [2838 to 2847].	
		Covered	2,500
		About ¾ miles east is a fine-grained, dark-green greenstone, which probably belongs here in the section.	
XIV.	r.	Light to dark-gray, irregularly banded, *conglomeritic quartz schist*, containing micaceous iron and magnetite. In one place the rock was a quartzite, with veins of white quartz. The white quartz pebbles vary up to the size of an egg, and are flattened, or have their longer axes in direction of the lamination. About ¾ miles east is a grayish specular conglomeritic schist, holding the same flattened pebbles of white arenaceous quartz. The matrix appears to be quartz and micaceous iron [2224]	200

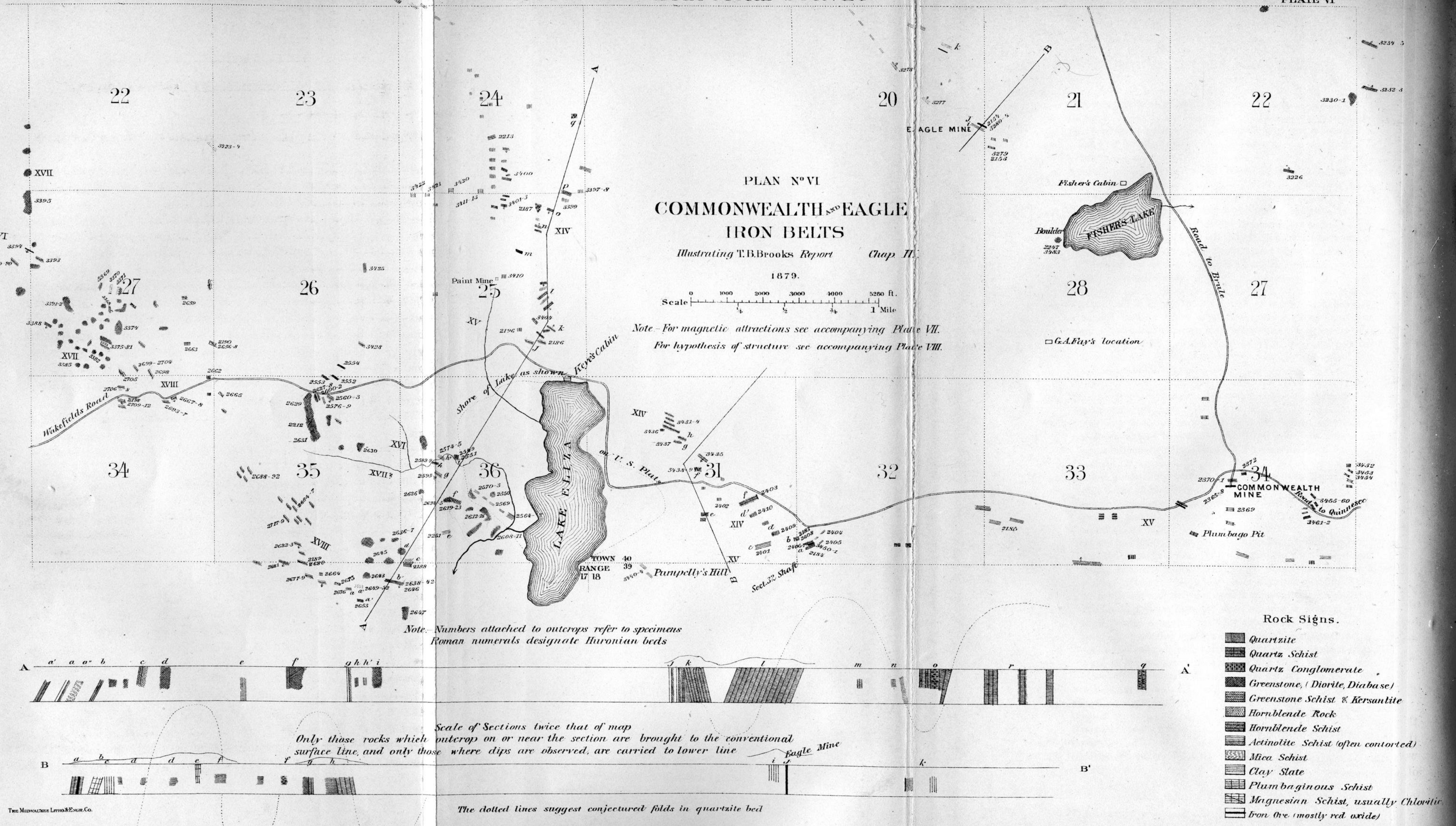
In 1878 I made out, just west of this section, the following very interesting series, from south to north, lying immediately north of, and, I suppose, under the quartzite:

Quartzose conglomerate schist, containing mica [2820].
Garnetiferous actinolite schist (eklogite) [2819].
Siliceous schist with hornblende [2818].
Hornblende schist [2817].
Pyritiferous, magnetitic slate, containing biotite [2816].
Black *hornblende schist* [2814].

Description of Geological Section C–C. See PLATE V. From south to north, and, to *gg* at least, in descending order.

No. of bed.			Thickness in feet.
XVIII.	t.	At second fall. Gray *quartz schist*, varying to typical massive gray jointed *quartzite*. In places the schistose variety is faintly banded, containing mica [2231]	250
		Covered	200
	u.	Unctuous feeling *quartz-schist*, graduating into a massive variety	50
		Covered	150
	v.	Gneissic-looking schist, apparently *chloritic* [2232]. Forms barrier rock of upper fall	200
		Covered	250
	w.	*Hornblende schist*. Forms barrier rock of lower fall	50
		Covered	50
	x.	Faintly banded, fine-grained, *hornblende schist*, containing calcite	150
		Covered	150

No. of bed.			Thickness in feet.
		Quartz and *hornblende schist*, interbedded	50
		Covered	400
	y.	*Quartzose hornblendic schist.* Across the river and a little below is a gray quartzose schist	100
		Covered	300
	z.	Decomposed *hornblendic schist*, becoming more quartzose fifty steps down stream	100
		Covered	200
	aa.	Grayish-black, fine-grained slaty *hornblendic ? schist*	100
		At the upper rapids of the first fall, probably just north of *aa*, is a *hornblendic schist*, with soft slaty laminæ, which by weathering have left projecting the sharp ragged edges of hornblende. Twenty-five steps down stream is a banded arenaceous quartzose schist, sometimes slaty.	
		Covered	300
	bb.	First fall. The barrier rock is a dark greenish-gray to blackish, banded, obscure schist, somewhat gneissic, which has been called *micaceous chloritic slaty-schist*, and *blackish-gray mica slate* [2236, 2830]. Below, about 20 steps, the same rock has thin chloritic (?) laminæ, which are minutely corrugated like the mica schists	250
		Covered	100
XVI.	*cc.*	Blackish-green, soft, perfectly cleavable, *chloro-argillaceous slate*, with numerous joints [2237]	25
	dd.	Underlying *cc* to the north, is a light olive-green, very coarse-grained, altered *actinolite schist* [2238], which in places was apparently undergoing alteration into chloritic schist	100
		Covered	300
XV.	*ee.*	Banded, greenish and purplish hard ferruginous (magnetic) *actinolite schist* [2240, 2241].	
	ff.	Banded *ferruginous quartz schist*, composed of laminæ of magnetic ore, and thicker ones of arenaceous white to yellow saccharoidal quartz [2242].	
		This bed was traced by its magnetic attractions, which are broad and strong at the outcrop, E. S. E. across the river, with diminishing influence and narrowing zone, possibly produced by a sinking anticlinal. See below. The structural relations of this actinolite ore with the great quartz conglomerate which shows itself a short distance to the west, where it is overlaid on the south by clay slate, was not fully made out. It is believed to overlie it, belonging with the clay-slate. The magnetic actinolite schist at this locality bears much resemblance to that lying south of the quartzite in S. E. qr. of Sec. 25, T. 40, R. 17, and is probably the same horizon, that is to say, a part of the Commonwealth ore bed, XV.	
	gg.	*Conglomerate*, see *r* above.	
		Covered.	
		Hornblende gneiss [2805].	
		Covered.	
	hh.	*Chloritic (?) slate.*	
		Covered.	



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ii. *Mica schist,* apparently chloritic [2239], similar to *bb*, but softer. Covered.

jj. *Chloro-argillaceous slate.*

6. Commonwealth and Eagle Mine Rocks. Ts. 39 and 40 N., Rs. 17 and 18 E., Wis. See PLATE VI.

I have rarely found so small an area presenting so many outcrops and magnetic attractions, and occupied by so few and well characterized rocks, the structure of which gave me so much trouble as has the district about Lake Eliza, more especially to the N. and W. Our observations in 1874 proved entirely inadequate, and the greater part of the work in 1877 and 1878 was devoted to this troublesome question of the sequence and relative age of these rocks, which, I believe, is at last satisfactorily solved. The exposures of rock are detailed on Plate VI, the magnetic attractions on Plate VII, and the generalized facts and hypothesis of structure on Plate VIII, as well as on both the Atlas Maps of the Menominee region. These rocks undoubtedly belong to the Upper Huronian, embracing the middle and lower portions. The extensive drift areas on the S., E., N. and W., completely isolate this district, forcing us to rely largely on lithological characters in establishing its equivalency.

The questions involved are no less important economically than scientifically, since it concerns the western extension of the Commonwealth range as well as the significance of the numerous attractions W. from Lake Eliza.

The oldest and most northeasterly rock in this series, bed XIV, is the great *quartzite* which covers one-half of Secs. 24 and 25, T. 40, R. 17. Traced S. E., it disappears in the S. E. qr. of Sec. 31, T. 40, R. 18, where it sinks beneath the supposed Commonwealth anticlinal. Northwestward it has been traced beyond Polar's location, at the S. W. corner of Sec. 13. To the S. W., and overlying this bed, is the Commonwealth iron horizon in which *clay-slate*, graduating into carbonaceous and chloritic varieties, and often laminated with saccharoidal quartz, is the prevailing rock. Its position and extension for 4 miles E. of Lake Eliza, is well-known. At the lake one wing makes a bend to the N. W., widening probably from folds. It occupies a broad area on Secs. 26, 25, 24, 23 and 14, beyond which nothing definite is known.

Except some highly magnetic actinolite schist, which seems to divide this bed from the underlying quartzite, and which is best exposed at the center of the S. E. qr. of Sec. 25, no decided indications of iron were seen, although rusty, partially decomposed slates were frequently observed. Since the Commonwealth deposit and rich, soft ores generally do not outcrop, the fact that merchantable ore was not seen has no especial significance.

S. W. of the known localities where bed XV is exposed, is a flat belt without outcrops, which may be occupied by the soft uppermost members of the bed.

We now arrive, in ascending order, at bed XVI, to which belongs most if not all of the strong magnetic attractions W. and N. W. of Lake Eliza. Where best exposed, on Secs. 35 and 36, it is made up of a thick stratum of *clay-slate* and *argillaceous schist*, possessing oblique cleavage, which graduates into hard varieties, suggesting aphanitic greenstone. On both sides of this clay slate is the magnetic rock which, where observed, is an *actinolite schist*, altered in places to some oxide of iron; sometimes the black, which takes the form of the actinolite crystals through pseudo-morphism. The actinolite schists, rich in iron, possibly to the point of producing merchantable ores, near the quarter-post between Secs. 27 and 28, are believed to belong to the same bed, XVI. See Plate VIII.

The few outcrops of *greenstone*, massive and schistose, found on the N. E. side of this magnetic range on Secs. 36 and 26, may belong with the actinolite schists, or to the overlying diorite bed XVII, involving a sharp fold in bed XVI, some indications of which were to be seen.

It seems probable that nearly all the massive *diorites* and associated *hornblende* rocks for several miles belong to one considerably plicated bed, XVII. The facts supporting this hypothesis will be seen by examination of Plates VI and VIII. The hornblende character of this bed is very pronounced, and the rock is undoubtedly a true diorite, which rock can be studied to excellent advantage here. At several points various amphibolic, micaceous, chloritic and argillaceous schists, associated with or graduating into massive varieties, were observed, which belonged to this bed and apparently to its upper portion.

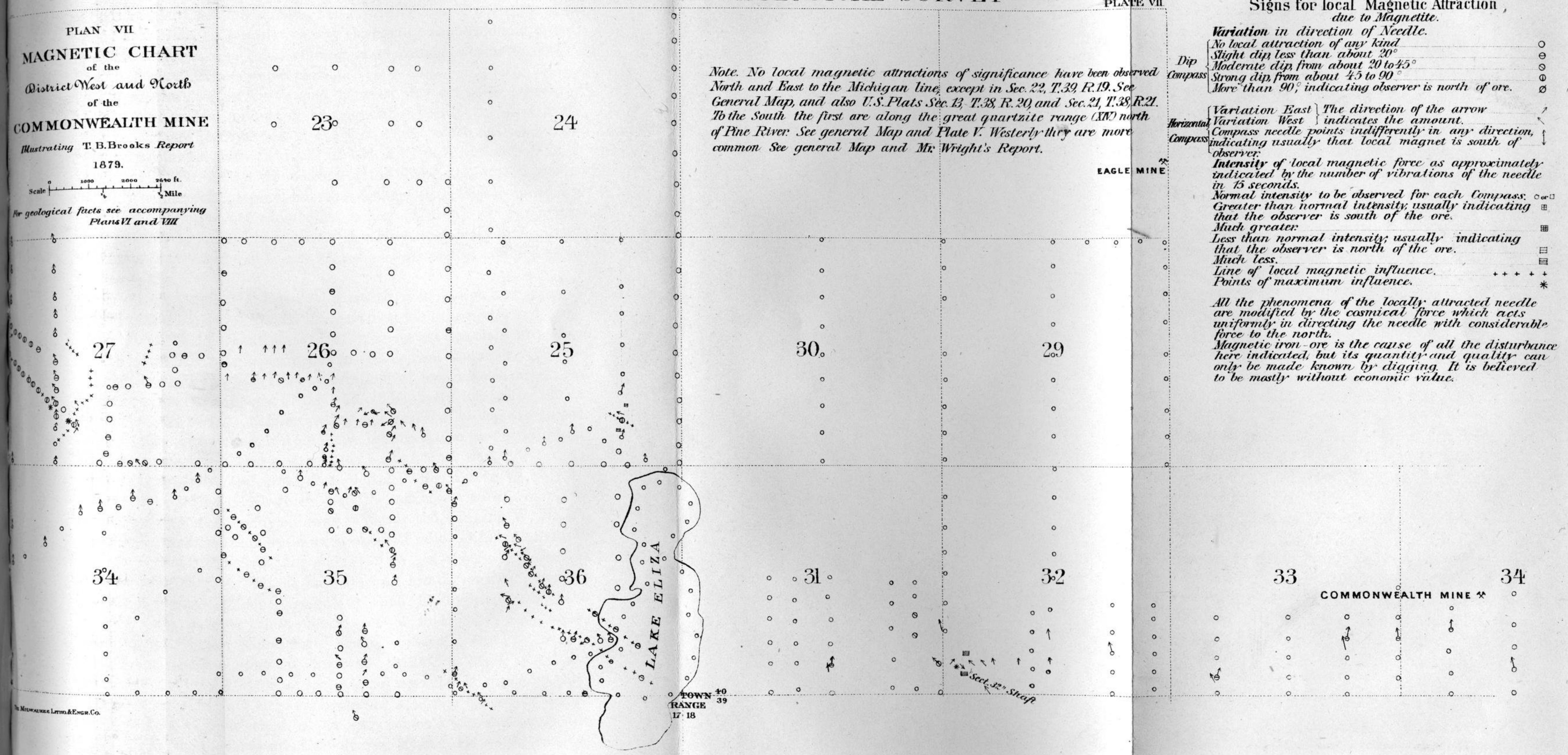
Immediately overlying and graduating into the softer argillaceous and chloritic layers just named, is a thin bed of *carbonaceous shale*, sometimes graphitic, in which there are quartz veins. This rock is best exposed in a N. W.–S. E. line passing near the corner of Secs. 27 and 35.

Next above, and forming the youngest member of the Lake Eliza series, is the *actinolite schist* bed, XVIII,[1] which forms an irregular

[1] On Plate VIII, a second hypothetical section is given, marked "possible folds," which makes the carbonaceous shale belong to bed XV, and this great actinolite schist bed the equivalent of XVI. Some facts strongly support this hypothesis, but the balance of the evidence is in favor of the assumed structure.

WISCONSIN GEOLOGICAL SURVEY

PLATE VII



synclinal basin extending, so far as exposures enable us to determine from the S. quarter-post of Sec. 35 to the N. quarter-post of Sec. 34' This rock differs from the actinolite schist of bed XVI, in being more typical, usually less ferruginous, and in the absence of clay-slate as an associated rock. A peculiar variety containing contorted and broken laminæ of quartz, sometimes a breccia in appearance, characterizes this bed, and may mark its upper portion.

No exposures of rock are found between this actinolite schist and the Pine river, save an outcrop of magnetic actinolite schist, near the center of the W. half of Sec. 2, T. 39, R. 17 E., which has some characters in common with the rocks of bed XVI, and less with XVIII.

In the N. W. bluff of Pine river, at the elbow, are large exposures of a very soft, reddish-gray, unctuous-feeling slate, which splits into long, slender prisms of rhomboidal section [2731–3]. It is a hydro-micaceous rock, probably sericite. A related rock was found in test-pits three-fourths of a mile east of the Commonwealth, to which series it may belong.

The above sketch of the general character, distribution and sequence of the Lake Eliza rocks, taken in connection with the plates and maps, will, it is believed, be sufficient for all who are not especially interested in the minute details, especially as to lithological character. For the benefit of such, the following descriptions of sections are given; the one east and the one west of the lake. They were located on the results of work in 1874, before the Commonwealth mine was discovered. On present information, it would have been better to pass one through the mine, that is, farther east, and the other farther west.

Description of Geological Section A-A'. See PLATE VI.

a. Brown to grayish-green, banded, *actinolite schist*, in places magnetic and occasionally siliceous. Heavy bed, striking W. N. W., in which direction it can be followed one-half mile. Dips high to south [2676–9]. At 175 steps N., and 1175 W. of the S. E. corner of Sec. 35, T. 40, R. 17, is an obscure brown variety, mottled and weathered, splitting irregularly, and highly contorted, indicating unmistakably the presence of a fold [2682–3]. About 700 steps N., the same rock again appears. Just E. and S. of the S. quarter post of Sec. 27 [2705], as well as at several points in the S. E. qr. of section, and near the W. quarter post of Sec. 35 [2688–92], are large exposures of a highly contorted, banded actinolite and quartz schist, which often presents a brecciated appearance from the breaking up of the quartz layers.[1] It is an interest-

[1] See my Mich. Geol. Report, 1873, Vol. II, p. 285.

ing fact that this variety, *i. e.*, holding saccharoidal quartz laminæ, is always highly contorted. It belongs undoubtedly to the great actinolite schist bed (XVIII), which our hypothesis of structure (Plate VIII) makes a synclinal. It presents a great range in variety from the presence of accidental minerals and weathering, which can be advantageously studied in the north part of Sec. 34 and south part of Sec. 27 [2693–2712].

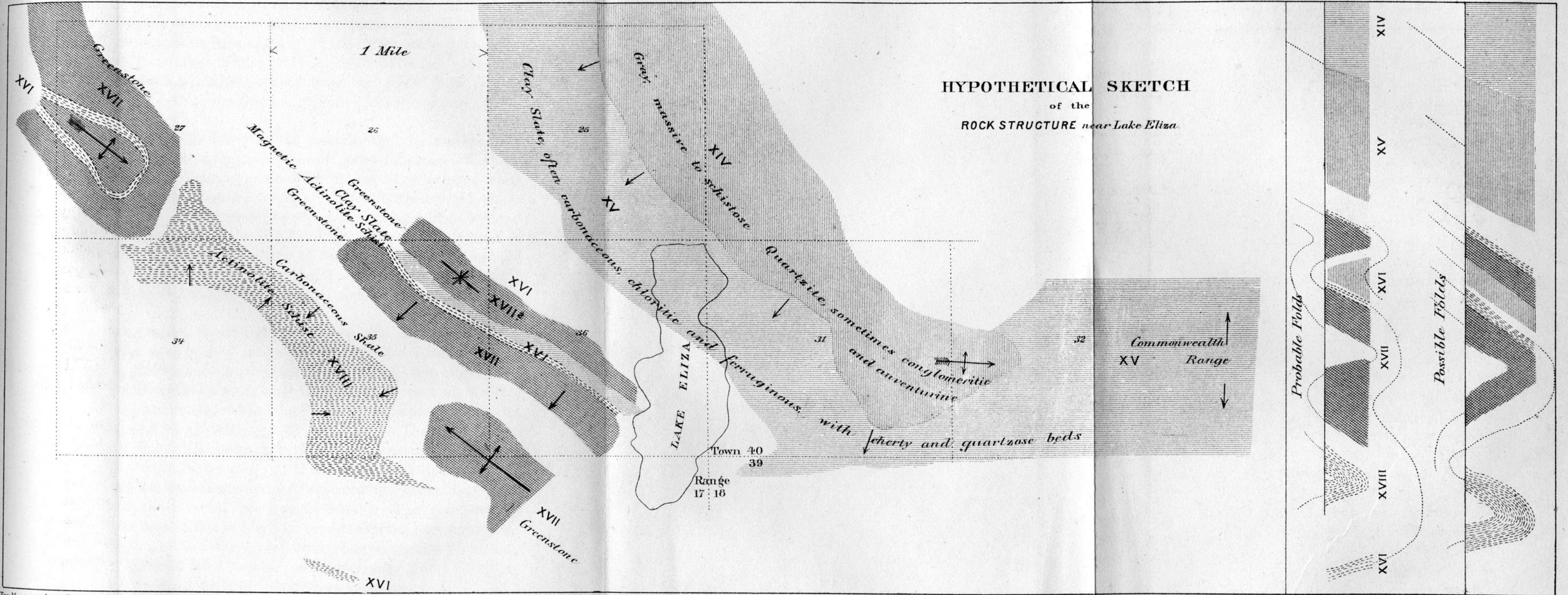
a'. Immediately south of the range of actinolite schist, and near the line of the section, is an amphibole schist [2653], the structural relations of which with *a* are not made out.

a. On the north side of the actinolite schist, and therefore, as we suppose, older, is a beautiful and rare variety of *mica schist*, associated with weathered pyritiferous *clay-slate* and *chloritic schist* [2649–52]. West and north, and probably in the same horizon, is the graphitic (carbonaceous) schist [2664]. An identical rock, occupying the same stratigraphical position, occurs in a N. W.-S. E. bed of considerable thickness, passing near the corner of Secs. 27–35 [2662–5], associated with soft slates and holding narrow veins of white quartz. The rock seems identical with the carbonaceous shale of the Commonwealth range, and may belong to the same bed, which is possible with the structure shown on the second section of Plate VIII. I have, however, here regarded it as younger, and placed it, provisionally, as the upper member of the underlying great greenstone bed XVII, to which it may be supposed to be connected through its associated soft slates, but to which bed, on the whole, it has little affinity.

b. This outcrop is a fair example of the transitions and associations of greenstones with hornblendic and mica schists. The following varieties were observed: hornblende schist, containing biotite, chloritic in appearance [2638]; fissile mica schist [2639]; micaceous greenstone [2640]; micaceous diorite [2641]; micaceous greenstone schist [2642]. It will be observed that these rocks have some resemblance to *a''*, but it is believed they are associated schistose and altered varieties of the great greenstone bed XVII? so extensively developed to the N. and E., as well as on Sec. 27.

Closely related schists occupying the same stratigraphical position occur on Sec. 27, 300 steps N. of S. E. corner [2656–8].

c. to *f.* On the E. ½ of Sec. 35 and S. ½ of Sec. 36 are numerous exposures of a dark-colored, coarse-grained, massive to schistose rock related to the greenstones, presenting an usually large number of varieties, which may be said to lie between black, coarse-grained hornblende rocks on one side, chloro-micaceous, and related schists on another, with true diorites for the third side. The massive green-



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stones and associated schists on Sec. 27 [2674–95] are believed to belong to the same bed, as will be seen on Plate VIII, which gives hypothesis of structure. The micaceous, chloritic, and argillaceous schists, and perhaps the carbonaceous schist, associated with greenstone schist described under *b*, constitute the upper portion of this bed. The lower portion is made up of the more massive varieties, in which, however, semi-schistose beds appear. It is only necessary to mention the prevailing varieties: diorite [2611–13, 2643, 3375–7]; greenstone schist [2621, 2625, 2628, 3381]; hornblende rock [2622, 2624]; micaceous diorite [2641]; pyritiferous diorite [2636]; micaceous diabase [2620].

Next N. E. of, and underlying the great diorite bed, is an interesting stratum of alternating members of *magnetic actinolite schist*, having oblique cleavage and graduating into hard *argillaceous schist* and perhaps obscure *greenstone schists*. This affords a highly magnetic belt, which can be traced by outcrops shown on Plate VI, and magnetic attractions on Plate VII, from the center of the S. half of Lake Eliza N. W. to near the center of Sec. 26. What is believed to be the same bed appears again near the W. quarter post of Sec. 27, where it is supposed to form an anticlinal sinking to the S. E. See Plate VIII.

g. Passing to details we find at outcrop *g*, Sec. A-A, light-brown, magnetic friable varieties of *actinolite schist* [2595–6]; others banded and ochrey [2597]; in some instances the crystals are quite large [2598]. On Wakefield's road, near the N. quarter post of Sec. 35, are indentical and related varieties, one being hematite-red, exposed on both sides of the clay-slates [2600–2, 2560–3]. The most highly ferruginous variety, constituting perhaps a merchantable ore, was seen just N. of the W. quarter-post of Sec. 27 in a test-pit. The red oxide of iron had here almost entirely replaced the actinolite, retaining, however, the form of its crystals [3394]. The prospects for merchantable ores in this bed will be considered in the accompanying economic report of Mr. Wright. I would, however, remark that this is a totally different ore in origin and appearance from either the Commonwealth-Eagle or Breen–Quinnesec ranges, and is found in a younger horizon. Regarding the argillaceous and apparently middle member of this bed, it is interesting as presenting everywhere a true cleavage[1] which is constant in strke and dip, *i. e.*, N. 80° W., and nearly vertical, and varying from a coarse and imperfectly fissile slate [2564–75] laminated with quartz, to a hard, semi-schistose, ringing

[1] See remarks on cleavage in Chap. III, under Clay Slate.

rock [2583–7], which seems more like aphanitic greenstone than any form of argillite. The best point to study the slate as to its varieties and structure, is just N. W. of the outlet of Lake Eliza, where the bedding planes are highly contorted and quartz laminæ abound [2564–8].

i. Bordering this magnetic belt on the N. E., and perhaps belonging to it, are several outcrops of *greenstone* and related schist [2549–54], which may possibly be the lowest member of bed XVII, with which this rock has lithological affinities, brought there by a sharp fold.

Passing a belt of low, flat country without outcrops, but supposed to be underlaid by the uppermost soft slates of bed XVI, we arrive at the Commonwealth range, here composed, so far as could be judged from the few exposures, of *soft argillaceous* and *chloritic slates*, generally more or less carbonaceous. Some varieties of the latter rock are very light, jet black, exceedingly soft and homogenous slates, evidently highly charged with carbon [3410]. The graphitic varieties are quite common, are usually harder, more schistose, and sometimes porous [2196]. True fissure veins filled with quartz showing the comb structure, have been more frequently observed in this rock than in any other [3409].

The identity of this rock with that described under a″ and its possible equivalency, has been pointed out. The effect of weathering on this soft rock has nearly always covered it with soil, and it is only by thorough search under the roots of fallen trees, aided by a few test-pits, that we are brought to believe that it constitutes a broad belt N. and W. of Lake Eliza, limited on the E. by the quartzite.

Easterly from the lake, on the Commonwealth range proper, and especially along the face of the bluff which forms the south side of the range, exposures are more numerous, especially in the banks of the rivulets. Here, about one-quarter of a mile S. W. of the Commonwealth mine, the so-called "plumbago mine" has been opened. The same associations of clay and chloritic slates, in great variety and insensibly graduating into each other, occur [2185, 2369, 2404–5]. Highly altered, mottled, porous varieties are seen in test-pits on the east side of Sec. 34 [3452–62], and identical altered varieties along the north line of Sec. 25, T. 40, R. 17 [3411–22].[1] Hard, black varieties,

[1] "*Paint mine*" *and bog-ores.* — The rusty, weathered, porous character, apparently caused by the decomposition of iron pyrites, of the soft schists of this bed, has already been mentioned. Although belonging to Mr. Wright's Economic Report, it is proper here to suggest the probable bearing of this fact on the origin of the brown ferruginous conglomerates cemented by iron-oxide, which can be best seen at Mr. Keyes' "paint

with ochrey quartz and chloritic beds, occur at Pumpelly's hill, at N. qr. post, Sec. 6, T. 39, R. 18.

Ferruginous argillaceous or chloritic schists are abundant N. of "Sec. 32" mine.

The alternating beds of banded ferruginous quartz schists (flag-ores), soft iron-stained argillaceous and chloritic schists, and especially the characteristic layers of white, ochrey, saccharoidal quartz, banded with carbonaceous slate, which characterize the Commonwealth [3463–9] and Eagle [2152–4, 3277–80] mine series, together with the associated ores, will be fully considered in Mr. Wright's economic chapter.[1]

j. Returning to the line of our section we find ¼ mile N. of lake Eliza at the base of bed XV, *magnetic actinolite schists*, interlaminated with thick and thin layers of white quartz and containing a layer two inches thick of quite pure, black, magnetic ore [2186], which gave 49 per cent. of metallic iron. This passes north into an irregularly banded schist, gray, brown, and black laminæ of arenaceous quartz, magnetite and actinolite schist, in places contorted [3405–7]. Next to the north is seen a brown, hard, magnetic, slaty schist, with iron-rust in seams, which gives a dark graphitic streak.

k. Northeasterly of the slate (Commonwealth rocks) and underlying them, is the quartzite bed XIV, which, near this section, forms the highest hills in the vicinity. The following varieties are exposed, from south to north:

Coarse-grained *quartz-schist,* holding white reddish and blue grains of quartz.

Quartzose *chloritic-schist*, resembling novaculite, but coarser.

Quartzite, massive to schistose.

Chloro-quartz-schist, colored red on splitting planes.

Honey-yellow to purplish-red *quartz-schist.*

Light-gray, faintly banded, massive to schistose, *quartzite*, with a distinct N. E. dip of 78° in the splitting planes. Here is a strong attraction and a local magnetic variation of 70° W.

Light-gray, faintly banded, *quartz-schist.*

Grayish-white *quartz-schist;* dip of splitting planes 85° S.

Two more beds of same variety.

---

mine," near the center of Sec. 25, but which occur at several other points in the neighborhood. They are apparently formed by the cementing and ferrification of the soil, roots, etc., together with the underlying sub-soil, by the iron-oxide released by the supposed decomposition of the pyrites. No true bog-ores were observed, but they will probably be found by exploring in the swamps.

[1] He has already given a preliminary description and sketch of the Commonwealth mine in the Annual Report of 1877.

Another bed with several splitting planes, corrugated like the mica schists, suggesting minute ripple marks.

Light, greenish-gray *quartz-schist.*

Another bed of same; dip of splitting planes 82° N. E.

Covered, but judging by the number of boulders of *chloritic quartz schist,* suggesting novaculite, which lie on the surface, it is underlaid by this rock.

In a recent test-pit which is about 680 steps N. and 610 W. of the S. E. corner of Sec. 25, *i. e.*, near *k*, is exposed irregularly banded *quartzite,* in places conglomeritic, and *chlorite schist.* Strike N. 60° W., dip 90° [3404]. This is probably the uppermost layer, since the plumbago is also exposed.

About 100 steps S. E., at the brow of the hill, the quartzite is banded and highly contorted, to the point apparently of breaking up some of the laminæ into fragments, giving it the appearance of a true conglomerate, which, indeed, it may be, since the equivalent of this bed, N. of the Pine river, is a true conglomerate-schist.

l. Quartz-schist, light-gray to red on weathered surface, succeeded by schistose and massive *quartzites* for 1000 feet.

Covered about 700 feet.

m. Chloro? quartz-schist.

Covered about 500 feet.

n. Two beds of *quartz-schist* with an interval of 100 feet between them. The northern outcrop has a northerly dip of 75° in splitting planes.

o. Quartz schist, in some places slightly chloritic and containing conglomeritic layers with rounded pebbles of white quartz; also jasper and reddish mica [2187]. Some beds have a southerly dip of 80°.

p. Quartzose schist, in places conglomeritic with pebbles of white quartz, and in one place highly contorted; 800 paces west is a mass of *quartzite* 1800 feet thick, the northern part of which is a micaceous *quartz-schist,* the red mica lying in planes oblique to the principal splitting planes [2213]. Another variety is a massive gray quartzite with minute silvery micaceous scales (aventurine).

Covered about 2000 feet, except one outcrop of *quartz-schist.*

q. Altered *conglomerate,* from a test-pit.

Cleavage? bedding and joint planes of the quartzite.

The bedding of the quartzite XIV is very obscure, and it is only after many days' observation in 1874 and 1878, supplemented by the later valuable notes of Geo. A. Fay, that I am able to distinguish with considerable certainty between the several kinds of structural planes.

(1) Most conspicuous, and to be seen nearly everywhere, is a fine, straight, parallel "linear elongation" of the particles, suggesting the grain of wood. These lines and the planes which they mark are very constant in direction, averaging N. 80° W., and differing, probably, not more than 10° from this bearing anywhere on Secs. 24 and 25. Their dip is as constant, being about 80° to the S. These planes seem to often mark a semi-schistose structure, producing imperfect flags. The strike and dip of these planes is exactly parallel with that of the clay-slate of bed XVI, about a mile and a half S. W., and is not parallel with any considerable number of known bedding planes, which could not be the case, however, since they are constantly varying in direction.

These facts, in connection with what follows, leads me to believe that this grain ("wuchs") is due to the same cause which produced the cleavage in the clay-slate. Incipient or false cleavage planes might be used to express the idea. I have seen a true granite at Meissen on the Elbe, which splits into thin flags.

(2) Nearly at right-angles with the above and dipping at a high angle, are occasional well-defined planes and cracks which are unquestionable joints.

(3) At rare intervals and usually seen after close inspection, can be found a faint banding or striping in the quartzite, and, less seldom, a seam or layer of another rock, *e. g.*, chlorite, which are the true bedding planes. They are found to vary from N. by W. to W. N. W., averaging perhaps near the general quartzite area as marked on Plate VIII. The dips of these planes are as irregular as the strikes, although usually at high angles and to the south; northeasterly and easterly dips were observed, and in one instance as low as 60°.

Of the several points where these phenomena can be seen, two are on the Indian trail leading north through Sec. 25, *i. e.*, 1800 steps N., 900 W., and 1900 N., 900 W., of S. E. Cor. [3401–3]. Not enough authentic strikes and dips of bedding planes were found to justify us in attempting to make out the structure of the quartzite bed. With minor folds it is believed to be an anticlinal.

Description of Geological Section, B-B', crossing "Sec. 32" shaft, Commonwealth range, and Eagle Mine. From south to north.

a. "Sec. 32" shaft. Near the S. W. corner of Sec. 32, T. 40 N., R. 18 E., Wis., is a shaft 62 feet deep, which began with one foot of *specular ore* at the top, increased to 8 feet, then narrowed up to less than one foot at a depth of 20 feet, and had at the bottom a thickness of about ten feet, according to Mr. James Tobin. Apparently about two-thirds of the material from the shaft is a rich, merchantable, granular, specular ore (martite), not slaty, but in places showing a dull banding. The upper portion contained the greatest admixture of rock. Except in its containing somewhat more pyrites, this ore is identical in appearance with the first class, granular, hard ores of the Marquette region.

Although in the Commonwealth range (XV), this ore differs greatly in appearance, the Commonwealth ore being softer, redder and more earthy, suggesting the rich brown varieties of the Marquette soft hematites. Analyses and fuller descriptions of this ore will be given in Mr. Wright's economic chapter.

Both walls of the ore-mass are banded *quartz schist*, holding laminæ of magnetic and specular ore and martite. The quartz is of the saccharoidal character which characterizes this range, and in places contains flattened pebble-like pieces — whether originally pebbles or since formed by the faulting plications and attritions of the laminæ, was not determined. Within 50 steps easterly and in the direction of the strike, are the characteristic chloritic, argillaceous and carbonaceous schists and slates, uncovered in test-pits, rendering the presence of a fault probable.

In the vicinity can be found ferruginous, quartzose, chloritic and argillaceous schists and slates in every variety [2400–8, 2184, 3445–51].

The natural exposures of ferruginous rocks and strong magnetic attractions, which were first observed by Col. Chas. Whittlesey at this locality, many years ago, drew attention to its promise of merchantable ores; but it was not until test-pits were sunk by H. D. Fisher, under the auspices of the Commonwealth Iron Co., H. A. Tuttle, president, in the summer of 1876, that a workable deposit was found on Sec. 34. The locality, on the whole, has much resemblance to the Michigamme range, except that it is far less magnetic. The horizontal needle varied, however, from 140° E. to 70° W. within 100 steps.

Between the shaft and the road, to the north, is a considerable bed of argillaceous or chloritic slate, presenting much variety in color from the presence of iron, showing green, red, brown, drab, and beautifully mottled colors [2404–5].

b. Under the roots of a tree is a loose ledge of an altered earthy brown arenaceous *chloritic? schist* [2183], which produces magnetic variation. This rock resembles and has about the same stratigraphical position, *i. e.*, at the base of XV, as *(j)* of the preceding section.

c. Clay slate and *(d) quartzite*, with covered spaces separating them from the preceding and following described rocks.

e. Argillaceous and *chloritic* slates with *carbonaceous* slates on the S.

Whether the quartzites *d* and *d'* [2420] belong to XV or XIV, is not known. It is probable that no sharp line divides them. There can be no doubt, however, but that the following belongs to the older formation:

f. "Aventurine" gray *quartzite*. A very extensive outcrop, in every way similar to *h* described below, except it is more massive, presenting but few faint traces of the linear parallelism (incipient cleavage) described in considering this quartzite where it is crossed by the previous section. The term *aventurine* was provisionally applied to distinguish this rock on account of the presence of minute scales of a reddish micaceous mineral which gives the fresh fracture in some specimens a beautiful sparkling appearance, and suggesting the possibility of its having value for ornamental purposes if polished.

Descending the quartzite hill, we pass several outcrops of quartzite; we find N. of the road at 975 steps N., 1030 W., a loose ledge of a tough, blackish, fine-grained schist [3438–9], with quartz laminæ, and carbonaceous slates near it; 150 steps to the N. is another large exposure of quartzite.

g. Dark-green, fine-grained schist, resembling some chloritic greenstone schists, but which Mr. Julien calls *biotite-gneiss* [3436–7]. The resemblance of this rock to that found on the N. side of the quartz-conglomerate, near the S. E. corner of Sec. 20, T. 39, R. 18 [2809–10], is interesting, since they probably have the same stratigraphical position, that is, immediately underlie the great quartzite; and in connection with the supposed equivalent series in the S. E. $\frac{1}{4}$ of Sec. 13, T. 39, R. 17, afford the best clue to the character of bed XIII. This is the more important, since the quartzite entirely disappears to the eastward.

h. In a hill about 75 feet high is a large exposure of massive, grayish to reddish *quartzite*, with no evidence of bedding except on a few square inches at one point. On the top of the ridge, it is light gray and massive [3434]. On the south crest the weathering influence has in places extended nearly an inch, coloring the rock reddish and yellowish, and rendering it porous. Fine veins of white quartz cross what appears to be bedding.

To the north is a whitish-gray *quartz schist*, holding scales of red mica (aventurine?), and being colored brick-red in certain irregular, sharply-defined blotches which extend into the rock.

Argillaceous or *chloritic* slate in a bed 8 feet thick, imbedded in the quartzite near top of the hill. Strike N. 65° W., dip 80° S. [3433].

Chloro-quartz schist, with seams of reddish mica. Whitish-gray, highly crystalline, massive to schistose, quartzite, banded with aventurine layers.

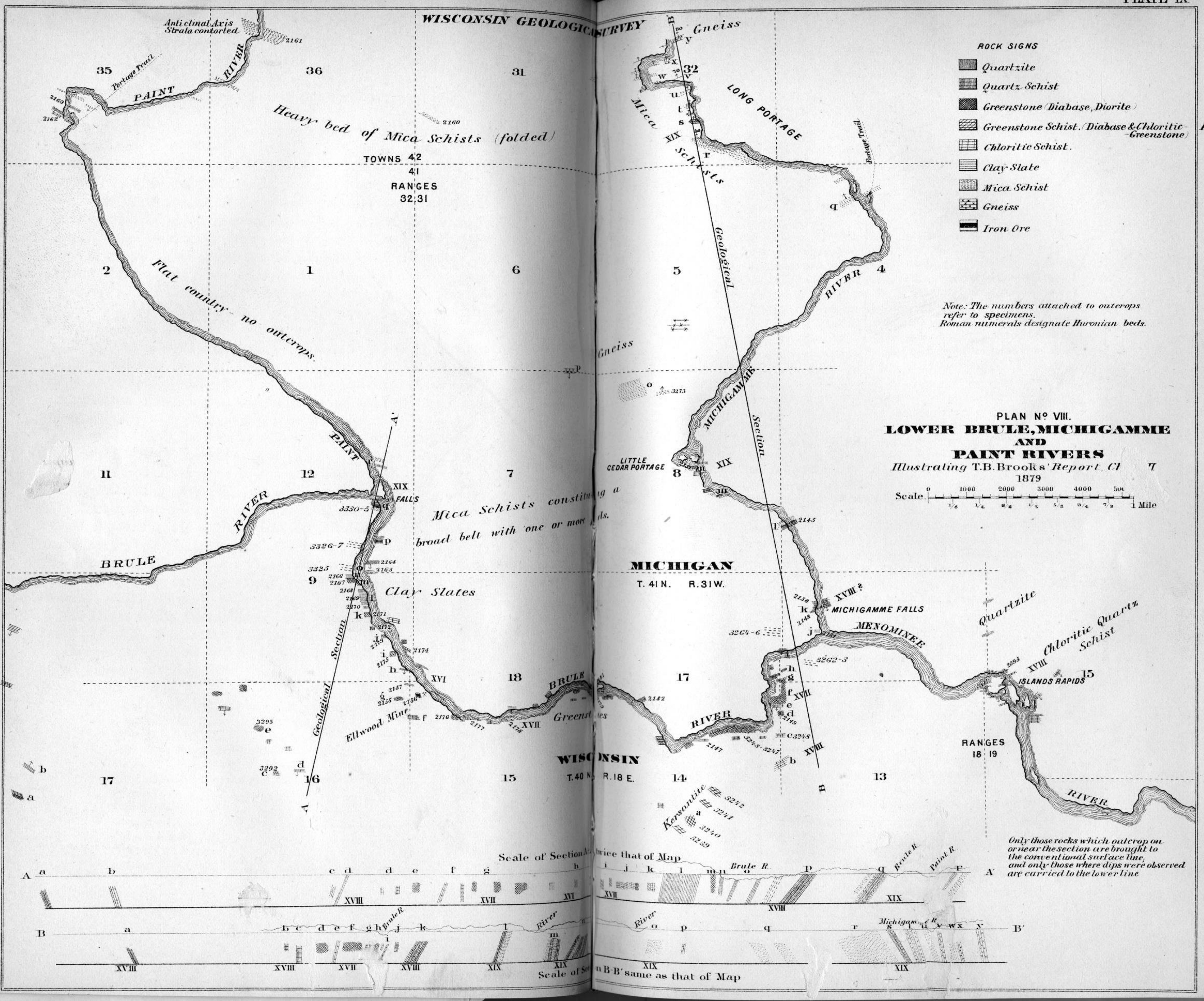
j. k. Passing N. E. over a flat country without outcrops or attractions for $2\frac{1}{2}$ miles, we reach the Eagle mine, where there is a repetition of the Commonwealth rocks, already fully described, save that no workable mass of equally rich ore has been found, and the orey rocks suggest rather hydrated or brown ores than red. The workings have exposed a thick bed of what might be called hematitic "flag-ore," the laminæ being highly contorted [2154, 3280–4]. The usual irregular vein and nodular-like masses of quartz which generally occur in sharply plicated beds, are found here. Clay slates occur south of the ore, and are extensively developed to the N. W. [3277–8]. East and south is an abundance of carbonaceous slate. In the hill just south of the exploration house are the best examples of the occurrence of white and ochrey saccharoidal laminæ in clay and carbonaceous slates [2153, 3279]. For analyses and full description of this promising iron location, see Mr. Wright's economic chapter.

The broad belt of flat country without outcrops or magnetic attractions dividing the Commonwealth and Eagle iron ranges, has made it impossible to discover their structural relations. Their identity in lithological character places their equivalency beyond all question. The absence of the great quartzite at both the Eagle and the Commonwealth is puzzling, and points toward the probability of each being an anticlinal. The contorted laminæ at the Eagle, point unmistakably to the presence of a fold, but no such evidence was observed at the Commonwealth. Since future workings are likely to soon supply additional facts, it is not worth while to conjecture farther on present data.

7. Lower Brule, Michigamme, and Paint rivers sections. T. 40 N., R. 18 E., Wis., and T. 41 N., R. 31 W., Mich.

Description of Geological Section A-A.' See Plate IX. From south to north, crossing folds.

No. of bed.		*Thickness in feet.*
a.	Light-grayish-green, fine-grained *greenstone*, somewhat schistose and chloritic.	
	Covered.	
b.	Dark-green *chloritic schist*, somewhat arenaceous.	
	Covered.	
c.	Light greenish-gray *greenstone schist* (kersantite?) [3292]	100
	Covered	100
d.	*Chloritic schist*	50
	Covered	500
	Chloritic schist	75
	Covered	150
	Chloritic schist	75


WISCONSIN GEOLOGICAL SURVEY
PLAN No VIII.
LOWER BRULE, MICHIGAMME AND PAINT RIVERS
Illustrating T.B. Brooks' Report, Ch 7
1879
Scale 0 1000 2000 3000 4000 1 Mile
ROCK SIGNS
Quartzite
Quartz Schist
Greenstone (Diabase, Diorite)
Greenstone Schist. (Diabase & Chloritic-Greenstone)
Chloritic Schist.
Clay Slate
Mica Schist
Gneiss
Iron Ore
Note: The numbers attached to outcrops refer to specimens.
Roman numerals designate Huronian beds.
Anti clinal Axis Strata contorted
Portage Trail
PAINT RIVER
Heavy bed of Mica Schists (folded)
TOWNS 42 41
RANGES 32 31
Flat country - no outcrops.
Mica Schists
LONG PORTAGE
Geological Section
Gneiss
MICHIGAMME
LITTLE CEDAR PORTAGE
FALLS
Mica Schists constituting a broad belt with one or more folds.
BRULE RIVER
Clay Slates
MICHIGAN
T. 41 N. R. 31 W.
MICHIGAMME FALLS
MENOMINEE
Quartzite
Chloritic Quartz Schist
ISLANDS RAPIDS
Ellwood Mine
Greenstones
WISCONSIN
T. 40 N. R. 18 E.
RANGES 18 19
Kersantite
RIVER
Only those rocks which outcrop on or near the section are brought to the conventional surface line, and only those where dips were observed are carried to the lower line
Scale of Section A-A' twice that of Map
Scale of Section B-B' same as that of Map

No. of bed.			*Thickness in feet.*
		Covered	200
	e.	Light greenish-gray, fine-grained, massive, *chloritic greenstone* (kersanite) [3295]	100
		Covered	400
	f.	*Chloro-quartz schist*	75
		Covered	400
XVII.	*g.*	Fine-grained, massive, jointed greenish-gray *diabase* [2155]	250
		Just east in the edge of the bluff overlooking the river, the greenstone becomes more schistose, apparently chloritic, and contains narrow, irregular veins of dark purplish to brown, fine-grained, hematite ore [2156, 3300]. This is the "Ellwood Mine," where considerable work has been done on veins 2 to 12 inches thick. In 1874, I dissuaded the owners from working here, but they did not follow the advice. They are the best characterized, in fact, except the Gilmore mine in the Marquette region the only, veins of iron ore I have seen.	
		Covered	150
XVI.	*h.*	Greenish-drab *chloro-argillaceous ? slate,* in places colored with oxide of iron [2157]	100
		Covered	250
		Slate, identical with *h*	150
		Covered	150
		Slate, identical with *h*	50
		Covered	225
XVII.	*i.*	Very tough, fine-grained, green *diabase* [2175]	100
		Covered	50
	j.	Tough, hard, green, fine-grained *hornblende schist,* in places massive and jointed [2172], graduating towards *i* into a softer variety, suggesting chloritic schist, and a little farther south becoming soft and exceedingly tough [2173][1]	400
		Covered	400
	k.	Tough, blackish-green, *hornblende schist,* with oblique cleavage [2171][1]	20
		Soft, olive-green, shaly, *chloritic schist* [2170]	20
XVIII.	*l.*	Brulé *clay slates.* All shades of slate color, graduating into prevailing greenish-black varieties [3315–20]. In the southern part of the bed is a grayish-black, carbonaceous variety [2169]. Cleavage is perfect, and appears to be the bedding, as no other marking can be seen. Strike of cleavage seams N. 85° E., dip vertical. Contains large, bunchy veins of white quartz, around which the slate laminæ are warped	600
		Covered	100
	m.	Massive to schistose, green to grayish-green, *hornblende rock* [2167]. Micaceous and dioritic varieties occur [3321–2]	100
		Covered	30
	n.	Gray-green, perfectly laminated *clay slate,* like *o,* possibly chloritic [2166]	80
		Covered	150
	o.	*Chloritic (argillaceous ?) slates,* from green to black, splitting	

[1] Mr. Wright provisionally called these rocks, *chloritic amphibole rock.*

No. of bed.			Thickness in feet
		into long, thin prisms, containing bunchy veins of white quartz, conforming with cleavage and bedding (?) planes [2164]. A system of strong and nearly horizontal joints is conspicuous. On the south is a black slaty and apparently carbonaceous variety [2165]	300
		Covered. (Later observations find mica schists on the west side of the river [3326-8].)	
	p.	*Quartz schist* containing micaceous layers, jointed and in places massive, becoming micaceous and schistose to the south	150
		Covered	800
XIX.	q.	Series at mouth of Paint river.	
		Mica schist	25
		Covered	15
		Mica schist passing into	6
		Quartzose mica schist graduating into	10
		Mica schist which passes into	9
		Quartzose mica schist	40
		Massive *quartzite*	20
		Mica schist with quartz veins	20
		Massive gray *quartzite*, jointed, forming barrier rock at falls	40
		Covered, possibly a fold.	
	r.	*Micaceous quartzite*	25
		Covered	50
		Mica schist	25

Description of Geological Section B-B'. See PLATE IX. From south to north, crossing several folds, making it impossible to determine the thickness even approximately.

No. of bed.			Thickness in feet.
	a.	About ½ mile west of the section in the S. ½ of Sec. 14 are several outcrops of more or less schistose greenstone, often apparently chloritic, which Mr. Julien designates *kersantites* [3239-42]. The apparent strike of these rocks, about N. W., and their isolation, makes it impossible to establish their relation with the following series.	
		Covered.	
XVIII.	b.	*Chloritic (?) schist.*	
		Covered.	
	c.	*Chloro-quartz schist,* probably argillaceous. Half a mile west in the same bed is chloro-clay slate [2147].	
		Covered.	
		At the Islands rapids the supposed equivalents of *b* and *c*, are more fully developed. See description below.	
XVII.	d.	Coarse-grained, dark grayish-green, *hornblendic greenstone* [2149]. Ledge 150 feet high. Westerly in this bed are several outcrops of various greenstones.	
	e.	*Chloritic schist.*	
	f.	*Hornblendic greenstone* like *d*, and hornblende schists [3249-51].	
	g.	*Chloritic schist.*	
		Covered.	

No. of bed.			*Thickness in feet.*
		Chloritic schist.	
	h.	Fine-grained *diorite* [3253]; to the north becoming micaceous and chloritic [3255-6].	
		Covered. (W. N. W. on river bank are ledges of *greenstone,* with large dykes of quartz and *chloritic schist.)*	
		(Later observations find *chloritic (?) schist* [3257-9] and *greenstone schist* [3260-1] between *h* and *i.)*	
	i.	Arenaceous *chloritic? schist* on north side of river. *Biotite schist* occurs to the east on the south side of the river [3262-3].	
		Covered.	
XVIII.	*j.*	Massive, jointed, gray, often micaceous, *quartzite,* with minute crystals of feldspar [2151, 3267]. About 500 steps west are *mica schists* [3264-6], and still farther west and north, is a highly altered, ferruginous, garnetiferous mica schist [3266].	
	k.	Michigamme Falls series.	
		Mica schist [2148]	50
		Gray *micaceous quartzite*	20
		Quartz schist, graduating into *chloritic,* with veins of white quartz and red feldspar	40
		Massive, coarse-grained, hard, jointed, *micaceous quartzite* [2158]	20
		Chloro? quartz schist, varying from a true massive *quartzite* to a micaceous schist	65
		Quartzose micaceous schist	50
		Covered	2,000
XIX.	*l.*	Micaceous *quartz schist,* graduating into a *mica schist* with corrugated surface [2145]	100
		Covered	1,000
		At Cedar Portage, and just below, are the following varieties of *mica schist* and *quartzite,* all dipping south:	
	m.	Minutely corrugated, soft, silvery, *mica schist*	200
		Covered	
		Micaceous quartz schist	
		Covered	
		Mica schist, not corrugated, and containing large grains of mica	
		Covered	
		Corrugated *mica schist*	
		Covered	
		Micaceous quartz schist	
		Covered	400
	n.	Massive to schistose, *micaceous quartzose* rock, in places a true *quartzite,* cut into prismatic blocks by strong vertical E. and W. joint planes. The dip of bedding planes is about 45° to the south	25
		Covered	50
		Mica schist	25
		Micaceous quartz schist	
		Covered	80
		Mica schist	40
		Massive schistose *micaceous quartzite* [2159]	
		Mica schist	

No. of bed.		Thickness in feet.
	Covered	20
	Massive greenish-gray *quartzite*, in places micaceous. Forms barrier rock of main fall	40
	Covered	185
	Typical corrugated *mica schist*, passing into a massive gray *quartzite*	25
	Covered.	
o.	*Mica schist*, somewhat flaggy	800
	Just east is a *micaceous quartzite* [3273].	
	Covered	350
p.	*Gneiss*	50
	Covered.	
	The following rocks, *q* to *y*, constitute the Long Portage series, dipping north.	
q.	*Mica schists* more or less quartzose, similar to and the equivalents of the Cedar Portage schists [1252–3], but here dipping north or in the opposite direction, proving that one or more folds have been passed.	
	Covered.	
r.	*Mica schist*, alternating with *gneiss*, generally flaggy or schistose [2452]	1250
	About 1¾ miles west, and a little north, is an outcrop of *mica schist* containing staurolite [2160]. The same rock crosses the Paint one mile farther west and north, where it also contains staurolite. This is important and interesting since this mineral characterizes the same bed of mica schist (XIX) in the Marquette region, where it is associated with andalusite. Neither mineral has been observed elsewhere in the series.	
s.	*Hornblende schist* or *gneiss*, black, slaty, banded with gneissic layers [2453]	100
t.	*Gneiss* and *mica schist*	300
	Covered	150
u.	*Staurolitic mica schist* on south, overlaid with *mica schist* and *gneiss* [2455]	400
	Covered	150
v.	*Gneiss*	100
w.	*Mica schist*	100
x.	*Micaceous quartz-schist* or *gneiss* [2381, 2457]	250
	Covered	500
y.	Gneiss	150

We have now arrived at the limit of the large scale map, Plate IX, which ends the detailed description. Referring to the atlas map of the Menominee region, we may carry an outline section several miles farther north and embrace some very interesting and little-known Huronian beds, which are undoubtedly the youngest of the series. Just above the head of the Long Portage trail is a heavy bed of *gneiss*, dipping north at a high angle. From this point to the Norway Portage, about seven miles N. E. by N., as the bird flies, are occasional outcrops along the river of *hornblendic* and other rocks, often *granitic* in appearance [2383–5, 2458–63]. They are probably the equivalents of the hornblendic and granitic rocks so prevalent for many miles to the eastward, as well as for some distance to the west and northwest. See general map. These rocks are assigned to the granitic bed XX. See *a*, Big Quinnesec section, No. 3.

Having crossed the broad synclinal, undoubtedly possessing minor folds, we find it limited on the north by the Norway Portage chloritic and hornblende schists, exposed for a thickness of over 1,000 feet [2387–98]. They dip south at a high angle under the granite hornblende belt just described, and are probably the equivalents of some portion of the Long Portage series on the opposite side of this synclinal, although these differ from the prevailing rocks of that series, in being decidedly more chloritic and hornblendic.

Islands Rapids beds Menominee river, on Sec. 18, T. 40 N., R. 19 E., Wis., from south to north.

Chloritic? slate with strong cleavage planes, graduating into a... *Quartzose schist*, and this into... Massive gray *quartzite* ...	80
Covered ...	300
Chloritic schist ...	10
Covered ...	70
Quartzite, with soft schistose layers...	25
Chloritic schist, with quartzose layers...	30
Covered ...	10
Alternating beds of *chloritic* and *quartz schist*, graduating into each other.....	65
Covered ...	25
A series of alternating beds of *chloritic schist*, *quartz schist* and *quartzite*......	50
River.	
Alternating beds of *chloritic schist*, *chloro-quartz* schist, and massive, jointed *quartzite* [2095] ...	80

Separating the quartzite and the chloritic schist is a vein of white quartz.
400 to 700 steps north is a massive, reddish-gray *quartzite*.

The above rocks belong to bed XVIII, so far as their age is fixed, and are supposed to be the equivalents of *b* and *c* of Section B-B′ above described, as well as of the Michigamme Falls series, *k*. These latter rocks are, however, micaceous. Since the Islands Rapids rocks were only provisionally named in the field, and no pieces taken, they may be more micaceous than chloritic.

CHAPTER III.

MINERAL COMPOSITION, TRANSITIONS AND ASSOCIATIONS OF THE MENOMINEE ROCKS.

While the leading idea of the following popular description of the Huronian rocks of the Menominee region, and comparisons instituted with rocks of corresponding age of other districts, is to make it useful to the explorer, prospector and land-owner, the grouping employed and the mode of treatment being based on their associations and transitions, one into the other, will, I believe, have interest to the geologist. It is too often the case that lithologists, from lack of opportunity or taste, describe and classify rocks with little reference to their relations to each other, their locality and stratigraphical position. Rocks made at one time, or at one spot, or under identical conditions, are here placed together so far as possible, although they may differ widely in composition and physical character.

"Nearly all rocks," says Prof. Dana, "are combinations[1] of two or more minerals, and are not definite compounds, hence not *species* in the scientific sense of the word, only kinds." The limits between these kinds are ill-defined, one graduating insensibly into the other. For example, the Huronian marbles pass, through the accession of sand, an original deposit, into quartzite — a totally different rock. In other cases the change comes through the alteration of an original constituent mineral into another, as in the case of the amphibole constituent of the crystalline greenstones, which is often observed completely changed into chlorite or mica. Pseudomorphism has converted certain actinolite schists into a kind of iron ore.

It would be very desirable to trace in every case the exact nature and, if possible, the cause of the observed transition, but so much of this as has not been incidentally covered by Dr. Wichmann must be left to the future investigator. Should such investigation aim at being comprehensive and exhaustive, the large number of specimens col-

[1] Mechanical mixtures, I think, would often express the idea better.

lected,[1] the facts here given as to location, stratigraphical position and associations, will, it is believed, have much value.

At present lithology seems to be in a chaotic and transition state. We are breaking away from old nomenclatures and methods of investigation, and have as yet little that is universally accepted, or that surely will be final. Chemistry and mineralogy, alone or united, dealing with collections of hand specimens, have, it seems to me, failed: let us add stratigraphy and give more weight to what can be gathered only in the field. If all united can bring a satisfactory nomenclature and classification to embrace all crystalline rocks, it will certainly be a great achievement in science. Meantime we need not be afraid to use our old and somewhat vague terms in describing obscure and ill-defined *kinds* of old rocks, which are constantly transforming themselves by devious ways into other equally vague *kinds*, striving, it would appear, to elude the grasp of the investigator.

Holding these views, I shall only attempt to separate and consider the most abundant and conspicuous groups which are bounded by the broader lines, and, in describing these, will deal chiefly with their more obvious physical characters, leaving to specialists the work of ascertaining the exact mineral composition, nice distinctions, and the application of the new nomenclature. By the aid of specimen numbers,[2] everywhere scattered through the text, reference may be made to the index and thence to the minute descriptions of Messrs. Wichmann and Wright.[3]

The former describes, in Chap. V, the minerals entering into the composition of rocks and their lithological combinations, and these need not be here re-described. Dr. Wichmann, who had no opportunity to study the rocks in the field, based his classification on the mineralogical composition and physical condition of the rocks. This classification has the sanction of some of the most eminent European lithologists, and is undoubtedly the best for the arrangement of specimens considered apart from their locality, associations and mode of occurrence. It was necessarily the only one available

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[1] My entire collection, embracing every specimen named in this report, is now deposited in the Amer. Museum of Natural History, N. Y., where it is accessible to students. Those specimens to be found at Madison are given in the index.

[2] Collection numbers are bracketed, thus, [ ]; typical-suite numbers, thus, ( ). See Index.

[3] Their chapters and this one having been prepared at widely different times and places, could not have been brought together had it been desired. Each one has attempted to make his work complete as far as possible without reference to the other. The original idea was that Mr. Wright's chapter on lithology should form a part of this report. It is, however, given in his independent report, following this.

to him. In the Am. Jour. Sci., Vol. XII, Sept., 1876, I arranged all of the Huronian rocks then known to me, and which had been determined by competent lithologists, according to Dana's classification (Manual of Geology, 1875).

I believe that the study of these rocks from the standpoint above indicated, in connection with the preceding sequence of strata (Table III), will throw light on the important question of how much weight can be attached to lithology in determining the equivalency of more or less widely-separated series of crystalline rocks. Writing on this subject, Mr. Hawes remarks that "like rocks indicate like conditions, and nothing more. If there is a general similarity in the composition and crystalline condition of a series of rocks in Michigan and on the Connecticut, it indicates like conditions for the accumulation of sediments and like location with reference to forces producing recrystallization. See remarks on greenstones, p. 233, Geol. of New Hampshire, Part IV." Had Mr. Hawes found certain kinds of rock occupying the same stratigraphical position in the two named, together with other intermediate series, an exceedingly improbable case, I admit, then we should have on a continental scale what I have found true in a basin which may have contained 20,000 square miles. See remarks on this subject in Chapter I, and of Dr. Hunt, in Appendix A. For reasons given in the letter of transmittal, I shall not attempt to follow it here. In a drift region, where there are few outcrops (and these hard to find in the forests), no fossils, vertical dips and strikes at every point of the compass, like the one in which I have labored, the field-geologist is driven to closely heed the lithological characters of the rocks as his best help in identifying beds. Following this method, I have proved to my own satisfaction that certain formations (*e. g.*, V and XIX) retain essentially the same mineral character for a distance of over 60 miles in one direction, and one of them at least for 150 miles in another. I see no reason why this may not be true for much greater distances, provided the basin be sufficiently extensive. The composition of other horizons is more or less, often entirely, changed.

1. Iron Ore Rocks. They are subdivided into:

A. *Magnetites, and magnetic quartzose and amphibolic rocks.*

B. *Specular hematites, martites and siliceous, jaspery and argillaceous hematitic rocks.*

C. *Limonitic quartzose ores and rocks, often containing turgite hematite and manganese.*

These varieties, passing as they do, by insensible gradations into each other, as well as each into the accompanying quartzose, hornblendic, magnesian and argillaceous rocks, present great difficulties in classification, especially if we attempt to introduce the economic idea, as in this case.

The more obvious transitions of these several ores of iron into each other and into the associated rocks, are as follows:

Magnetic and hematitic actinolite schists (sometimes called tremolite and anthophyllite), which occasionally become rich in iron through alteration of the amphibole mineral, are not uncommon.

Next to quartz, magnesian minerals, especially chlorite, are most abundant; making *chloritic varieties* of the iron ores not rare. Argillaceous schists, related to the magnesian, and often hard to distinguish from them, are common.

Magnetite,
Graduates through Martite, into
Hematite,
Which graduates into Turgite and
Limonite.

Through the accession of quartz, these ores pass into *quartzose varieties* and then into *ferruginous quartz schists*, and *ferruginous quartz conglomerates*. Cherty and jaspery forms of the quartz are common.

The hematites and limonites of the Menominee region (XV) are associated with carbonaceous shales and true clay slates. In the Marquette region, manganese accompanies the limonites.

In the Marquette region, it is well known that the pure magnetites are only found in the Michigamme district, the ores losing this property entirely to the eastward and westward, and, to a less extent, southward. The facts regarding two of the ferruginous horizons are here given. The Menominee region affords no parallel example, as pure magnetites are there absent.

Bed XIII. West to East.

Quartzose to jaspery varieties exist in all, and form a parallel series.

- Magnetite (massive, granular).
- Magnetite with some hematite (purple powder).
- Martite, with magnetite.
- Martite and hematite.
- Specular ore (massive).
- Specular-hematite schist.
- Micaceous-hematite schist.
- Limonitic specular ore.
- Turgite?
- Limonite with göthite.

With these ores are associated small interstratified beds of clay and chloritic slate, and hydromica schist.

Bed XII. West to East.

Red-banded quartzose magnetic ore.
Red-banded magnetic quartz schist.
Red-banded specular quartz schist (micaceous).
Brown-banded limonitic quartz schist.
Brown quartzose limonitic schist.
Turgite?
Limonite (manganiferous).
Ochre.

Magnetites, *Hematites* (usually specular), *Limonites*, and related ferruginous rocks are very abundant in the Middle and Lower Huronian, especially in the eastern portion of Huronian area south of Lake Superior, while they are comparatively rare in the same series in Canada.[1] At least seven out of the twenty beds of the Marquette region are ferruginous, and four have produced first-class ores, and this is true of at least two beds of the Menominee series, VI and XV. The rich specular hematite, which is so far most extensively mined, is mostly confined, however, to bed XIII, in which the richest magnetites also occur. There is less iron ore and of lower grade, so far as observed, in the Black River and Penokee series.

The magnetites and specular hematites graduate into each other through martite, which is abundant. They are also sometimes interstratified in the same bed, although seldom in juxtaposition. Nearly the same may be said of the hematites and limonites, but not of the latter and magnetites, which are never found together. These facts support the hypothesis that these ores, whatever their origin, were once all magnetites, part of which were afterward oxidized to hematites, and part of these in turn by hydration were converted into limonites.

While magnetic attraction is very common in the Pine river district, Wisconsin, no typical ore of this class has as yet been found in quantity. In my Michigan Report, 1873, I predicted that it never would be found, from the absence of boulders, abundance of limonites and related ores, and the peculiarities of the local attractions[2] to be observed on the Michigan side of the river. My Wisconsin investigations have not caused me to modify this view.

Iron-oxide, except as disseminated grains of magnetite and in a few instances in small unworkable beds, is entirely absent from the Laurentian and Copper-bearing series of the Archæan south of Lake Superior, while in Canada the largest deposits are reported as occurring in the Laurentian. Titaniferous iron ore, so abundant in the

[1] Use is here made of my "classified list, etc.," Amer. Jour. Sci., Sept., 1876.
[2] See Plate VII and explanations, this report.

Archæan of Canada and northern New York, has not been observed south of Lake Superior. In several hundred analyses of these ores,[1] I have only once seen "a trace" of titanium reported. Franklinite has not been observed.

(A.) *Magnetites and Magnetic Quartzose and Amphibolic Rocks.* Most abundant and, except the amphibolic kinds, found only in typical forms in the western part of the Marquette region.

a. *Rich in iron (iron ores).*

a 1. Blackish granular magnetites, massive to semi-schistose, fine to coarse grained, compact to friable (39, 40, 41, 42).

a 2. Cryptocrystalline, compact, tabular, schistose, sometimes containing actinolite (17?)

b. *Poor in iron, rich in quartz (magnetic quartzose rocks). Most abundant in the Marquette region, especially in the western parts, also very abundant in the Penokee (Bad river) series.*

b 1. Banded, arenaceous quartz and magnetic layers (52), [732,[2] 734,[3] 2184].

This rock was found in the western part of the Commonwealth property, and was the only variety of ore naturally exposed.[4] This ferruginous quartz schist is characterized by a tendency to become conglomeritic or brecciated. It also shows more or less of the sugary character in its quartz layers, so prevalent in the Pine river quartzites.

b 2. Intimate mixtures of magnetite (with hematite) and quartzose matter, often cherty [80, 1741]. Magnetic siliceous schist (flag ore) (23, 15). Both varieties graduate into ferruginous quartzites.

c. *Ferruginous rocks, rich in amphibole, the iron oxides, magnetic, hematitic and ochrey*, including such actinolitic schists as are rich in iron. Very abundant in the Menominee region, westerly of Lake Eliza.

c 1. Banded quartzose, amphibolic (actinolitic according to Dr. Wichmann), magnetic schists (130), [2240]. The distribution of this rock is not yet fully made out, nor is its stratigraphical position fixed. It is not impossible that actinolite occurs in appreciable quantities in two horizons. The accompanying magnetite will render it comparatively easy to unravel its structure through magnetic observations. It is interesting to note the rarity of amphibole as an associate of rich iron ores occurring south of Lake Superior, as compared with those of the Eastern States and Scandinavia. The Michigamme mine (magnetic) shows considerable actinolite in No. 4 shaft. Future developments may prove it more abundant than now appears (1874).

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[1] See my Mich. Rep., Vol. I, Ch. X, 1873. [2] See Julien's description, Mich. Geol. Rep., Vol. II, p. 183. [3] Same, p. 79. [4] Rich granular specular ore has since been found in workable quantities at this locality (154), [3451], which is known as "Sec. 32" Mine.

Since the above was written a much more important distinct bed of this rock (152, 153) has been made out west of Lake Eliza, which is believed to be younger than that described above. See Plates VI, VIII. Breitung's Iron Location, in Sec. 28, T. 39, R. 18 E., Wis., is believed to belong to this bed. Near the Pine river are boulders of a good granular, steely ore, showing brown spots on fresh fracture. It is unlike the ore in place, described above, and still more unlike the Commonwealth. There is every probability that the parent bed is near.

According to Dr. Wichmann, the iron ore at Penokee Gap is a related variety (148), as is also the ore from the Magnetic mine, Marquette region (17).

c 2. Manganiferous actinolitic magnetite schists (58). Only in western part of Marquette region, constituting bed XVII.

c 3. Garnetiferous actinolitic magnetite schist (eklogite) (27). Only in one bed in the Marquette region.

(B.) *Specular Hematites, Martites, and siliceous, jaspery, argillaceous Hematitic rocks.* Most abundant and typical in the eastern part of the Marquette region.

a. *Rich in iron.*

a 1. Granular, massive to semi-schistose, specular hematite and martite. Usually contain a little magnetite. Not relatively so plenty as the magnetites of corresponding structure (5). Abundant in the Marquette region. The same ore has recently been found in workable quantity at the "Sec. 32 mine," Commonwealth company's property, Wis. (154) [3451].

a 2. Chloritic semi-schistose, specular ores (43), not abundant except in the New York mine.

a 3. Specular-iron schists, often slaty, and passing into micaceous-iron varieties (the most abundant form of hematite) (38, 45, 47, 48); only found in the Marquette region until the summer of 1878, when a similar ore was found at what is now known as the Norway mine, in the Menominee region. The quantity does not seem large, however, the prevailing ore being that described below under *a* 6.

a 4. Micaceous-iron slaty schist; graduates into the last, *a* 3. When interstratified with magnetic ore, it usually contains magnetite (46, 49); as yet only found in the Marquette region.

a 5. Kaolinic specular schist (2, 44). Rare, and observed only in the eastern part of the Marquette region.

a 6. Purplish to pigeon color, shaly to sandy, generally rich in iron, dull, fine specular ore (136, 67). Confined, as far as known, to bed VI, Sturgeon River district, Menominee region. It is now being produced in large quantities from the Breen-Quinnesec range of mines.

Nearly 100,000 tons of Bessemer ore were produced the first year, 1878. This ore has not yet been found in Wisconsin, although the formation exists there, as is elsewhere proven.

a 7. The earthy red oxide ore of the Commonwealth mine.[1] This ore, while closely related to the best ores of the Marquette and Menominee regions, possesses characteristics which are new and need to be stated. It is a red-oxide, intermediate in appearance between the specular and earthy hematite (limonite) ores of Marquette, probably identical with the specular ores in composition, as shown by Mr. Wright's analysis. It is believed to contain too much phosphorus to permit its use for steel. It may be called a soft, red oxide, less specular than the Marquette ores. This soft character will make the mining very easy, and I believe help the reduction in the furnace. It is not like any Marquette ore, but nearest the "hard hematite" of the Jackson mine. Nor is it at all like the Quinnesec and Breen ores, which are very friable, a kind of specular iron sandstone.

The pure ore is as free from silica or jasper as any I ever saw when so little work had been done. The small amount of material which will require sorting out seems to be more chloritic than quartzose, hence less objectionable. While the ore is less shining or specular than the Marquette ores, the steely luster which characterizes some of the best ores of that region is common here, the Commonwealth ore being much softer. Mr. Tuttle thinks the ore gets harder on exposure to the air.

The south one-third of the bed is more siliceous, having both the common banded form of the Marquette jaspery ores ("mixed ores"), and a peculiar form of white quartz which seems to have crystallized in irregular angular cavities in the ore, presenting the appearance of quartz breccia, with matrix of specular ore.

Some of the ore in and south of the shaft has a red-chalk (keil) character, *i. e.*, easily cut, very red, and having a suggestion of chloritic schist strongly impregnated with iron oxide. The Eagle mine is undoubtedly in the same formation, and its ore resembles the Commonwealth; but containing, as it does, several per cent. of water, it is more nearly related to the limonite class, under which it is described.

b. *Quartzose specular Hematites, poor in iron, rich in quartz. Abundant. Graduates into hematitic quartz schist.*

b 1. Banded, micaceous iron, quartzose schist (16, 32, 33). Abundant in the Marquette and Menominee regions, Michigan.

[1] This was written before it was decided that Mr. Wright would prepare the Economic Report on the Menominee Region. Could I see his report this might probably be omitted.

b 2. Banded specular iron with jaspery quartz ("mixed ore"), the laminæ often plicated and faulted to the extent sometimes of producing a breccia.[1] Abundant with specular ores in the eastern part of the Marquette region (37) [1196]. Similar but more jaspery and less ferruginous rocks occur in the Black River series, Mich. (84). A related rock, containing, in addition to the specular laminæ, minute gash veins of specular ore, occurs at Felch Mt., Menominee region [999].[2] Very rich hand specimens of ore can be obtained at the same locality. Closely related rocks, but magnetic, occur at "Sec. 32" Mine, Wis.

b 3. Intimate mixture of specular hematite (often magnetic) with quartzose matter, often cherty. Hematitic siliceous schist ("flag ore"). Very abundant in Marquette and Menominee regions, Michigan; less common in Wis. (68, 19, 36). Sometimes contains grains, apparently of decomposed garnets (bird's-eye ore) (6).

c. *Hematitic argillaceous, hydro-magnesian and micaceous schists*, sometimes graduating into limonitic varieties, and usually associated with rich iron ore. Poor in iron; generally diffused, but not abundant. Included under varieties of clay and chloritic slate and mica schist.

C. *Limonites and related hydrated oxides of iron, with the quartzose rocks into which they graduate.*

Earthy, ochrey brownish and yellowish ores derived from the hydration of hematites into which they graduate. They often contain kaolin and manganese. Occurring in irregular, pockety, masses they appear to be residual deposits resulting from a more or less complete dissolving out of the silica from quartzose hematite schists or "flag ores." The abrupt transition of one rock into the other is common, one end of a specimen being a ferruginous quartzose flag, and the other a merchantable limonite ore.

a. Rich in iron (the "soft hematite ores" of the Lake Superior iron trade). Abundant in the east part of the Marquette region, and at the Breen and Emmet mines, Menominee region, associated with red hematites but never with magnetites.

a 1. With little or no manganese (34, 35). A hard, red variety, rich in iron, and containing four per cent. of water, occurs in the Menominee region, at the Eagle mine, associated with chloritic, ochrey clay and plumbaginous schists and slates, and banded with quartzose schists, often ferruginous. The specimen which was made

[1] See Appendix K, Vol. II, Mich. Geol. Rep., for description and figures of this breccia.
[2] Julien, Mich. Geol. Rep., Vol. II, p. 81.

up of many chips collected when the explorations were quite limited, gave Prof. W. W. Daniels (disregarding fractions) 53 per cent. of metallic iron, 14 per cent. of silica, 4 per cent. of water, 34-1000 per cent. of phosphorus — a good ore. More recent explorations to the north have discovered still richer ores. This ore is evidently closely related to the Commonwealth, but contains more water. If found in quantity, and low enough in phosphorus, it would rank with the best soft hematite ores of the Marquette region, although harder. See description of Commonwealth ores above.

a 2. Richer in manganese (specimens of pure pyrolusite being sometimes found) (24, 25) [893]. Confined chiefly to bed X, Marquette region.

b. Poor in iron, rich in quartz, often ochrey. Graduates into limonitic quartz schist. A very siliceous variety of the two prevailing kinds in which a less proportion of the silica seems to have been dissolved out (26, 57) [994,[1] 883[2]]. Generally diffused but not abundant. Was not observed in the Penokee series.

Those desiring fuller and more strictly scientific information regarding the ferruginous group of rocks are referred to the two following chapters under specimens (39, 40, 41, 42, 17, 148, magnetite); (5, 67, 135, 136, 25, 34, 35, 24, 43, 44, hematite). For microscopic characteristics exclusively, see specimens [80, 1741, 2240 magnetite]; (16 hematite); [222, 549, 893, limonite].

2. Quartzite. One of the most widely distributed, both stratigraphically and geographically of Huronian rocks. In the Marquette region, it graduates into marble on one hand and into protogine? on the other, with intercalated beds of novaculite and clay-slate having oblique cleavage.[3] Occasionally the flaggy forms show ripple marks, and on Black river, Michigan, the false stratification of the original sandstone can be seen. Semi-schistose is the prevailing structure. Massive varieties with no marks of bedding are common.

A peculiar linear parallelism in the quartz grains, giving the weathered surface a delicate faint banding, suggesting bedding, but which is really an incipient or false cleavage, has often been mistaken for planes of stratification. This subject is considered in Chap. II, in describing the Lake Eliza rocks. According to Prof. Irving (see Geol. of Wis., 1877, vol. II, p. 504), this rock is extensively developed in

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[1] Julien, Mich. Geol. Rep., Vol. 2, p. 82.

[2] The same, p. 83.

[3] The quartzites in the eastern part of the Marquette region were for the first time last year thoroughly studied by Dr. Rominger, the results of which will be given in his forthcoming report.

heavy beds at Baraboo, in central Wisconsin, where it is associated with quartz porphyries, a rock not found in its typical varieties in the Huronian of Michigan. Quartzite also occurs in the Penokee series.

The following diagram may give a general idea of the chief transitions of quartzite into associated rocks. It never graduates into greenstone nor amphibole rocks.

Gneiss. Mica Schist.
Micaceous Quartz Schist.

Arenaceous Quartz Schist. Sandstone. Conglomerate.

IN THE MENOMINEE REGION.

Quartzite and Quartz Schist.

(Not including either jaspery, cherty nor ferruginous varieties.)

Holds intercalated beds of clay slate with oblique cleavage, also novaculite. It graduates through the accession of other minerals, in the direction of its strike, into

IN THE MARQUETTE REGION.

Chloritic Quartz Schist. Chloritic Schist.

Talcy Quartz Schist. Dolomitic Quartzite.
Protogine? Dolomite.

In the Menominee region are two beds — II, which is wide-spread on the Michigan side, and XIV, quite abundant on the Wisconsin side. Less abundant in IX and XVIII. In the Sturgeon river district, Bed II is thick and massive, forming usually a high ridge, and north and east of Lake Eliza, Bed XIV, which is often conglomeritic, has the same character. The latter is largely exposed on the Lower Pine, north side, where it usually contains specular hematite, and is also conglomeritic and schistose in structure. This bed is characterized by a decided sugary (saccharoidal) appearance, both of the massive quartzite and of the pebbles in the conglomerate, which is not observed in the Marquette region, nor indeed in any other quartzites with which I am acquainted, south of Lake Superior. Actinolite (?) [1088] and specular hematite and magnetite occur occasionally as accidental minerals, and less often garnets [1722]. An unctuous-feeling (talcy?) schistose variety occurs in Wisconsin, and it is talc or mica which gives the quartzite S. E. and N. of Lake Eliza an aventurine character [2187, 2213, 2403, 2410].

A. A very large proportion of the quartzites are white to light-gray, sometimes with brownish, greenish, and reddish tints, fine-grained, arenaceous, massive to semi-schistose, the grains often glassy. Bed II, Menominee region, is mostly of this rock, and it enters largely into Beds V and XIV, Marquette region. It is associated with the slates of Huron Bay, and occurs in the Black river and Bad river series. It is evidently a more or less metamorphosed quartz sandstone [361, 891,[1] 990,[2] 1251,[3] 1628, 1629], (137, 21). Sometimes this rock becomes much coarser-grained, almost granitoid; *e. g.* (8), which is an aggregate largely of grains of glassy quartz and black mica (?). [2088] is a faintly-banded, semi-schistose variety. [2085] is colored green by actinolite. In beds XIV and XVIII are quartz schists containing some unctuous-feeling mineral [2213, 2216]. At Felch Mt., a reddish variety of this quartzite contains numerous minute seams and veins of specular ore. It will be classed under Ferruginous Quartzose rocks.

B. Micaceous quartz schist, often conglomeritic. Light to dark-gray, fine-grained. Typical varieties of this rock occur in bed XVIII (140), [2206, 2222, 2225], and identical rocks [2223] in bed XVII, Menominee region. In the Marquette region, the micaceous varieties are usually conglomeritic and ferruginous [1085[4]], (51) and (50) not conglomeritic. Closely related are the conglomeritic specular schist [2224] of bed XIV, Menominee region, and the conglomeritic variety containing red mica (aventurine) [2187]. In Sec. 25, T. 40, R. 17, Wis., is a quartz schist containing some unctuous-feeling, hydrous-magnesian mineral with mica (aventurine) [2213], and at the mouth of the Poplar is a similar rock without mica [2216].

C. The micaceous conglomerate schists of *B*, lead us naturally to the true and well characterized *quartz-conglomerates*, which occur chiefly in bed XIV, Marquette region [688,[5] 715[5] to 721, 727[5]] (145).

D. Closely related to the micaceous quartz schists, and associated with them in bed XVIII, Menominee region, on the upper Menominee river where they are very abundant, are dark grayish-green, fine to medium-grained *chloritic* and *micaceous* varieties [2151, 2158, 2095] (138). An arenaceous variety [432] from bed V, Marquette, may also be placed here.

E. Medium to dark bluish-gray, arenaceous and slightly compacted, with numerous minute quartz veins, massive, weathering to a brown friable sandstone, the coating sometimes being an inch deep. This variety occurs most abundantly, associated with cleavable clay-slates, south of Lake Hanbury [2256 to 2259, 1618] (139). It is rarely found in the Marquette region [1447, 242]. Near the N. E. corner of Sec. 3, T. 40 N., R. 30 W., Mich., is a gray, banded, thinly bedded, and often quite friable arenaceous sandstone. This belongs

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[1] Julien, Mich. Geol. Rep., Vol. II, p. 79. [2] Ibid., p. 68. [3] Ibid., p. 69.

[4] Julien, Mich. Geol. Rep., Vol. II, p. 66.

[5] Julien, Mich. Geol. Rep., Vol. II, pp. 61-63.

to bed II, and proves its great range in texture, *i. e.*, from glassy quartzite to friable sandstone.

F. A peculiar *saccharoidal quartz-schist* is found in the Commonwealth and Eagle Mine series, associated with clay and carbonaceous slates; and a very similar rock, often contorted, occurs in the magnetic actinolite schist at the iron location near quarter-post between Secs. 27 and 28, T. 40 N., R. 17 E., Wis. It varies from white to a yellowish ochrey color, and is quite friable [2191, 3389]. Have not observed it in Michigan.

G. Jaspers, cherts, hornstones, and related siliceous schists, gray, black, red, green, banded, and brecciated, often ferruginous. Without raising the question whether true mineralogical jaspers occur, about which there is some difference of opinion, and whether such doubtful rocks can be separated from cherts and hornstones, there will be considered here the following varieties:

a. Light to dark-gray, banded, cherty, siliceous schists, having a somewhat deep brown weather-coating, best represented in the Middle Huronian at Black R. [1436, 1484,[1] 1441, 1500,[2] 1510.[3]] A closely related rock [1683] occurs in the North Iron Belt, Menominee region, and also at the Eagle mine [2152].

b. Lydianstone or black hornstone occurs in the Gogebic region [1437].

c. The banded, red, ferruginous, jaspery schists. The purest type of this rock occurs also in the Black River region [1485,[4] 1486][4] (98).[5] But the most abundant and best known variety is the branded "jaspery" schists ("mixed ores") associated with the specular ores of the Marquette region [1196] (37). The relations of these rocks to the last named have been mentioned.

d. Brecciated and conglomeritic varieties, which appear to have originated from an internal fracturing and displacement of the quartzose layers *in situ.* Abundant in the Black River region (85)[6] [1490].[6] See Appendix K, Vol. II, Mich. Geol. Rep., for description and hypothesis of formation of similar rocks from the Marquette region.

Those desiring fuller and more strictly scientific information regarding the quartzose group of rocks are referred to the two following chapters, under specimens (8, 21, 50, 137, 139, 138, 145, 51, 26, 19, 52, 23, 140, 16, 32, 33, 36, 57).

For microscopic characteristics exclusively, see specimens [361, 891,

[1] Julien, Mich. Geol. Rep., Vol. II, p. 83. [2] Ibid., p. 83. [3] Ibid., p. 88.
[4] Julien, Mich. Geol. Rep., Vol. II, p. 87. [5] Julien, Mich. Geol. Rep., Vol. II, p. 167.
[6] Julien, Mich. Geol. Rep., Vol. II, p. 67.

1174, 1629, 734, 1722, 732, 2205, 1088, 432, 1196, 1510, 1436, 1500, 1441, 1683].

The two following families of rock, embraced popularly under the general term of "marble," so graduate into each other, and into quartzose varieties, as to make it difficult to draw anything like sharp limiting lines. The general remarks, it is believed, will apply to both kinds. There is no doubt but that the magnesian (dolomite) family is by far the most prevalent. In using "marble" in the popular sense, we, of course, do not intend to embrace quartzites which have frequently been mistaken for "marbles," especially in the Menominee region. Except possibly in small variegated blocks, there is as yet no promise of economic value in any of these so-called marbles.

3. Limestone (marble).

A. A white *crystalline limestone* occurs in the North Iron Belt, Sturgeon river district, Menominee region (Bed X?), holding numerous, large, light-green crystals of tremolite, which weather black and present a very rough weathered surface (142). In this rock Dr. Wichmann observed wollastonite, as well as fluid enclosures. The presence of tremolite and absence of magnesia characterize this bed and make it easy to distinguish it from the older and far more extensive dolomitic horizon.

B. *Siliceous Limestone.* A variety in which the quartz exists in grains, appearing on the weathered surface almost like sand (141), occurs midway between the Marquette and Menominee regions, in Sec. 4, T. 43 N., R. 31 W., Mich. I have regarded it as belonging to Bed V; but it may be younger.

C. *Micaceous limestone* (144), brown and schistose, observed at one point only, in Sec. 13, T. 47 N., R. 28 W., Mich., and may belong to bed V.

D. *Argillaceous and conglomerate limestone*, in thin beds on the south shore and on the island in Lake Antoine, Menominee region [1786 to 1789]. Reticulated seams of quartz in places cause a peculiar pitted weather surface [2957].

According to Prof. Irving a "siliceous, crystalline limestone with some white quartzite," occurs near the base of the Penokee series, occupying apparently nearly the position of my great calcareous and quartzose formation (V). This rock has not been observed in the Huronian of Central Wisconsin, nor as a surface rock in that part of Oconto county embraced in my examinations. That it underlies the whole of the Pine R. district at some unknown depth, there can be little doubt. The reported existence of "marble" associated with quartzite, south of the Brule R. in the S. E. part of T. 41 N., R. 16

E., Wis., is significant and well worthy of investigation. What is known about it will be found in Mr. Wright's report which covers that region. Dr. Rominger, State Geologist, of Michigan, has spent two seasons in investigating the eastern part of the Marquette region, where the " marbles " and associated quartzose and argillaceous rocks are extensively developed. His report will greatly increase our knowledge of this interesting family.

4. Dolomite Marble. A crystalline limestone containing a varying amount of magnesia to the point of becoming a true dolomite marble, is abundant on the Michigan side in the Menominee region. Its not having been seen in Wisconsin except rarely in boulders, is one of the strong proofs that the Lower Huronian is mostly, if not entirely, concealed there by drift and the younger Huronian beds. This remark will probably apply with equal force to the Breen-Quinnesec ore (VI) which immediately overlies the marble. In the Marquette region it occurs in or immediately over the great bed of quartzite, and has been included by me in bed V. It and the associated quartzite are interstratified with beds of novaculite and clay slate, with oblique cleavage [1635, 795,[1]] (11). It is often quartzose in disseminated grains, or in cherty seams, which weather black and give the surface a ribbed appearance (143). In the Marquette region it is light gray, pink, and salmon-colored, mottled, fine to very coarse-grained [797 [2]] (9). In the Menominee region are grayish and slightly bluish, fine-grained varieties (66) [1635, 2068]. All the specimens designated above came from the same marble-quartzite bed (No. V) which the presence of this rock may be said to characterize. No accidental minerals except quartz and calcite have been observed.

Those desiring fuller and more strictly scientific information regarding the calcareous group of rocks, are referred to the two following chapters under specimens (9, 11, 66, 142, 97, 144, 141, 143), and for microscopic characteristics exclusively, see specimens [2086, 1744, 21, limestone]; [795, 1635, 797, 1626, dolomite].

5. Clay-Slates. Clay-slates being soft rocks, are very liable to be concealed through their conversion into soil by weathering influences. Again, their intimate relation with and transition into magnesian and hydro-micaceous and carbonaceous rocks, renders their limits very difficult to define, hence future investigations may greatly change and improve the grouping here employed. I have divided them provisionally into three groups:

A. Where they exist as subordinate beds in quartzites, limestones and actinolite schists, being interstratified with layers of these rocks.

[1] Described by Julien, Mich. Geol. Rep., Vol. II, p. 57. [2] Ibid., p. 58.

B. Where they exist in independent beds, constituting the prevailing rock of a given stratum or horizon.

C. Where they occur in subordinate beds, in iron-ore rocks, alternating with layers of the same, as well as of magnesian schists. All field observers of clay slates are aware of the frequent difficulty of distinguishing between cleavage and stratification planes. The cleavage planes are always far more constant in strike, and parallel with the great axes of folds in a wide region. The dip is always at a high angle, and equally constant. The stratification planes in a sharply folded region of crystalline rocks would naturally average in strike and dip nearly the same as the cleavage planes. It is not impossible, therefore, that my classification into those having oblique cleavage, and those in which the cleavage is undistinguishable, but yet may exist parallel with the bedding, is largely arbitrary. The instances, I think, are rare in which the bedding planes could be readily separated from the cleavage, except where the slates were associated with other and harder rocks. These may be supposed to have interfered with the free movement of the argillaceous material during the period of disturbance, which brought the beds into their present nearly vertical positions, just as a miniature model made up of different colored layers of wax and an intercalated sheet of lead, and brought under pressure to illustrate the origin of cleavage planes, would present a quite different cross section from what it would if the lead were not present. The colored bands of wax would certainly be much nearer parallel with the cleavage planes in the last than in the first instance. The thickness of the argillaceous and intercalated harder beds would, of course, modify these planes.

The following diagram illustrates the common transitions of those varieties of clay slate not associated with limestones or quartzites; *i. e.*, groups B and C:

Keil (red chalk). Red Iron Ores.
Ferruginous varieties.

Carbonaceous and Plumbaginous Slate and Shale and Graphite.	**Clay Slate.** The variety usually without distinguishable oblique cleavage, graduates into	Micaceous Clay Slate (Phyllite). Mica Schist.

Chloritic Clay Slate.
Chloritic Schist.
Also into a talcy-feeling soft schist (hydro-micaceous?), often ferruginous.

A. The typical clay slates with oblique cleavage, and affording in some instances roofing slate, are usually, it is believed, intimately associated with quartzites, although I do not know much of the Huron Bay slate district where the best roofing slates are found (81). It occurs in the Negaunee district, in bed VIII (20), and in the Menominee region, south of Lake Hanbury, in bed IX? [1617, 1620] (113). Compare also [983.[1]] When these obliquely-cleavable slates occur associated with calcareous rocks, as in bed V, easterly from Negaunee, the slate has usually more or less of a novaculite character and gray to purple and greenish tints, instead of the ordinary slate colors (10, 12, 13) [804,[2] 805,[2] 810,[3] 814[4]].

B. Clay slates which form independent beds, or greatly predominate in certain strata, like XV, Marquette region, and XI, portions of XVIII, and the "Commonwealth" bed, XV, Menominee region, are characterized, first: by the absence of distinguishable oblique (true) cleavage, the fissile character being apparently due to lamination or bedding. These rocks, therefore, correspond with Cotta's Schiefer-thon (argillaceous shale schist or slate), (114), [2185, 2147, 2237]; second: by the presence of accessory minerals, chiefly chlorite, mica, carbon, iron, and silica, to the extent of completely altering their character, and through which they pass into entirely different kinds of rock.

a. Chloritic varieties, grayish and blackish-green, often not distinguishable by the eye from true chloritic schists [2140, 2164, 2165, 2168, 820[5]]; undistinguishable are certain chloritic schists (55), [2094].

b. Near this border line are also *pyritiferous and ferruginous varieties* [2251, 2183, 2140], which also approach in some of their characters the typical varieties [2185, 2237].

c. Micaceous varieties (phyllite), (111) [2270, 692,[6] 1526], and related micaceous argillites [2137, 1173] (56). A mica schist [2058] from below the Little Quinnesec is closely related.

d. Carbonaceous varieties [2169] (115, 64) [1163, 2134], to the extent of being over one-fourth carbon. An apparent exception to this is the occurrence of a carbonaceous shale, with quartzite, in S. E. qr. of Sec. 25, T. 40, R. 17 E. Whether it has oblique cleavage or not, is not known.

e. Ferruginous varieties. These border on family C, but differ in that while they are associated with iron-ores, they greatly predominate, and are much less ferruginous than the others, being rather

[1] Julien, Mich. Geol. Rep., Vol. II, p. 114. [2] Id., p. 85. [3] Id., p. 99. [4] Id., p. 100.

[5] Julien, Mich. Geol. Rep., Vol. II, p. 95.

[6] Julien, Mich. Geol. Rep., Vol. II, p. 98.

rusty stained argillaceous rock [2272, 2193 to 2195]. A light-drab and brown variety [2157], is closely related to class C.

f. Siliceous varieties [2081], through which the rocks graduate into quartzose schists, are not well defined, but may be supposed to include Julien's feldspathic argillite, although Dr. Wichmann has distributed this kind of rock among chloritic, micaceous rocks and argillites. A more siliceous and somewhat ferruginous variety occurs at the Eagle mine [2152].

C. Interstratified with the iron-ores, especially with the limonitic and siliceous varieties, are gray, red brown and mottled slates, which are believed to be generally argillaceous, but may be sometimes chloritic. The quantity of iron oxide, which is sometimes 25 per cent., makes it very difficult to determine the exact character of the rock. So far as observed, this group like the first is without oblique cleavage, hence rather an argillaceous shale. The red chalks, so common in the mines of the Negaunee district, and at Kimball's cut, in that vicinity, are of this class. Abundant in, or adjacent to bed VI, Menominee region [2249, highly ferruginous], [1623, red and brown mottled] [2067, ash colored]. Through related unctious-feeling schists [1081, 1120], this kind of rock graduates into hydro-micaceous varieties (53,54), all of which occur interstratified with iron-ores, but are described under other kinds of rock.

Those desiring fuller and more strictly scientific information regarding the argillaceous group of rocks, are referred to the two following chapters under specimens (20, 81, 91, 113, 114, 64, 115, 111, 73, 74, 10, 12, 13, 56). For microscopic characteristics exclusively, see specimens [983, 998, 807, 814, 2067, 2147, 2237, 1163, 2134, 2169, 3064].

6. Talc Schist. The typical rock, according to Dr. Wichmann's determinations, has been observed only at Marquette (74), and at the Washington mine [1081].[1] Unctious-feeling, micaceous and chloritic rocks, often called talcose, are more abundant (53, 54, 112). A related schist in physical character occurring on the Menominee, at the foot of the Big Quinnesec Falls [2071, 2862], and heretofore called talc-schist,

[1] Julien, Mich. Geol. Rep., Vol. II, p. 116. In February, 1879, Mr. Julien re-examined this rock with the following results: "It contains less than 4 per cent. magnesia, a large amount of ferric oxide, and only a small amount of water and carbonaceous matter. There is too small an amount of magnesia and water to render probable the presence of talc, and the large amount of iron, together with the magnesia, may better be assigned to biotite. This is the more probable from the gray color of the rock. Its minute black scales, I therefore believe to be biotite, and the white scales some hydromica. Name, altered biotite schist." Regarding (74) Mr. Julien says: "contains very little iron, but nearly 7 per cent. magnesia, equivalent to 19 per cent. talc. Name, talcose argillite."

Dr. Wichmann decides to be hydro-micaceous, and calls it sericite schist. It is a serious question, it would seem, whether any true talc schists have yet been found in this rock series.

For fuller and more strictly scientific information regarding the rocks heretofore called talcose, see the two following chapters under specimens (74, 53, 54, 112), and for microscopic characteristics exclusively, see specimens (74), [1081].

7. Chloritic Rocks. Of all the vague lines separating the several families of rocks, none is harder to recognize than the division between this and the preceding argillaceous group. As the mud under the waters of rivers, lakes and the oceans varies in character and composition, so do these rocks, which are but secondary, hardened forms of such mud. When the metamorphosing forces have gone far enough, the mud is carried through these families by insensible steps into micaceous rocks. These are the reasons why the argillo-chloritic and chloro-argillaceous varieties figure so conspicuously.

An unevenly splitting gray-green schist associated with greenstones, and apparently derived from them by alteration of the amphibole, is included in this family, although its origin and associations are widely different from the above. This seems to be one end of the chain which connects massive crystalline greenstones through diabase?, kersantite, micaceous greenstone, greenstone schist, chloritic (greenstone) schist into this secondary chloritic schist. All these varieties may sometimes be found in one outcrop, but usually one variety characterizes one bed for some distance. This variety should undoubtedly have a distinctive name, and will here be designated by the last descriptive name employed above, chloritic (greenstone) schist.

The idea on which I have grouped the rocks in this chapter would render it quite as proper to place this kind of rock with the greenstones; but convenience of reference, with other considerations, has led to placing it with the other kinds of chloritic schist.

The following diagram presents the leading facts:

GREENSTONES.

Diabase and *Diorite*.
Kersantite or Mica Traps.
Chlorite and Micaceous Greenstone Schists.
Graduate through the alteration of the Amphibole constituent into a variety of

Quartzose Chloritic Schists.
Chloritic Quartz Schists.
Quartzite.

Chloritic Schist.

Micaceous Chloritic Schists.
Chloritic Mica Schists.
Biotite Mica Schists.

Argillo-Chloritic Schists.

Clay Slates and Argillites.

Ferruginous Clay Slates.
Iron Ores.

A. *The pseudomorphous chloritic rock* of bed XIII, Spurr-Michigamme range (89 [1]), so well described by Julien and Pumpelly, seems to be nearly pure, dark-green, massive chlorite. Bunches and small lenticular masses of identical rocks, containing garnet, occur in greenstones at Republic Mt. This pure pseudomorphous and garnetiferous variety has not been observed in the Menominee region. Mining operations may probably develop it.

B. A less pure, grayish-green, eminently schistose but seldom slaty, and not well-defined variety, has affinities with hornblendic and micaceous schists (134), [2143], which compare with [2270, 2178, 1250 [2]] (114), and closely related are Julien's feldspathic argillites (132 [3]) [422] and others.

C. An extensive group of light gray-green chloritic schists, which have generally been called *argillo-chloritic* or *chloro-argillaceous*, on account of their intermediate character, is developed in the Menominee region [2053, 2055, 2058, 2082, 2094, 1613] (55). These graduate on the one hand into clay slates, as has been stated, and on the other through unctuous-feeling, probably hydro-magnesian rocks [1120, 1081], into hydro-mica slate (53), all of which occur in iron ores in bed XIII, Marquette. Certain talcy schists from Marquette (73, 74), are also related, but are in an entirely different stratigraphical position. A peculiar variety of banded, irregularly mottled, evidently highly

[1] Julien, Mich. Geol. Rep., Vol. II, pp. 94, 95, sp. 729, 730, 731. [2] Id., p. 108. [3] Id., p. 104 (sp. 982).

altered, in places arenaceous, schist [3455, 3459], which is probably chloritic, is found in the prospecting pits on the east side of Sec. 34, T. 40, R. 18, Wis. The associated, more or less carbonaceous, clay slates, the saccharoidal quartz seams, and unctuous-feeling schists, together with the locality, renders it almost certain that it belongs to the Commonwealth series, bed XV [3452 to 3462]. This locality exhibits a very interesting series of the several schists and slates accompanying the iron.

D. One of the largest, most generally distributed, and at the same time, obscure varieties, embraces those chloritic rocks that are associated with greenstones and hornblende schists, being in many instances but schistose and altered varieties of the same. These rocks have heretofore been called dioritic schists and chloritic diorites. They are usually dark grayish-green, and of exceedingly uneven, irregular, schistose structure, never producing slates and seldom flags. Some have affinities with hornblende schists, and at the same time with some of Dr. Wichmann's diabases (70), [2132, 2178, 2180], and others have affinities with diorites and diabases [825,[1] 906,[2] 2063, 2144, 261]. Others, again, incline toward micaceous and argillaceous schists [1640] (133) [137, 2097]. Compare, also [2078, 537, 931]. Many are obscure and altered [146, 2173, 2170]. The following chloritic schists (named by Dr. Wichmann) do not readily come under any of the above classes; in several instances they are more or less weathered, and never, it is believed, do they occur in quantity [2108, 337, 2082] (108).

Those desiring fuller and more strictly scientific information regarding the chloritic group of rocks, are referred to the two following chapters under specimens (55, 73, 119, 134, 31, 132, 89, 133, 63). For microscopic characteristics exclusively, see specimens [1250, 2082, 2094, 2097, 2132, 137, 906, 982, 729, 2091, 2078, 537, 931, 2227].

8. **Greenstones.** This term is employed in a sort of double sense: 1st, as the name of a large family of rocks, including diorite, diabase, gabbro, and the secondary forms of these rocks through the alteration of the amphibole. 2nd. To designate any related fine-grained rock, the true character of which has not been determined, but which undoubtedly belongs to this class. When used in the latter sense, it should be prefixed by "undetermined" or "aphanitic," but often this is not done. Competent lithologists are, I believe, agreed that the very fine-grained and aphanitic greenstones can only be properly named through the microscopic examination of a thin section. This

[1] Julien, Mich. Geol. Rep., Vol. II, p. 174. [2] Id. p. 102.

cannot be done in the field, perhaps not at all, on account of the cost and delay; meantime a name must provisionally be employed. This in time becomes so fixed in notes and MSS. that it is difficult to eradicate it. Further, I have a feeling that it often is not a matter of importance to determine whether pyroxene or hornblende characterizes a particular rock and the exact extent of the alterations in the same. If the determinations made of my specimens are to be relied on, then this difference in the bi-silicate mineral seems often accidental and local. They appear to graduate into each other, whether through alteration or original difference in composition, cannot always be ascertained.

In my Michigan report, diorite was used as the synonym for greenstone. Here that term is intended to embrace only the unaltered hornblendic varieties of greenstone.[1]

The following diagram illustrates my general views of the observed transitions of greenstones (believed to be mostly metamorphosed sediments[2]) into related rocks. Where the kersantites (mica-traps), a new name in the lithology of these rocks, lately applied provisionally by Mr. Julien to certain semi-schistose varieties (155), [2872, 3246, 3344], should be placed, I will not attempt to determine. Fortunately the name *melaphyr*, under which term Prof. Pumpelly embraces many of the greenstones of the Copper series, has never been applied to a Huronian greenstone.

SERPENTOIDAL ROCKS (rare) are believed to have been derived by alteration from

SERPENTINOIDAL GREENSTONE.

DIABASE. Chloritic do. Chlorite Schist. — GABBRO. — **Greenstone.** embracing — DIABASE. — CHLORITIC DIABASE. Kersantite? Chlorite Schist.

DIORITE.

HORNBLENDIC DIORITE.

Hornblende rock and rarely schist.

Hornblende Gneiss. — Micaceous Hornblende Schist.

Hornblendic Mica Schist

Mica Schist.

Gneiss.

Following strictly the plan of arrangement of rocks sketched at the beginning of this chapter, the chloritic schists associated with and undoubtedly derived from the greenstones, should be described here, but for convenience and other considerations they are placed under chloritic schist.

[1] See Dr. Hunt's remarks on greenstones in appendix.

[2] Dr. Wichmann regards them as eruptive. See his remarks on diabase, Chap. V.

The great greenstone bed which lies immediately under the chief iron ore formations (XII and XIII) of the Marquette region, presents according to early determinations of the specimens the following varieties in an air line distance of twenty miles.

Bed XI. From Republic Mt., north and east to Negaunee.
- Hornblendic schist (micaceous).
- Hornblendic gneiss.
- Hornblendic diorite.
- Diorite (micaceous greenstone, green mica schist).
- Dioritic schist.
- Diabase?
- Decomposed diabase?
- Chloritic schist (micaceous).
- Chloritic schist (porphyritic).

A. Diabase. Abundant, especially south of L'Anse, and in the Menominee region, southwest of Sturgeon Falls and on the Lower Brulé, and perhaps also at Twin Falls. This name is often applied by Dr. Wichmann to obscure fine-grained "greenstones," which have usually been called diorites, greenstone schists and chloritic greenstones. The rocks called diabase by Dr. Wichmann can be conveniently divided into several tolerably distinct varieties, often entirely different in appearance and doubtless in origin.

a. Julien's "Black Trappean Diorites" (provisionally so named), from L'Anse Iron Range [884[1]], (82[2]). See his descriptions of physical character in Mich. Geol. Rep., Vol. II.

They are black, somewhat coarse-grained, highly crystalline. This variety has not been seen elsewhere south of Lake Superior. It resembles the "trap-dykes" at the Washington mine (79, 94), embraced in Group E. The serpentine (78) and related rocks [1659, 911[3]] have affinities with this group, of which they may be altered varieties.

b. Associated with the above at L'Anse, and also found in the Marquette quarries, is a more or less decomposed, mottled, yellowish, brownish and greenish, massive rock, medium to fine-grained, and sometimes a sand, which Dr. Wichmann designates decomposed diabase [888 [4]] (122 [5]) (121 [6]) (99 [7]).

c. Here are embraced rocks which have heretofore been usually called chloritic diorites and dioritic schists, together with more massive but related varieties. In their appearance and stratigraphical relations they are distinct varieties, and seem to be intermediate be-

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[1] Julien, Mich. Geol. Rep., Vol. II, p. 176. [2] Id., pp. 178, 179 (sp. 912, 913, 915).

[3] Julien, Mich. Geol. Rep., Vol. II, p. 180.

[4] Julien, Mich. Geol. Rep., Vol. II, p. 177. [5] Id., p. 177 (sp. 889). [6] Id., p. 170 (sp. 821). [7] Id., p. 180 (sp. 887).

tween the hornblendic rock and diorites on the one hand, and chlorite-schists on the other. Dr. Wichmann first called (70) a chloritic schist, and later, diabase. The rocks at the "Gorge" on the M. H. & O. R. R. (70), belong here, as well as similar rocks found in bed IX (31) and bed XI [526], Marquette region. In the Menominee region, bed XVII contains typical varieties of this class [2155, 2262], and also bed XVI (119), [2079]. A related rock is found in bed XVII? [2059]. This class differs more widely in physical appearance from (*a*) than from any other variety of greenstone. Were I discussing these rocks from the standpoint of their origin, I might regard the latter (*a*), as eruptive, and the former (*c*), as metamorphic. Dr. Wichmann regards them all as having the former origin.

d. Gray to blackish-green, medium to fine-grained, massive to semi-schistose rocks, intermediate in appearance between groups A and C, and more closely resembling Dr. Wichmann's diorites than any other variety of diabase. They occur in the Marquette quarries (120,[1] 72), in the Huron Bay district [996[2]], and at Lake Gogebic [1501[3]]. The hornblendic and micaceous bed XIX, of the Menominee region, contains similar rock [2072]. This was the first and almost only diabase recognized in his preliminary determinations by Mr. Wright, who does not apply this name to as many rocks as Dr. Wichmann does.

e. The trap dykes of the Washington mine afford a green-black, massive, hard, heavy rock, quite unlike the other groups (79, 94[4]). A "trap" from near Black river [1558], west of Gogebic, belongs here, as well as the Laurentian "trap" [1382[5]], which is, however, much finer grained. This variety has not been observed in the Menominee region.

B. Diorite. This term, used in my Michigan Report, 1873, as a synonym for greenstone, is here confined to those greenstones in which the amphibole is black hornblende. To distinguish pyroxene characterizing diabase from hornblende which characterizes diorite is very difficult, hence many greenstones which have heretofore been termed diorites even by good lithologists, Dr. Wichmann includes under diabase, greatly restricting the rocks to which the term diorite has been applied. The so-called diorite-schists are nearly all excluded, being distributed under diabase, mica, and chlorite-schists and kersantite.

Diorite is abundant, especially in the eastern part of the Marquette region, in bed XI? (118), but at no locality south of Lake Superior

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[1] Julien, Mich. Geol. Rep., Vol. II, p. 173 (spec. 827). [2] Id., p. 179. [3] Id., p. 160.
[4] Julien, Mich. Geol. Rep., Vol. II, p. 181 (spec. 1110). [5] Id., p. 182.

seen by me are true diorites so abundant as in bed XVII?, extensively developed westerly of Lake Eliza, especially in Secs. 36 and 27, T. 40 N., R. 17 E., Wis., where it is associated with and graduates into massive coarse-grained hornblende rock on the one side, and schistose varieties which graduate into micaceous, chloritic and argillaceous schists on the other [2611–13, 3375–77]. See Plate VI and description, Chap. II.

A gabbro-like variety is found in a heavy bed (XVI) on the Menominee river, between Sturgeon Falls and the Big Quinnesec Falls (69)[1], [2113, 2070]. At the latter locality (in XVIII) occurs the coarsest variety of greenstone anywhere observed. Since the several lithologists who have examined this variety disagree as to whether they are true gabbros, I have employed the descriptive name of *gabbro-diorite*. Massive to semi-schistose, medium to fine-grained (and occasionally coarse-grained) varieties are: (118), (75), [464, 37, 479, 1726, 1453, 1401, 2280]. Altered [563, 1713, 1730]. Diorite-porphyry [2098, 2070]. Quartz-diorite (118).

C. Gabbro. Messrs. Rutley, Wapler and Pumpelly have agreed in giving the name *gabbro* to a certain rather abundant, coarse-grained, massive to semi-schistose greenstone, with white to light-green compact feldspar and a peculiar gray-green amphibolic mineral. A hand-specimen of this rock from Sturgeon Falls (69) was first provisionally called "porphyritic diorite" by Julien (Mich. Geol. Report, Vol. II, p. 210). Since then it has been examined microscopically by several lithologists, three of whom have agreed on the name *gabbro*. The rock prevails in bed XVI as seen along the river [2098] from Sturgeon Falls to the Little Quinnesec, and forms just below the latter point a high ledge [2113]. At the Big Quinnesec Falls, the corresponding great greenstone bed has changed its character, and only one small bed of the gabbro-greenstone [2070] was observed at the foot of the great falls. Above the gneiss, however, and apparently in bed XVIII, this rock again occurs. This is the only locality where I have seen this rock in the Huronian. Its rarity in this series and the fact that it is a rather abundant variety of greenstone in the Copper series, possesses it with much interest. Diabase is the only other greenstone common to the two series. It is structurally like the other greenstones and holds slaty, chloritic beds, into which rock it very likely graduates by insensible transitions.

D. Kersantite (MICA TRAP). Certain gray to greenish-gray fine-

[1] Prof. Pumpelly says of this specimen: "Saussurite-gabbro (or hornblende-gabbro) contains saussurite, diallage, hornblende. Identical under the microscope with the coarser crystalline rock of Upper Quinnesec Falls."

grained greenstone schists, quite abundant in the middle portion of the Upper Huronian at the Big Quinnesec (155), [2864, 2865, 2867, 2872, 2995], on the Lower Brulé [3239 to 3248], and on Sec. 27, T. 40, R. 17 E., Wis. [3344, 3345], have been designated kersantites and hydro-mica traps, by Mr. Julien, based on a microscopic study of one thin-section (155) and inspection of others. These rocks are closely related to many of Dr. Wichmann's diabase schists and related chloritic schists. The grayer color of these schists may help to identify them in the field. There can be but little doubt but that they are altered rocks.

Those desiring fuller and more strictly scientific information regarding the greenstone group of rocks, are referred to the two following chapters under specimens (70, 72, 79, 82, 94, 99, 120, 121, 122, diabase); (75, 118, diorite); (69, gabbro); (155, kersantite). For microscopic characteristics exclusively, see specimens [912, 913, 1110, 3079, 2072, 884, 1427, 1501, 1659, 889, 3070, 1616, 2059, 821, 827, 2079, 996, diabase]; [464, 3075, 37, 563, 2098, 192, 1730, 1726, 1713, diorite].

9. Syenite. Observed only in the Lower Huronian near Marquette, associated with diorite, into which it seems to graduate. Rich in orthoclase (116 [1]), [1724]. · Hornblendic (77). For description of physical and microscopic characteristics of the above specimens, see the two following chapters.

10. Hornblendic Rocks. The Huronian hornblendic rocks are conveniently grouped as follows:

A. Blackish-green to black, medium to coarse-grained, massive to semi-schistose, the crystalline facets of the hornblende being without parallelism: (18, 22, 30, 123), medium-grained; (88),[2] [2188], (126), [745],[3] coarse-grained. Similar in general appearance are such diorite rocks as (75), such syenitic rocks as (77). Somewhat related is a diabase (82)[4] from the L'Anse range. Lighter colored and still more like greenstones in appearance are (127), [1636], (71).

B. The semi-schistose varieties of group A graduate into true hornblende schists, blackish-green to black, medium to fine-grained, the hornblende facets being usually parallel with the schistose structure [1752], (125). Sometimes faintly banded (128), often micaceous (128, 29, 71, 127), and associated with and graduating into mica schists, but rarely into greenstones; see bed XIX. Closely related in appearance are some fine-grained, black, Laurentian schists [1224,[5] 1229], but the

[1] Julien, Mich. Geol. Rep., Vol. II, p. 161*(sp. 1720).

[2] Julien, Mich. Geol. Rep., Vol. II, p. 140 (sp. 1089). [3] Id., p. 164. [4] Id., pp. 178–9 (sp. 912, 913, 915).

[5] Julien, Mich. Geol. Rep., Vol. II, p. 133.

hornblende facets are always longer and parallel with each other, presenting a marked broken, fibrous appearance.

C. Dark, olive-green, fine-grained; splits unevenly, presenting a semi-conchoidal fracture, and presenting no discernible crystalline facets of hornblende; luster dull and somewhat like chlorite [2171, 2172, 2177]. The rock is often chloritic, and graduates into and is associated with chloritic schist (2170). Certain intermediate varieties, apparently somewhat altered, have been called diabase by Dr. Wichmann [2155]. Mr. Wright designates the hornblendic varieties, amphibole, which conveniently distinguishes them from group B, with which they have comparatively little resemblance in physical characters.

D. The rocks classed here are intermediate in character between hornblendic rocks and greenstones, and are subdivided into:

a. Lightish-gray-green, fine-grained to crypto-crystalline, massive, often possessing a jointed structure. The constituent minerals cannot usually be discerned even with the loupe. Whether they are diorites or hornblendic rocks can only be determined by the microscope [2122, 2051, 113]. Here belong certain gray-green, usually fine-grained schists, which have heretofore often been denominated dioritic. A feldspathic mineral is believed to be present, and whether the hornblende prevails to the extent of making it a hornblende schist, can only be determined by the microscope. They are generally chloritic in appearance and sometimes gneissic (76), [2052, 1086,[1] 817[2]]. Compare also [1761, 527, 325, 1614, 1528,[3] 2261, 1099,[4] 1103,[5] 1087,[6] 2089].

Diagram showing the transitions of hornblende into associated rocks:

GNEISS.
Mica-Schist.
Hornblendic Mica-Schist.
Micaceous Hornblende-Schist.

Hornblende-Gneiss.

Hornblende-schist.

Chloritic Hornblende-schist.
Chlorite Schist.

Feldspathic Hornblende rock.
Diorite.

[1] Julien, Mich. Geol. Rep., Vol. II, p. 136. [2] Id., p. 175. [3] Id., p. 171. [4] Id., p. 168. [5] Id., p. 156. [6] Id., p. 136.

Those desiring fuller and more strictly scientific information regarding the hornblendic group of rocks, are referred to the following chapters under specimens (18, 22, 30, 123, 126, 29, 76, 88, 124, 125, 71, 127, 128). For microscopic characteristics exclusively, see specimens [1752, 2167, 745, 1636, 2261, 2124, 1761, 527, 3071, 3029, 2182, 3076, 325, 1614, 1528, 2051, 2122, 1099, 3022, 1103, 1087, 2089, 2135, 2061, 817, 113].

11. Actinolite Schist. There are two varieties: A. *Typical.* This is found only in Pine river district, Wis., in the Upper Huronian (129), [2198], and is very coarse; the radiated fibrous crystals being often an inch or more in length. A very soft variety which hardened on exposure to the air, contained over 6 per cent. of water, and was apparently changed to chlorite. A variety of this rock is associated with the hornblende schists at the base of bed XIX, northwest of the junction of the Pine and Poplar rivers, and at various points in the extension of bed XIX to the northwest.

B. *Magnetic*, in which the amphibole mineral is acicular and sometimes plumose, closely resembling anthophyllite. Some weathered specimens submitted to Prof. Brush were named anthophyllite schist, and are so designated in my Michigan Report. Dr. Wichmann carefully examined this mineral, and finds it to be undoubtedly actinolite. This variety makes up bed XVII, Marquette series, where it is manganiferous and ferruginous. It is related to eklogites, or the latter may be a garnetiferous variety of it.

Magnetic actinolite[1] *schist* is very abundant westerly of Lake Eliza on Secs. 36, 35, 34, 27, 26, 25, T. 40 N., R. 17 E., Wis. It occurs in certainly two, and possibly in three, distinct beds of the Upper Huronian. See Plate VII. The iron-oxide present seems to be a pseudomorph after the actinolite crystals, and is black, red and brown (153, 130), [2560, 2676, 2686]. The alteration is sometimes so complete as to produce an ore of iron (153), already mentioned.

a. Gray-green and black, magnetic and manganiferous (58, 59) [1116,[2] 1115,[3] 1032,[4] 1033[4]], from bed XVII, Marquette region. Compare (130), [221, 308, 177].

b. Magnetic, quartzose, containing arenaceous quartzose laminæ and red hematite [2241, 2192], bed XV, Menominee region.

c. Garnetiferous actinolite schist (eklogite) (27), [1088],[5] from bed X, Michigan, and (151) from XIII, Menominee region.

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[1] According to Julien, possibly *tremolite*.

[2] Julien, Mich. Geol. Rep., Vol. II, p. 92. [3] Id., p. 93. [4] Wright, id., p. 223.

[5] Julien, Mich. Geol. Rep., Vol. II, p. 91.

Those desiring fuller and more strictly scientific information regarding the actinolite group of rocks, are referred to the two following chapters under specimens (129, 105, 58, 131, 152). For microscopic characteristics exclusively, see specimens [2198, 2238, 221, 308, 1116, 1155, 2241, 177].

12. Tremolite Schist. Mr. Julien has applied this name to certain rare varieties of rock belonging to the youngest Huronian as developed southwest of Sturgeon Falls [2480] on the Menominee, and between Norway and Long Portages on the Michigamme [2390, 2462]. Prof. Pumpelly, however, says of one of the latter [2390], that it consists predominantly of *plagioclase*, and of hornblende and biotite.

13. Garnetiferous rocks. This rock is rare in the Huronian and has been observed, so far as I know, only at the places mentioned below. As an accessory mineral, garnet is not infrequently found in micaceous, hornblendic and chloritic schists, especially in the more typical varieties of the latter, which often holds very large impure crystals. Closely related to eklogite, and differing apparently in the substitution of a micaceous for the amphibolic mineral, is a highly garnetiferous schist containing magnetite and associated with magnetic mica schist, observed only near the corner of Secs. 5, 6, 7 and 8, T. 41, R. 30, Mich. (150).

A. Eklogite. Rare; [1091] and (27), both from the Marquette region. See class *c* of actinolite schists. On the north side of the great conglomeritic quartzite, S. E. qr. Sec. 13, T. 39, R. 17, is a similar rock (151).

For description of the physical and microscopic characteristics of the above mentioned specimens, see the two following chapters.

14. Mica Schist. The mica-schists may be conveniently divided as follows:

A. The mica chiefly biotite, and often staurolitic. Brown, fissile, soft, slaty, shining, fresh surface, often corrugated, the cross-fracture showing grains of quartz. Characterizes bed XIX, both in the Marquette and Menominee regions [2145, 2146, 2162, 2163]. Through the accession of other minerals, we have a blackish mica-schist, with crystals of staurolite, andalusite, and often garnet, around which the mica leaves warp themselves, producing a warty schistose structure (61)[1] [2160]. This staurolitic mica-schist, bed XIX, is more persistent in its lithological character than any other of the series, save, perhaps, the quartzite-marble bed V.

[1] Julien, Mich. Geol. Rep., Vol. II, p. 155.

B. A hard, firm, gneissic variety, having much resemblance to the German schiefer-gneiss, occurs at the portage of the Paint river [1252][1]; and north of the north iron belt, in the Menominee region, is apparently the same formation. A variety in which hornblende prevails (128) is abundant in bed XIX, especially south of Pine river, where the staurolitic variety has not been observed. For a rare massive, semi-porphyritic variety, see typical suite (106).

C. Dark-green mica-schist, resembling chlorite, with minute wavy structure, like B, but holding none of its accessory minerals, and associated with and probably an altered form of the greenstones, occurs in bed XI, Marquette region (107), [527, 537, 2106, 931]. Compare also [2058, 2222, 2225, 2239, 2254, 442], which have been called chloritic and talcy, and are not intimately associated with greenstones. A rare but beautiful, greenish to blackish, variety (biotite schist) occurs in the middle portion of the upper Huronian, W. and S. W. of Lake Eliza [2638, 2651, 3370].

D. Light-gray, unctuous-feeling, soft, slaty schist, probably hydromicaceous; only found with iron ores in bed XIII, Marquette region (53, 54). These rocks closely resemble the so-called talc-schist [1081[2]] of the Washington mine as well as the sericite schists of the Menominee region (112).

E. Iron-gray, lusterless, feldspathic or argillaceous obscure mica-schists, with ragged, splitting surfaces, holding leaves of black mica to be seen on the splitting surfaces. Apparently intermediate in character between argillites, mica schists, and chloritic schists [1101[3]], (104[3]). Related is the obscure feldspathic mica schist (103) of typical suite.

F. Garnetiferous and magnetic, blackish mica schist, splitting on bedding planes into thick slates, with glistening surfaces (109). This rare rock is associated with the equally rare garnet rock (150) in the Lower Huronian of the Menominee region, into which it graduates.

In the clay-slate bed XV, Marquette region, non-magnetic garnetiferous mica-schists (phyllite) occur (56). A related rock (108) occurs on the Pine river, Wis. These varieties lead us naturally to the next variety:

G. Phyllite, which is the transition variety, connecting clay-slate and mica-schist (111, 108, 56). Dr. Wichmann describes calcareous and actinolitic varieties, which are not common [1100, 2255], (105). The rocks which he finds characterized by muscovite, are so scattered

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[1] Julien, Mich. Geol. Rep., Vol. II, p. 130.

[2] Julien, Mich. Geol. Rep., Vol. II, p. 116. [3] Id., pp. 105, 106.

stratigraphically and geographically that the attempt to group them, according to the plan of this chapter, would be futile.

Those desiring fuller and more strictly scientific information regarding the micaceous group of rocks, are referred to the two following chapters, under specimens (61, 109, 53, 90, 104, 105, 108, 103, 106, 89, 156, 110).[1] For microscopic characteristics exclusively, see specimens [2162, 2163, 327, 1101, 1102, 2087, 2212, 2254, 2090, 2255, 2058, 2222, 2225, 2239, 442].

15. Hydro-Mica Schists. From the beginning, "soap-rock" was a common term among the Marquette iron miners for certain soft, gray, pearly, greasy-feeling schists, found associated with the ores, and even as late as Dr. Credner's excellent paper,[2] beds of talc schist constituted important members of the Huronian series. The investigations of Dr. C. Dewey and others have proved that most of the rocks of this class have some hydro-mica as their essential constituent. The studies of Lake Superior rocks by Messrs. Wichmann and Julien have so diminished the number of the so-called talc schists, that, as has already been remarked in speaking of this group, it is questionable if any true undoubted talc rocks, to the extent of constituting beds, remain. On this point the experts are not entirely agreed. (See *talc schist*, and Nos. 53, 54, 74, in following chapter.)

So far as Dr. Wichmann's investigations extend, sericite is the only hydro-mica observed (112). So insensible is the change of this rock into argillite, and so difficult is its determination in thin-section under the microscope, that chemical analysis must often be resorted to here as well as in separating it from the talc-schist. The soft and friable character of this rock prevents it being seen in outcrops unless exposed by running water, as is the case on a large scale in the north bank of the Pine river, in Sec. 34, T. 40, R. 17 E., Wis. [2731 to 2733]. The cleavage and jointing are more perfect here than has been observed elsewhere in this rock. Pencils of lozenge section, and less than ½ inch on a side, were obtained over a foot in length. This remarkable bed, which is believed to have a very considerable extension W. by N. and S. by E. under the drift-covered area, is undoubtedly Upper Huronian, and most likely in bed XV. Whether this Pine river hydro-mica schist belongs to the ferruginous clay-slate bed XV or not, the same rock is found in that bed northwest of Lake Eliza [3417, 3422], and a closely related, possibly argillaceous, rock occurs east of the Commonwealth mine [3452, 3453]. Following this horizon (the lower

[1] See, also, Dr. Hunt's remarks on mica schists under Montalban rocks, in appendix.
[2] Zeitschrift der Deutschen Geologischen Gesellschaft, XXI Band, 1869.

part of the Upper Huronian), we find at the Big Quinnesec Falls an important bed of true sericite-schist, as first determined by Dr. Wichmann [2071, 2862]. Still further in the same direction below Sturgeon Falls, and in a younger bed, is a schistose mixture of sericite and red orthoclase, formerly called protogine, but which Dr. Wichmann terms a sericite-gneiss (147). Passing to the base of the Middle Huronian, about which comparatively little is known except that it must be made up of soft rocks because nearly everywhere covered by drift, we find reposing on the iron-ores, VI, well-exposed at the Vulcan mine [2988, 2989] and in test-pits in the south part of Sec. 31, T. 40, R. 30 W., Mich. [2942 to 2945], a thick and important bed of sericite-schist, gray, red and mottled, graduating into and associated with several varieties of clay-slate. This formation we designate as bed VII. It is doubtful if it is sharply divided from the iron-ores, and beds of hydro-mica schist will undoubtedly be found interstratified with the latter, since this is everywhere the case in the Marquette region (53, 54) [1081]. This rock, however, has not been observed in the latter region in anything like as extensive beds as those above described.

I submitted some bits of this group of rocks to Prof. Dana, who remarks: "The conclusion you express respecting *talcose schist* is that I have reached from my study of Vermont slates and those of other parts of New England. The analyses made by Mr. Barker, and others by Hunt, prove this with regard to the Vermont "talcose" schist, and the Vermont Report consequently used the term *talcoid schist*. The name *hydro-mica* is a general one for them, whether damourite or sericite in composition. In fact, owing to the presence often of some free quartz, chemical analysis could not obtain uniform results. Hunt's *parophite*, a rock in Vermont, I am confident is of the same nature; it is in the Mineralogy under *pinite*, and it is an interesting fact that the varieties of *pinite* have essentially the composition of a hydro-mica, it being a hydrous potash-alumina mineral. * * * It is not possible to mark the limit between the hydromica schists and the argillites on one side, and fine-grained mica-schists on the other. Decidedly greasy is the characteristic."[1]

16. Gneiss. No typical mica-gneiss was found in the iron-bearing series so far as made out by me in the Marquette region, but Dr. Rominger considers certain granitic and gneissoid rocks north and west of Marquette, which I did not study but regarded as Laurentian, to belong to this series. I have but little doubt but that the

[1] See, also, Dr. Hunt's remarks on unctuous-feeling schists in appendix.

younger Huronian rock made out in the Menominee region (the granitic bed XX) will yet be identified in the Marquette region, and will be found to be more or less gneissic. The very rocks mentioned above may possibly be Upper Huronian; the granites, etc., southwest of Michigamme lake very probably are.

In the Menominee region gneiss is quite abundant in the Upper Huronian, not only as occasionally occurring in the granitic bed XX, but forms a distinct bed (XVII), occasionally granitic [2896], which is strongly developed on the Michigan side along the upper part of the Big Quinnesec rapids, where it is associated with chloritic schists and greenstones. An "augen" variety is found here (157), [2910, 2346]. The same beds outcrop extensively through the center of the east half of Sec. 24, T. 39, R. 17 E., where the black mica forms minute lenticular laminæ (146).

A. The gneiss above-named as characterizing bed XVII, presents besides the "augen" variety (not abundant), the following: (a). Fine-grained, schistose to sub-schistose, very hard, feldspathic and micaceous rock, weathering red on surface [2349]. (b). Typical gray gneiss with small crystals of triclinic feldspar, and large rare ones of orthoclase. Mr. Julien classifies these as biotite-gneisses, [2875 to 2880, 2908 to 2914]. Dr. Wichmann found what he regards as original calcite in the same rock (146). (c). Hornblendic varieties occur, through which the rock graduates into hornblende-schist and probably chloritic schist.

B. *Hornblende-gneiss* occurs in bed XIX, south of the Pine river near the Poplar, (117), [2761], and at a few other localities, [2120, 1762, 2105, 2805].

C. *Sericite-gneiss* (147), formerly called protogine, is found in bed XVII, at Sturgeon Falls on the Menominee. At Big Quinnesec, in an older bed is a somewhat similar rock, called sericite-schist, [2071].

D. *Granitic-gneiss*, often porphyritic, occurs as a semi-schistose variety of the granite of XX, [2859], and rarely in bed XVII, [2896].

E. A provisionally named *protogine conglomeritic gneiss* (65) occurs as the lowest Huronian rock at the falls of Sturgeon. In the typical suite several interesting specimens are described (102, 146, 117, 3, 7). Others of interest in the general collection are [1656, 2069, 1757].

F. An obscure, green-black, semi-schistose variety, resembling in physical character some greenstones, is found associated with the great quartzite bed XIV, in the vicinity of Lake Eliza [2743, 2746, 2822, 3437]. A related rock in appearance occurs west of the lake, and belongs apparently to a younger bed [2667].

G. On the south side of the Big Quinnesec basin are chloritic gneisses [2850, 2852], which illustrate the transition of this rock into chloritic schist, often associated with it in this vicinity.

Those desiring fuller and more strictly scientific information regarding the gneissic rocks, are referred to the two following chapters, under specimens (102, 146, 157, 3, 80, 7, 117, 147). For microscopic characteristics exclusively, see specimens [1641, 1656, 146, 2069, 2234, 944, 1, mica], [1762, 2120, 2211, 2105, hornblende], [1757, diorite], [3003, chlorite], [2271, sericite].

17. Granite. Until my survey of 1874, granite of Huronian age was not known, except as a small dyke at Felch Mountain. It is now certain that the large granite area south of the Quinnesec falls [2129, 2859], in Wisconsin, the granites and gneisses north of the North Iron belt [2421, 2423], and those between the Lower Michigamme and Paint rivers (101) [3338 to 3341], overlie conformably the younger Huronian schists, into which they send dykes. Except near the contact with the underlying schist, evidence of bedding is very rare, pointing towards its possibly being eruptive: *e. g.*, a great overflow at the end of the Huronian period. We have designated it bed XX, and, so far as made out, it is the youngest Huronian rock in the region.

I think it is probable that the extensive granitic belt southwest of Lake Michigamme may be the equivalent of the granite.[1] The work being done by Messrs, Irving and Wright in the Penokee range will undoubtedly throw light on the question of whether the granite area which there divides the Huronian and Copper series is of the same age, as conjectured by me.

Those desiring fuller and more strictly scientific information regarding the granitic group of rocks are referred to the two following chapters, under specimens (101, 96). For microscopic characteristics exclusively, see specimens [1715, 1749, 2129].

18. Porphyry. No well characterized felsite porphyries have been observed by me in the Huronian of the Menominee region, nor between Marquette and Bad river, Wis. Julien provisionally called No. (83) "green porphyry," but Dr. Wichmann, after careful study, determined it to be diabase, having some of the qualities of serpentine. It is probably an altered rock. In Central Wisconsin, according to Chamberlin (Geol. of Wis., Vol. II, pp. 249–251) and Irving (ditto pp. 519–521), bedded porphyries are very abundant in association with quartzite in a series of rocks which they assign to the Huronian period.

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[1] See my article on "The Youngest Huronian Rocks South of Lake Superior, and the age of the Copper-bearing Series," Am. Jour. Sci., Vol. XI, March, 1875.

In Foster & Whitney's Report,[1] Part 2, p. 26, etc., are several mentions of porphyritic rocks seen on the Menominee between Peminee and Quiver falls, and from the former locality I have collected specimens, although beyond the limits of my survey. Mr. Julien has described and named them under *porphyrites* (158, 159). The talcose slates, "porphyritic with large crystals of red feldspar," mentioned by F. & W., were not seen. Besides, at this locality, a related rock was found 1,500 paces W. of the S. E. corner of Sec. 21, T. 41, R. 32, Mich., associated with the granite of bed XX, hence occupying, as near as I can determine, the same stratigraphical position as the Peminee falls series, *i. e.*, youngest Huronian. These two localities are the only ones in the Upper Peninsula of Michigan, or in extreme Northern Wisconsin, where I have observed rocks of this class in the Huronian series.

The porphyries mentioned in Owen's Reports as occurring on the Minnesota shore of Lake Superior, may be of the same age. The abundance of porphyry pebbles in the conglomerate of the Copper-series also points strongly towards their existence in the rocks of the next older period. I do not find that the Canadian geologists have observed porphyries either in the Huronian or Laurentian bordering the great lakes. For additional notes regarding these rocks, see the following chapter, under Nos. 158 to 161; also, Dr. Hunt's remarks on porphyries in Appendix. Unfortunately no rocks of this class were submitted to Dr. Wichmann.

19. Serpentine. Serpentinoidal rocks, apparently altered greenstones (78), and having somewhat of an eruptive character, are rare. At the Sturgeon falls are related rocks [1247,[2] 2263], as well as in the L'Anse Iron range (83). The locality of the serpentine on Presqu' isle [876 [3]], described by Foster & Whitney, is classical, but still there is some uncertainty as to its age. It is probably Huronian, and presents some of the phenomena of an eruptive mass.[4]

[1] In Part 1, p. 70, they mention "porphyritic traps" and "quartzose porphyry" as occurring in the Copper series of rocks.

[2] Julien, Mich. Geol. Rep., Vol. II, p. 166. [3] Id., p. 165.

[4] See Appendix for Dr. Hunt's remarks on serpentine.

CHAPTER IV.

DESCRIPTION OF TYPICAL ROCKS.

Description of a suite of typical rocks, from the Huronian series south of Lake Superior, embracing 162 specimens, and believed to include all kinds and the chief varieties.

The selection of this suite has extended through twelve years, and embraces the most interesting varieties from my collection of Huronian rocks of over 4,000 specimens. A brief mention was made of specimens 1 to 81 under provisional names, in Appendix B, Mich. Geol. Report, 1873. Including the Wisconsin suite sent to Madison, twenty-seven duplicates of these rocks were distributed to cabinets, institutions and individuals in various parts of the United States and Europe.[1]

In 1876, the collection had increased to 145 specimens, and a considerable number having been determined by competent lithologists, a "classified list" was published in the Amer. Jour. of Science, September, 1876. The 162 specimens now constituting the collection, embrace, as I believe, all the Huronian rocks found by Messrs. Irving

[1] University of Michigan, Ann Arbor, Mich.; Michigan State Library, Lansing, Mich.; State Agricultural College, Lansing, Mich.; Hillsdale College, Hillsdale, Mich.; Kalamazoo College, Kalamazoo, Mich.; Adrian College, Adrian, Mich.; Albion College, Albion, Mich.; Olivet College, Olivet, Mich.; Boston Institute of Technology, Boston, Mass.; Harvard University, Cambridge, Mass.; School of Mines, University of Pennsylvania, Philadelphia, Pa.; School of Mines, Columbia College, New York; Union College, Schenectady, N. Y.; Cornell University, Ithaca, N. Y.; Smithsonian Institute, Washington, D. C.; Sheffield Scientific School, Yale College, New Haven, Conn.; Stevens Institute, Hoboken, N. J.; Washington University, St. Louis, Mo.; The State Cabinet, Madison, Wis.; Royal School of Mines, Stockholm, Sweden; Royal School of Mines, Freiberg, Saxony; Museum of Practical Geology, London, England; Canadian Geological Survey; United States Military Academy, West Point, N. Y.; Prof. Raphael Pumpelly, Owego, N. Y.; A. R. Marvin, Esq., Cambridge, Massachusetts (after Mr. Marvin's death, this suite was donated by his widow to the University of Leipsic); Alexis A. Julien, Esq., School of Mines, New York; J. Blodgett Britton, Esq., Philadelphia, Pa. (It may be well to state that these collections were made by Maj. Brooks personally, and are independent of those distributed by the Wisconsin survey, in accordance with legal requirement. — T. C. C.)

and Wright in Wisconsin, and not before represented. A few familiar rocks under new names, or from new and important localities or beds, have been added.

The suite is now deposited, with my entire collection, including several hundred thin sections, in the American Museum of Natural History, New York city, where it is available for study; and I hope sometime to publish a final and revised descriptive catalogue, which shall bring the nomenclature up to the then present state of lithology. It is my intention to duplicate it for exchange; meantime the best half is available to students from the wide distribution of duplicates. By condensing, as it were, the chief lithological interest on a comparatively few specimens selected with great care, the studies and comparisons of those who have not time nor inclination for protracted work, is greatly facilitated. These smaller suites can be duplicated and scattered, while the few great collections must remain in one place necessarily inaccessible to many who might desire to consult them.

In the following alphabetical index of specimens, the free use of the interrogation point signifies either provisional or doubtful names, some obscure specimens having as many as *four* names under which they are indexed.

The preceding chapter may be used as one kind of lithological classification, and the Table of Sequence as a stratigraphical and geographical arrangement of this collection, the specimens of which are here arranged under the collection-numbers.

The final names, descriptions of thin sections, and many of the comparisons with rocks of other regions, are by the following-named gentlemen, who have examined either the hand-specimens or thin sections of the rock of this suite under which their observations appear: Samuel Allpert, Geo. J. Brush, T. Sterry Hunt, Geo. W. Hawes, Alexis A. Julien, Raphael Pumpelly, Frank Rutley, A. E. Törnebohm, Chas. E. Wright and Arthur Wichmann.

Nos. 1, 4, 14, 60, 62, 63, 80, 86, 87, 92, 93, 95, 100, are wanting. Nos. 140, 143, 141, 78, 116, 118, 79, 82, 120, 102, 117, 104, 109, 107, 106, 129, 58, 123, 126, 124, 125, 127, 55, 89, 134, 112, 27, 37, 12, 139, constitute R. Fuess's (Berlin) "Selection No. 8. Thirty thin sections of Typical Huronian rocks from south of Lake Superior, from collection of Major T. B. Brooks."

ALPHABETICAL INDEX.

Alphabetical Index — (continued).

No. 2 (3002[1]).— **Martite schist** (Julien) (porous, granular, specular

[1] The numbers in brackets are the collection numbers.

ore). Compare Nos. 43, 44. Differs from Julien's No. 239, Mich. Rep., Vol. II, p. 123, in being cellular and containing kaolin. Is rather fine-grained, slightly magnetic, massive, pseudomorphous after magnetite. Sp. Gr. 4.12 to 4.39. Rich in metallic iron and valuable as an ore.

Loc. Below bed V near "Old Michigan Mine," in a small, irregular, possibly seggregated, mass in schist. A similar ore, but less porous, is found in bed XIII, Marquette region, and also in the Menominee region in bed VI. The Gillmore and Chippewa ores in the same horizon are related. See Mich. Geol. Rep., Vol. I, p. 94. In neither case does the amount seem large.

No. 3 (3003). — **Chlorite-gneiss** (Wichmann). Has also been called talcoid gneiss. Compare Nos. 65 and 102. Has much resemblance to Laurentian chloritic gneisses and to Huronian protogine gneisses. Greenish-gray, semi-schistose, weathering brown. Sp. Gr. 2.65 to 2.76. Constitutes a bold east and west ridge two miles north of Clarksburgh, probably bed V, as large quantities of a similar rock are found in Secs. 25, 26, 27, 28, 29, T. 47, R. 27, replacing or associated with the quartzite of bed V. Related rocks, believed to be Laurentian, occur in Sec. 16, T. 49, R. 33, L'Anse Iron District. See Julien's Nos. 298, 299, Mich. Geol. Rep., Vol. II, p. 154, and remarks, p. 31.

"The feldspar-constituent is chiefly represented by orthoclase, which is much altered. The change starts from the fissures, and numerous scales of a mica-like mineral have been derived from it. Plagioclase is recognizable by the twin-lamellation, which it shows in polarized light. The large pellucid granules of quartz contain many fluid-enclosures and some colorless microlites. Membranes of hydrated oxide of iron occur in the fissures. Chlorite is less abundant than the above mentioned constituents. It forms irregular green scales and folia, which generally are aggregated in clusters. Small individuals of hornblende appear but are not of frequent occurrence. A little apatite is present in orthoclase."— Wichmann. See, also, his report, § 106, for a description of this rock.

"Has some resemblance to certain reddish gneisses that are found in some parts of East and West Gothia and even elsewhere. These are, however, not common or well-defined types among the Swedish gneisses. The same may be said of Nos. 65, 80, and (870)." [1]—Törnebohm.

"The section of this rock under the microscope is seen to consist of irregular patches of quartz composed of aggregates of crystals, of feldspar somewhat altered, and finely disseminated scales of a green

[1] Julien, Mich. Geol. Rep., Vol. II, p. 143.

mineral which is dichroic and may be either chlorite or hornblende, for the most part probably the latter. The rock is some form of gneiss or granulite. Other minerals than those specified may be present. The feldspar appears, at all events, partly to be orthoclase." —Rutley.

No. 5 (3005).—Fine-grained **Hematite schist** (siliceous specular ore). Compare Nos. 6, 68, 43. Related to Julien's No. 240, Mich. Rep., Vol. II, p. 123. Numerous small, ill-defined octahedra; occasional minute quartz veins; somewhat hard; feebly magnetic; schistose to massive, the latter being far less common. Sp. Gr. 2.65 to 2.76. An average sample gave Chandler and Cairns: $Fe^2 O^3$ 83.70, MnO, trace, Al^2O^3 3.34, CaO .75, MgO .34, S .03, PO^5 .24, SiO^2 10.67, HO .87, = 99.94.

Loc. Below bed V. West-End Pit, Cascade Mines. A workable layer of a good quality of specular ore, associated with the quartzose hematitic flags (No. 6) which prevail. Similar, but more quartzose than the massive varieties of ore from bed XIII, Marquette, and more like that in Sec. 31, T. 42, R. 29, bed VI, Menominee region. See Julien's No. 239, Mich. Rep., Vol. II, p. 123. Has been smelted for several years.

No. 6 (3006).—**Granuliferous specular-iron schist** (Julien) (bird's-eye ore). Resembles, except in granules, No. 68. Compare Nos. 38, 45. Less rich in iron than Julien's No. 237, Mich. Rep., Vol. II, p. 122. Made up of micaceous-iron, with considerable siliceous matter, in which are imbedded numerous small grains of decomposed garnets (?), around which the micaceous scales warp. Sp. Gr. 3.61 to 3.90. An average sample gave Britton: Fe^2O^3 71.98, MnO .01, Al^2O^3 .68, CaO .16, MgO .06, S .04, PO^5 .07, insoluble siliceous matter 25.26, HO 1.03. Alkalies undetermined and lost, .71, = 100.00.

Loc. Below bed V, Bagley Pit, Cascade Mines, where it constitutes a variety of the prevailing siliceous specular flag-ore. Somewhat similar ores are found in beds X, VIII and VI, Marquette region, and bed VI, Menominee region. The "bird's eye" variety has only been found in the Cascade range in quantity. Has been worked to a limited extent, but is less valuable than No. 5. Contains not enough iron and too much silica.

No. 7 (3007).—**Red orthoclase granitic gneiss.** No allies. Compare No. 96. A coarse crystalline aggregate, chiefly of white quartz and flesh-colored orthoclase, with perhaps a little white mica.

Has considerable lithological resemblance to granite veins in bed XIX, Menominee region, as well as to similar dykes in the Laurentian. Sp. Gr. 2.53 to 2.62.

Loc. One hundred yards north of the west-end pit, Cascade mines, and probably in bed IV. Apparently quite local, and possibly a dyke. It has nearly the same stratigraphical position as the syenite, No. 116, and the feldspar is similar, but no other resemblance.

"Something like that rock may no doubt be found among the Swedish gneisses, but certainly only as a rare and local variety. At the moment, I remember no instance."— Törnebohm.

No. 8 (3008). — **Glassy, arenaceous quartzite.** (Brownish-gray quartzite.) Compare Nos. 138, 21 and 137. Julien's No. 129 is finer grained and contains more ochre, and weathers whiter. Mich. Rep., Vol. II, page 69. See also references under No. 137. Massive, made up of medium-sized, glassy, crystalline grains of quartz, and a little black mica. Weathered surface but little changed. Is more granitoid in appearance than the great quartzite bed II, of the Menominee region (No. 137). Sp. Gr. 2.65 to 2.71.

Loc. Bed V, Republic mine, where it constitutes a thick layer, the lowermost of that series reposing nonconformably on the Laurentian, overlaid by chloritic schist. Where calcareous rocks are present, as in the eastern portion of the region, there is an almost insensible gradation from quartzites to dolomites. See Julien's 110, Mich. Rep., Vol. II, p. 59. See also remarks under the limestone, No. 141. A pure variety was crushed and employed for Bessemer converters, for which purpose it is said to have answered well.

No. 9 (3009). — **Mottled dolomite-marble** (Julien). Compare Nos. 143, 11, 66, all from same bed. Several varieties are described by Julien in Mich. Rep., Vol. II, pp. 56 to 61. Mottled white and dull-red, fine-grained, semi-schistose; effervesces with acid only when pulverized. Sp. Gr. 2.80 to 3.06. See analysis of No. 66.

Loc. Bed V. Chocolate flux quarry, near Marquette; associated with quartzose rocks and beds of brownish argillaceous slate (novaculite, Nos. 10, 12), and underlaid by hydrous magnesian slates and quartzites. All much contorted. See Mich. Rep., Vol. II, p. 243, Fig. 18. Similar rocks occur at the Morgan furnace and near Lake Fairbanks in same bed. A purer variety constitutes the greater part of bed V, Menominee region. See Nos. 66, 143, 142. Has been used as a flux to a limited extent. Too much silica and magnesia. Beautifully variegated varieties occur, but usually there are so many joints and seams as to render it available only for building purposes.

No. 10 (3010). — **Novaculite** (Wright). Has also been called chloritic schist and clay slate. Similar to Nos. 12 and 13. Resembles Julien's Nos. 182, 183, 190 to 193, Vol. II, Mich. Rep., pp. 95–100. A greenish-gray or chocolate, sometimes mottled, slate, intermediate in character between chloritic and clay slates, with oblique cleavage, moderately fissile. Sp. Gr. 2.78 to 2.87.

Loc. In bed V at Chocolate Quarry, L. S., associated with dolomites and quartzose rocks as described under No. 9. Has been found at several points in this bed. This kind of rock has not been observed elsewhere in the Archæan, south of Lake Superior.

No. 11 (3011).—**Salmon-colored dolomite** (Julien). (Coarsely crystalline marble.) Compare Nos. 142, 141 and 9. Julien's Nos. 108, 109, Mich. Rep., Vol. II, p. 58, are from same bed. A coarse, highly crystalline, lustrous mass, with large tabular crystals having some resemblance to orthoclase. Effervesces very slowly in cold acid. Sp. Gr. 2.78 to 2.87.

Loc. Bed V. Morgan Furnace Quarry. A pure and rare variety of the dolomite, associated with siliceous and mottled varieties, and with beds of the dark-purple novaculite, No. 12. See remarks under No. 9. The marble from this locality is the best known in this region for flux, and has been quite extensively employed.

No. 12 (3012).—**Novaculite** (Wright). Has been called purple clay slate and mottled feldspathic argillite. Similar to Nos. 10 and 13. Differs from No. 10 in being purplish-brown and spotted. Sp. Gr. 2.71 to 2.88.

Loc. Bed. V. Morgan Furnace Quarry. See Nos. 10, 11. Somewhat like the clay slate near Plauen in Voigtland, Saxony. (Wapler.) See No. 13 for use. "In the amorphous substance are many crystalline, colorless needles. Some hematite in form of small folia. A little quartz. The black substance is probably coal."—(Wichmann.)

No. 13 (3013).—**Novaculite** (Wright and Wichmann). Has been called clay slate and talcoid siliceous schist. Similar to Nos. 10 and 12. See Julien's No. 161, Mich. Rep., Vol. II, p. 85. Lighter colored, harder, less fissile and more lustrous than Nos. 10 or 12. Regarded as the most typical form of this rock. Sp. Gr. 2.71 to 2.78.

Loc. Bed V, Whetstone quarry, Teal lake. In a small lenticular bed, associated with quartzite. As early as 1850, whetstones were quite extensively quarried and sold from this locality, but are not at present.

"Novaculite represents especially clay slates which are rich in quartz, and numerous scales of a talcy mineral which are parallel to the splitting plane. The argillaceous material is filled with a dust-like material, and some clusters of hydrated oxide of iron. Small prisms of tourmaline occur, which generally have broken into several pieces. Hematite, in the form of small blood-red folia, is irregularly distributed throughout the whole rock. Irregular grains of garnet appear here and there."—Wichmann.

"Is not like anything in our Archæan formation, but has some resemblance to certain clay slates interstratified in the red sandstone of Dalecarlia, which is believed to be Cambrian. The same applies to No. 55."—Törnebohm.

No. 15 (3015).—**Magnetic mica slate** (Julien). Has been called greenstone schist, with much magnetite. Compare Nos. 23, 36 and 131. Fine-grained, grayish-black, apparently made up of quartz, magnetite, and chloritic (?) mica, which is conspicuous on weathered seams. Sp. Gr. 3.13 to 3.42.

Loc. Bed VI, Republic Mine, is chiefly made up of this schist, which is often distinctly banded on weathered surface; overlaid by greenstone and underlaid by quartzose and schistose rocks. Beds VIII and X of the Marquette series often contain similar rocks. Similar rocks occur near Ehrenfriedersdorf in Saxony (Wapler). See remarks under No. 23.

"In thin section the colorless and striated (or fibrous) mineral, which somewhat predominates in quantity, appears to be muscovite; between the crossed nicols, it polarizes brilliantly. Biotite is also prominent in scales of a brownish-green, brownish-yellow, etc., which are dichroitic. Magnetite is abundant in blackish-gray scales and plates, often presenting hexagonal and octagonal cross-sections. They are often encircled by ochreous films and chords of a brownish-yellow color. Quartz seems to be represented by a few clear and colorless granules."—Julien.

No. 16 (3016).—**Micaceous-iron quartz schist.** Popularly called "fish-scale ore." Similar to Nos. 32 and 33. Compare Nos. 37 and 49. Fine-grained, dull, reddish-brown, arenaceous quartz, to which a marked schistose structure is imparted by exceedingly thin laminæ, composed of angular scales of hemitite, which glisten and glitter on the splitting planes. Sp. Gr. 2.92 to 3.42.

Loc. At the Cannon Mine, Sec. 28, T. 47, R. 30, where this rock occurs in small quantities in, or near, bed V. In it is a seam one foot thick where the specular ore predominates. The rock graduates into or is intimately associated with micaceous quartz-schists. Except in the eminently micaceous character of the iron, this rock has resemblance to the similar schists of bed XII, Marquette region, and to certain ores in bed VI, S. W. of L. Antoine, in the Menominee region. This Cannon location has been much explored, but no valuable ore has been found in paying quantities.

No. 17 (3017).—**Chloritic magnetite schist** (Julien). (Tabular magnetic ore.) Compare Nos. 42, 23, 19, 148. Brownish-black, exceedingly fine-grained, hard, containing hornblende in irregular bunches and seams, and in places numerous quartz laminæ. It is tougher and more compact than any other equally rich magnetic ore. Sp. Gr. 4.15 to 4.51. An average sample gave F. B. Jenney: Fe^3O^4 78.35, Mn^2O^3 .10, Al^2O^3trace, CaO .69, MgO .21, S .58, PO^5 .151, insoluble siliceous matter 19.64, undetermined and lost .279=100.00.

Loc. Magnetic Mine, Sec. 20, T. 47, R. 30, from bed VI or IV, where it occurs associated with thin-bedded gray quartzite and overlaid by greenstone. See Mich. Rep., Vol. I, p. 132. This tabular hornblendic ore has not been observed elsewhere, but it resembles some varieties in bed XIII. See Julien's No. 228, Mich. Rep., Vol. II, p. 117.

A workable deposit of ore, which will yield about 55 per cent. of metallic iron in the furnace, has been opened.

"Appears to be identical with the variety of magnetite occurring west of Greensboro, N. C., and at other localities in that state."—Julien.

"In the thin section, magnetite largely predominates in minute octahedra, grouped together in an irregular network. Quartz occurs in colorless granules. Hornblende, brownish-yellow to brownish-green, is abundant here and there in radiated masses, with the usual cleavages and strong dichroism. By its green forms it is seen to pass into chlorite, which also occurs in irregular or bladed scales."—Julien.

No. 18 (3018).—**Hornblende rock** (Wright and Wichmann). Has also been called coarse Hornblendic Diorite. Like Nos. 22 and 30. Compare Nos. 77, 75 and 88. Resembles Julien's No. 303 (probably from same bed), Vol. II, p. 106. Greenish-black, speckled with gray, medium-grained, massive to semi-schistose, weathering gray and brown like the diorites, to which it is related in appearance, but is blacker and of higher specific gravity. Sp. Gr. 2.94 to 3.08.

Loc. Bed VII, Republic Mine. The prevailing rock in this bed, which has nearly the same character at the Washington Mine. Similar hornblende rocks also occur in bed IX. Exactly identical rocks have not been observed in the Menominee region, where they are often lighter colored and coarser grained, although Nos. 123 and 127 from there are closely related. Similar rocks are rare, if not absent, in the Gogebic region. "Compare with the similar variety from the Greensboro belt in N. C." (See Geol. of N. C., Vol. II)—Julien.

No. 19 (3019).—**Magnetic siliceous schist** (Julien). Resembles No. 23, which contains more iron, and No. 5. An iron-gray homogeneous mixture of fine-grained, compact quartz and magnetite grains.

Another, and the prevailing variety is schistose and in places almost slaty, the weathered surface of which is distinctly striped reddish, blackish, whitish and greenish, suggesting a rag carpet. The green color may be due to chlorite; the others are apparently from the oxides of iron. Sp. Gr. 3.46 to 3.57, which indicates considerable iron.

Loc. Bed VIII, Republic Mine, which is quite thin (40 to 50 feet), is mostly constituted of this schist, which is similar to that in bed VI.

No. 20 (3020).—**Clay slate.** Compare Nos. 81, 113 and 10. See Julien's Nos. 191 and 221, Mich. Rep., Vol. II, pp. 99 and 114. Dull, dark, brownish-gray, with imperfect, oblique cleavage, moderately fissile, clay slate. The bedding planes are marked by faint bands forming an angle in one specimen of 30° with the cleavage planes. Sp. Gr. 2.67 to 2.71.

Loc. Bed VIII, as exposed in the railroad cut, one mile E. of Negaunee. This rock is also to be seen on the S. shore of Teal lake. In another place it is associated with a quartzite similar to No. 21. Clay slates are most abundant in the L'Anse and Huron Bay districts of the Marquette region, and in the Menominee region, where they are usually destitute of oblique cleavage. Such cleavage appears to be confined to slates associated with quartzites or marble. See further remarks under No. 113. No slates that promise to have value equal to that represented by No. 81, have been found in this bed.

No. 21 (3021).—**Gray quartzite.** Compare Nos. 8 and 137. See Julien's Nos. 126 to 135, Mich. Rep., Vol. II, p. 68 to 72, for several varieties. Fine-grained, gray, arenaceous, glassy, slightly mottled with light-brown spots, massive, semi-conchoidal fracture, slightly influenced by weather. Sp. Gr. 2.64 to 2.69.

Loc. Bed VIII, N. W. end of Lake Fairbanks. This layer is neither thick nor wide-spread. The clay slates, No. 20, prevail in this bed. Similar quartzite occurs with the roofing slate in the Huron Bay district, and closely related rocks are generally distributed. See remarks under No. 137.

No. 22 (3022).—**Hornblende rock** (Wright, Rutley, Wichmann). A variety has been called micaceous altered diorite. Like Nos. 18 and 30. Compare Nos. 75 and 77. A little finer grained, otherwise like No. 18. Nos. 123 and 127 are the nearest, and not abundant, varieties observed in the Menominee region. A brownish micaceous mineral appears on the weathered surface of some varieties. Sp. Gr. 2.96 to 3.05.

Loc. From bed IX, Republic Mine, which is chiefly constituted of similar rocks, which graduate into varieties related to diorite.

"Under the microscope, the hornblende shows its characteristic structure. The green prisms lie confusedly together. In sections cut perpendicular to the main axis, the prismatic cleavage is distinctly recognizable by fissures, which cross one another at an angle of 124° 30′. In sections parallel to the main axis the prisms show a longitudinal striation. The hornblende is also characterized by a strong dichroism, which it shows when tested by a single nicol's prism. Aggregations of irregular individuals of orthoclase (and a little plagioclase) represent the ground-mass. The constituent individuals show partly a beginning of alteration. A little quartz appears in irregular water-clear grains. Small prisms of tourmaline occur now and then. Biotite is abundant, and always found associated with hornblende. Magnetite and titanoferrite are present. Hexagonal prisms and needles of apatite occur, especially piercing the green individuals of hornblende." — Wichmann. See also his report, § 144.

"This rock is composed of quartz and hornblende, together with a mineral which in section under the microscope is opaque, and which is probably partly pyrites and partly some altered form of hornblende. Apparently no magnetite is present, as the rock does not affect the needle. There are also some minute translucent prisms visible; among these, some may be apatite, but no good transverse sections are to be seen, and most likely the majority, if not all of them, are minute hornblende crystals." — Rutley.

No. 23 (3023). — **Magnetic siliceous schist.** Provisionally called, siliceous magnetic flag ore. Resembles No. 19. Compare No. 15. Contains more iron, otherwise like the slaty variety of No. 19. This abundant flaggy rock, of which there are numerous magnetic and hematitic varieties, is always a very fine-grained, nearly homogeneous mixture of iron oxide and siliceous matter, sometimes faintly banded, owing to the predominance of one or the other of the ingredients in certain laminæ. It will thus be seen to differ entirely in structure from such banded ferruginous quartzose rocks as Nos. 32, 37, 52, although very nearly agreeing with them in chemical composition. This is a typical flag-ore. These flag ores are not siliceous varieties of the specular schists represented by No. 45, into which they never graduate, and with which they are never stratigraphically associated, but which, unfortunately, they often resemble. Confounding the two has been and is still productive of great losses in mining operations. See Mich. Rep., Vol. I, p. 83. Sp. Gr. 3.73 to 3.86. Probably contains 40 per cent. of metallic iron.

Loc. Bed X, Republic Mine, like beds VI and VIII, is largely made up of these magnetic, striped on weathered surface, siliceous flags. To the eastward these beds change their character materially, being more hematitic and less banded. The chief exposure of the magnetic ore on the N. side of Penokee Gap, is very similar to this, but Dr. Wichmann finds hornblende in specimens of it. The siliceous flag ores, to which class this belongs, have been experimentally smelted, but were found to contain too much silica and too little iron, like the second-class or mixed ores, No. 37.

No. 24 (3024).—**Manganiferous ochrey hematite** ("soft hematite ore"). Like No. 35. Compare Nos. 135, 25, 34. Tiny seams and bunches of pyrolusite, quartz, and occasionally of kaolin. Brown to purplish-brown, earthy, about the hardness of chalk, irregular fracture. Passes into No. 25, which is a softer and more earthy form of the same. The amount of water chemically combined, averaging 4 per cent., indicates that the ores are not true limonites, but mixtures of the hydrous and anhydrous oxides, or perhaps turgite. Sp. Gr. 3.10 to 3.54. An average sample gave Chandler and Cairns: Fe^2O^3 65.40, Mn^2O^3 6.71, Al^2O^3 1.46, CaO .45, MgO .66, S. 04, PO^5 .16, SiO^2 22.67, HO combined, 1.88, uncombined .58=100.01.

Loc. Bed X. Near Negaunee. Associated with quartzose hematitic flags, of which these earthy ores seem to be an altered form from the dissolving out of the silica, and incident hydration of a part of the iron oxide — hence of the nature of residual deposits. See remarks under No. 136. They always occur in irregular pocket-like forms. Ferruginous brown chloritic and argillaceous slates are frequent. Although less rich in iron, they are more easily reduced and answer well for mixture, especially on account of the manganese, hence they are now mined to a considerable extent when the demand for iron is good.

No. 25 (3025).—**Disintegrated ochrey hematite** ("soft hematite ore"). Like No. 34. Compare Nos. 24, 35, and 135. A coarse angular residual gravel. A more earthy form of No. 24.

Loc. Bed X. Rolling Mill Mine, Negaunee. See remarks under No. 24. Map No. 5 of Atlas, Mich. Geological Report, 1873, represents the group of pits recently opened in this bed, from only a few of which has much ore been shipped.

No. 26 (3026).—**Limonitic quartz-schist.** Compare Nos. 24 and 25 from same bed, which may be regarded as a more altered form of the same rock. Chiefly brownish quartz, irregularly banded with limonite, hematite, and ochre, often porous and not infrequently containing kaolin in small irregular bunches. Varies from a hornstone to an earthly brown iron-ore, Nos. 24, 25, which is apparently the same rock with the silica mostly dissolved out. Sp. Gr. 2.99 to 3.38.

An average sample gave Chandler: Fe^2O^3 44.33, Al^2O^3 2.14, Mn^2O^3 .16, CaO .36, MgO .13, SiO^2 47.10, PO^5 .13, SO^3 .17, HO 5.19 = 99.71. By reducing the silica percentage and proportionally increasing the iron, we have the composition of the related ores.

Loc. Bed X., Foster Mine, and elsewhere in same bed, especially near Negaunee; always associated with the earthy limonitic ores, which often contain manganese. A similar rock occurs in bed XII, and below bed V, of the Negaunee district, and in bed VI, Menominee region, and in L'Anse iron range, and W. of L. Gogebic.

No. 27 (3027).— **Eklogite** (Wichmann, Brush). Provisional name, ferruginous, gray, garnetiferous schist. Related to 150. Compare No. 131 from same bed, also Nos. 58, 59, and 130. Identical with Wright's anthophyllite schist containing garnets, No. 1058, and with Julien's gray, anthophyllitic quartz schist, No. 174, Mich. Rep., Vol. II, pp. 228 and 91. Closely related to rocks which have been called anthophyllite schists, see Nos. 58, 59. Brownish-gray, faintly streaked with grayish-white, slightly glittering. A tough, somewhat hard, fine-grained, schistose rock, characterized by the prevalence of a brownish-gray, silvery, fibrous, amphibolic mineral, closely related to a mineral in Nos. 58 and 59, which Prof. Brush determined to be anthophylloidal, if not anthophyllite. Fracture uneven. Weathers reddish-brown. It has some resemblance to a greenstone found at Schwarzenberg, Saxony. Sp. Gr. 3.44 to 3.62. Its high specific gravity is due to the iron. Yields water in the matrass.

Loc. From bed X, S. of the Washington mine, which can be traced west to the Champion mine. South of the Keystone mine, it forms a heavy bed of magnetic schist, having a brown, mottled, weathered surface. Except in bed XVII, related rocks have not been seen in the Marquette region. In the Menominee region, similar rocks, more highly ferruginous and banded with arenaceous quartz layers, occur in beds XIII and XV. See 130.

"Under the microscope, we observe that this rock consists chiefly of two minerals. The one occurs as light-green, nearly colorless columns and needles. This mineral is shown by its optical properties to be a hornblendic one, and is called actinolite. These columns are placed nearly parallel to the schist-plane, often confusedly together. The other mineral is easily distinguishable, macroscopically, in the section, as garnet. Microscopically, these garnets are not sharply defined crystals, but appear in places as highly fissured grains. They are often pierced by needles and rocks of actinolite. Next to those we find numerous particles of magnetite."— Wichmann. See, also, his report, § 165.

"No rock of this kind has yet been distinguished in North Carolina." — Julien.

No. 28 (3028). — **Micaceous chiastolite schist** (Julien). Provisionally called green aphanitic argillaceous schist. No allies. Compare Nos. 131, 91 and 149. A dark-green, faintly banded on fresh fracture with black, crypto-crystalline schist, with eminently conchoidal fracture and no disposition to split on bedding planes. Is brittle and quite hard, but does not give fire with steel. Soon weathers to a greenish-brown on exposure to the air. On edges of thin splinters it fuses readily before the blowpipe to a black enamel. The magnet separates a small amount of magnetite from the powdered rock. Sp. Gr. 2.93 to 3.17. These differences are probably due to the variable amount of magnetite.

Loc. Bed X. N. W. end of L. Fairbanks in R. R. cut, overlaid by ferruginous siliceous schists, and underlaid by a soft, slaty rock. This very peculiar rock has not been observed elsewhere. No. 131 may be a coarser-grained variety, but it differs in containing much magnetite, and unmistakably an amphibolic mineral.

Mr. Rutley says: The foliation in this rock is strongly marked when seen in thin section under the microscope. The chief components are magnetite and felsitic matter, with some hornblende and quartz. The magnetite lies either in distinct crystals or in irregular patches and strings which may be aggregates of crystals. It is mostly massed in the latter manner, thus partly giving rise to the foliation. The hornblende crystals are small and not very numerous. They lie with their longest axes parallel to the foliation. The quartz occurs in little irregularly shaped spots, and there is in places a tendency on the part of the finely granular or crystalline particles of quartz to form thin lenticular partings in the felsitic substance. Some chlorite may be present, but the section examined was very thick and opaque, so that but little detail could be made out.

The rock attracts the magnetic needle strongly. It is a schist, probably some metamorphosed sedimentary rock, but it is difficult to give it any recognized name in the absence of further information.

"I never saw anything like it in Sweden."—Törnebohm.

"The thin section displays a very fine grain with minutely wavy laminæ. Clear and colorless cross-sections of chiastolite crystals are scattered through the section and visible to the naked eye; they exhibit a decided absorption for intensity, polarize rather brightly between the crossed nicols, and appear to consist of unaltered andalusite. The minute laminæ of the ground-mass bend around these crystals in the augen-structure. Magnetite also occurs in a few large square plates scattered through the section, and very abundantly in some laminæ in smaller particles. On examination of the ground-mass under a higher power, it is found to be mainly composed of minute, rounded granules, colorless to brownish white, polarizing feebly, which seem to be fragmentary debris of the chiastolite. Colorless isotrope grains or scales also are present in small quantity. Biotite is abundant, and even predominates in some laminæ in minute, irregular, leather-brown scales, also in narrow or linear blade-like cross-sections, which are strongly dichroitic." — Julien.

No. 29 (3029).— **Micaceous hornblende schist** (Wichmann). Hornblende schist (Wright, Rutley). Compare Nos. 127, 30. Blackish, between medium and fine-grained schists, which structure is imparted by the scales of black mica, in this particular, differing from No. 18, and bearing more resemblance to the hornblende schists, No. 128, from bed XIX, of the Menominee region. It also resembles the very fine-grained Laurentian rocks of the same class. See Julien's Nos. 328, 329, Mich. Rep., Vol. II, p. 169. Sp. Gr. 2.98 to 3.05.

Loc. Bed XI. Republic Mine. While this bed is essentially hornblendic and dioritic, its micaceous character is quite marked, as in this specimen and No. 107. The latter rock is also related to the chloritic varieties found in the same bed in the Negaunee district.

"The hand specimen of this rock resembles some of the Laurentian gneisses of the highlands of Scotland."— Rutley.

"Hornblende is microscopically present in fine green prisms which generally lie parallel to the schist-plane. Besides this, biotite is abundant in brown, irregular folia, which are strongly dichroitic. The occurrence of calcite is remarkable. Its small grains are aggregated in clusters, which are intermingled with small folia of biotite, and have formed in the ground-mass, which consists of an aggregation of irregular individuals of orthoclase. A little quartz is recognizable. Apatite in long, colorless prisms and needles, and sharply defined hexagonals, is not unfrequent." —Wichmann. See also § 135 of his report.

"Under the microscope, it is shown to consist of quartz and hornblende, and a few irregularly-shaped black patches, which may represent some alteration of the hornblende. The rock has no effect on the magnetic needle, so that there is apparently no magnetite present." — Rutley.

No. 30 (3030).— **Hornblende rock** (Wright). Provisionally named a black hornblendic diorite. Like Nos. 18 and 22. Compare Nos. 123 and 127. See description of No. 18. Rutley says: "Hornblende schist, with a little quartz and no other mineral." Sp. Gr. 2.74 to 3.04.

Loc. Bed XI. Republic Mine. This rock, almost identical with that of beds VII and IX, characterizes this stratum at this locality, but in the Negaunee district diorites and chloritic schists prevail in the same horizon.

"This rock is shown under the microscope to consist exclusively of quartz and strongly dichroic hornblende. It is a most beautiful object under the microscope, the quartz appearing in section as an inlaid pavement, lying in irregular patches between the hornblende; the latter forming crystalline aggregates or crystals of more or less perfect development. The rocks 22, 29 and 30, cannot be called diorites, as they contain no feldspars. They are almost identical with one another in mineral composition and in microscopic characters. They are hornblende schists." — Rutley.

No. 31 (3031). — **Feldspathic chlorite-schist** (Wichmann). Provisional name, micaceous greenstone schist. Compare Nos. 70, 119. Allied to Julien's Nos. 335 and 336, Mich. Rep., Vol. II, pp. 172, 173. Dark-green, almost aphanitic, splits unevenly, showing copper-colored micaceous leaves on the splitting surface. Sp. Gr. 2.78 to 2.82.

Loc. South of, and underlying, Grand Central ore-deposit at Negaunee, from bed IX, which is chiefly made up of hornblendic rocks and related greenstones. This variety is not abundant here or elsewhere.

"No. 31, with name altered from diabase to feldspathic chlorite schist, is, I believe, a good illustration of the partial conversion of a basaltic rock into a chloritic schist." — Allpert.

Mr. Rutley describes this rock as follows: "Under the pocket lens, this rock shows minute scales of a soft golden-brownish mica. Under the microscope, a thin section of the rock is seen to consist of crystals and fragments of crystals of feldspars more or less altered, in some cases showing very faint traces of twin striation, but in most instances appearing to be orthoclase, occasionally twinned on the Carlsbad type. Minute crystals of magnesian mica are also present, together with a considerable amount of green matter, which is probably either chlorite or serpentine; but no distinct hexagonal chlorite crystals are visible. Irregularly shaped, dark-brownish or black patches also occur and may be some alteration product after pyrites, such as limonite, while here and there a little calcspar is discernible. These and the green chloritic or serpentinous material are evidently secondary products, and indicate that the rock has undergone very great alteration. It is difficult to apply any suitable name to this rock. The magnesian mica crystals seem to be hardly plentiful enough to constitute the rock a minette, nor can it with propriety be called a micaceous felstone, as in hand specimens it bears no resemblance to felstone, from which it also differs in microscopic structure. The mode of occurrence of this rock would perhaps give a better clue to its real nature. I am disposed to think that it is some interbedded and highly altered rock. There is a somewhat fragmentary appearance about the imbedded minerals."

No. 32 (3032).—**Micaceous iron quartz-schist.** Like Nos. 33, 16. Compare Nos. 36, 37. Differs from No. 16 chiefly in the iron being less micaceous and concentrated in thicker laminæ, up to one-half inch. The red and whitish quartzose layers, which predominate, are fine-grained and arenaceous, and contain numerous grains or scales of specular ore. Sp. Gr. 3.09 to 3.80.

Loc. Bed XII. Republic Mine. This specimen and No. 33 represent the prevailing rock in this bed in the Michigamme district. For the Negaunee district, see Nos. 34, 35.

See remarks under No. 16 as to occurrence of related rocks. This kind of rock has never been found rich enough in iron to constitute an ore. The same bed in the Negaunee district is more highly ferruginous, and limonitic instead of specular. See Nos. 34, 35.

No. 33 (3033).—**Micaceous-iron quartz schist.** Like No. 32. Compare Nos. 16, 36 and 37. See Julien's Nos. 151 and 152, where the iron layers are mostly magnetite, Mich. Rep., Vol. II, p. 80. Like No. 32, except that the quartzose layers are crossed by minute veins of specular ore. Sp. Gr. 3.09 to 3.50.

Loc. Bed XII. Michigamme Mine. See remarks under No. 32. The similarity of this rock to the banded specular quartz (jaspery) schist of bed XIII, has been remarked. The division between these beds is not strongly marked. A related specular quartzite, in which the iron is not micaceous, and in which exist more numerous cross veins and bunches of highly crystalline hematite, occurs in the quartzite bed II, at the Felch Mt. The banded ferruginous quartzose rock of the Penokee iron range, Wis., where it can be traced for over ten miles, and is usually magnetic, is closely related to this.

No. 34 (3034).—**Disintegrated ochrey hematite** (soft hematite ore). Like No. 25. Compare Nos. 24, 35 and 135. Does not differ essentially in appearance from No. 25. Contains on the average more iron and less manganese, hence is of a lighter brown color. Sp. Gr. 4.12. An average sample gave Chandler and Cairns: Fe^2O^3 79.80, Mn^2O^3 .10, Al^2O^3 2.05, CaO .45, MgO .53, S .03, PO^5 .30, SiO^2 12.52, HO combined 4.11, HO uncombined .14 = 100.03.

Loc. Bed XII. Lake Superior Mine. The earthy limonitic portions of this bed differ in no essential respect from X., described under No. 24 and elsewhere, except in being less manganiferous. These ores are only found in the Negaunee district; followed west into the Michigamme they lose their water and become more quartzose. See Nos. 32, 33, 36 and 23. See remarks under No. 24.

No. 35 (3035).—**Ochrey hematite-schist.** More slaty than No. 24; softer than No. 135. Compare Nos. 25, 34. A schistose variety of No. 24, irregularly banded with schistose laminæ, and containing irregular bunches of a mineral determined by Prof. Brush to be kaolin. This specimen and No. 24 may be regarded as intermediate in character between the earthy form and the firm, compact, hard, more hematitic form, No. 135. Sp. Gr. 2.69 to 3.09. A piece gave F. H. Emmerton: Fe^2O^3 84.66, MnO 1.41, Al^2O^3 .13, CaO .40, MgO .007, PO^5 .084, S .02, SiO^2 12.70, HO .71 = 100.121.

Loc. Bed XII, Winthrop Mine. See remarks under Nos. 34 and 24.

No. 36 (3036).—**Micaceous-iron quartz-slate.** Similar to Nos. 32, 33. Compare Nos. 37, 23. Intermediate in character between the micaceous-iron quartz schists, Nos. 32 and 33, from bed XII, and the banded specular iron and quartz schists, No. 37. Sp. Gr. 3.41 to 3.88.

Loc. Bed XIII, or XII. Republic Mine. See remarks under No. 37.

"Has a remote resemblance to the poorer varieties of Swedish quartzose hematite ores, *e. g.*, those of Norberg and Uto, but is finer grained."—Törnebohm.

No. 37 (3037).—**Banded specular-iron jaspery schist** (mixed or jaspery ore of the mines). Compare Nos. 36, 32 and 33, also 52. It consists of jaspery quartz bands, varying from bright red to dull reddish brown, with occasional seams of white quartz, and usually pure specular ore of high luster. Martite is common and magnetite rare. These materials are arranged in alternating laminæ, varying in thickness up to one inch. These laminæ are often highly contorted, zigzagging, and turning sometimes in opposite directions within a few inches. The jasper bands are in places broken up into little rectangular fragments, which are slightly thrown out of place, as it were, by tiny faults; the ore fills the break, so that the whole mass has the appearance of a breccia. There is little doubt but that certain breccias, and possibly some conglomeratic rocks, have this origin. See Mich. Geol. Rep., Vol. II, pp. 285 to 292.

A similar rock, but with white quartz instead of the jaspery variety, and forming an intermediate variety between this and No. 52, occurs at the Washington group of mines. These differences are undoubtedly due to variation in degree of metamorphism. See remarks under No. 52. Wichmann remarks: "Quartz-grains filled and cemented with hydrated oxide of iron. Parallel zones consisting of magnetic and quartz are inserted." Sp. Gr. 3.31 to 3.98.

Loc. Bed XIII. Lake Superior Mine. The relations of this rock to the pure ores of this bed, are briefly referred to under the description of No. 45. The purer ores, as a rule, prevail in the upper portions of the bed, and the jaspery varieties in the lower part, where they sometimes pass by insensible gradations into the similar schist of XII. Has been smelted to a limited extent as a second-class ore, but the large amount of silica renders the reduction difficult. It is chemically nearly identical with the flag ores, No. 6.

No. 38 (3038).—**Specular-iron schist.** Like Nos. 45, 47 and 48. Compare No. 43. Allied to Julien's No. 237, Mich. Rep., Vol. II, p. 122. This specimen has many minute martite octahedra, and small brown spots and more quartz; otherwise is like No. 45, which see for full description. Sp. Gr. 4.47 to 4.97.

Loc. Bed XIII. Lake Angeline Mine. The specular iron-ores of this mine have usually a larger percentage of jaspery quartz mixed with them than is common in this bed. See No. 37. The Lake Angeline mine ranked ninth in order of production, in 1872.

No. 39 (3039).—**Granular magnetic ore** (shot ore). Compare Nos. 40, 41, 42. Julien's No. 229, Mich. Rep., Vol. II, p. 118, is a variety. Grayish-black, imperfectly crystalline grains, as large as mustard seeds, slightly compacted. Semi-schistose. Magnet separates 85 per cent. from the steely-black pulverized ore. Magnetic ores unlike the speculars, are generally massive and seldom schistose. Sp. Gr. 4.98 to 5.01. An average sample gave Britton: Metallic iron, 65.81, phosphorus, .061. For numerous analyses of these ores, see Mich. Rep., Vol. I, Chap. X.

Loc. Bed XIII. Republic Mine; constituting the uppermost layer next the quartzite, and separated from the great mass of specular ore by a thin bed of micaceous schists No. 53. Only at this mine and at the Champion do the magnetic and specular ores occur together in alternating beds in quantity. The two oxides are, however, more or less mixed at many localities, it being rare to find magnetite without hematite, or the converse, producing all shades in the powder from black, through purple to red. The prevailing ore at this mine is a rich specular slate, which, with this variety, has been extensively mined since 1872, when the mine was opened.

No. 40 (3040).—**Fine-grained magnetic ore.** See Nos. 39, 41,

42. Resembles Julien's No. 229, Mich. Rep., Vol. II, p. 118. Brownish-black, fine-grained, friable magnetite, differing from No. 39 chiefly in the smaller size of the imperfect octahedra and a somewhat higher luster. Magnet separates 95 per cent. from the grayish-black pulverized ore. Sp. Gr. 4.64 to 4.87. An average sample gave Chandler: Fe^3O^4 89.21, Mn^2O^3 trace, Al^2O^3 2.67, CaO .67, MgO .19, S .35, PO^5 trace, SiO^2 6.28 = 99.37.

Loc. Bed XIII. Spurr Mountain; chiefly magnetic ore in several varieties, in places banded with arenaceous quartz layers, No. 52, and containing lenticular layers of chloritic schist, No. 89. Largely mined since 1873, when work began.

No. 41 (3041).—**Hard fine-grained magnetic ore.** Similar to No. 40. Blackish-brown, somewhat mottled, differing from No. 40, chiefly in being more firmly compacted. Sp. Gr. 4.72 to 4.97. A piece gave Ralph Crooker: FeO 29.109, Fe^2O^3 61.631, MnO traces, Al^2O^3 2.120, CaO 1.070, S .002, SO^3 .008, PO^5 .057, SiO^2 3.280, HO 1.497, organic or carbonaceous matter, .340, TiO^2 .032 = 99.146.

Loc. Bed XIII. Michigamme Mine. See remarks under No. 40. No specular ore has as yet been found in the Spurr-Michigamme ranges. Extensively mined.

No. 42 (3042).—**Hard magnetic ore.** Compare Nos. 39, 40, 41, and also No. 17. Allied to Julien's No. 228, Mich. Rep., Vol. II, p. 117. Differs from No. 41 in being more schistose, finer-grained, and in containing a little chlorite. Sp. Gr. 4.86 to 4.95. An average sample gave Chandler and Cairns: FeO 21.60, Fe^2O^3 55.80, Mn^2O^3 .10, Al^2O^3 4.34, CaO .77, MgO .84, S .16, PO^5 .12, SiO^2 15.41, HO .81 = 99.95.

Loc. Bed XIII. Edwards Mine; associated with chloritic schist and banded jaspery ore, the whole presenting a peculiar lenticular structure. See Mich. Rep., Vol. I, p. 278. A large amount of this ore has been mined.

No. 43 (3043).—**Magnetic brecciated hematite schist** (granular green specular ore, with martite). Compare Nos. 38, 5, 45. Between Julien's Nos. 228 and 239, Mich. Rep., Vol. II, pp. 117 and 123. A transition variety between the magnetites and hematites, composed largely of octahedra of martite, apparently not wholly altered to hematite, for the magnet lifts from 6 to 40 per cent. of the brownish-purple to purplish-black powder (depending on the relative amount of the two oxides). Contains considerable chlorite. This specimen contains angular fragments of quartzose ferruginous schist, which have apparently been produced since the deposition, by the breaking up of the siliceous laminæ, perhaps through internal motion induced by the force of crystallization. See illustration bearing on this point in Vol. II, p. 285, Mich. Rep. See, also, remarks under Nos. 37 and 52. Sp. Gr. 4.01 to 4.40.

Loc. Bed XIII. New York Mine. Portions of this deposit contain more disseminated chlorite and more martite, sometimes slightly magnetic, than has been observed at any other mine. The proportion of phosphorus is also slightly larger, up to one-fifth of one per cent. Extensively mined.

No. 44 (3044).— **Kaolinic hematite schist** (specular slate ore). Allied to No. 2. Compare also Nos. 43, 38, 45. Contains kaolin, and is intermediate in character between Nos. 2 and 45. Kaolin is rare in this kind of ore, but more abundant in the earthy limonites. Sp. Gr. 4.54 to 4.69.

Loc. Bed XIII. Cleveland Mine, school-house opening. See remarks under No. 45.

No. 45 (3045).— **Specular-iron schist** (steely specular ore). Like Nos. 38, 47 and 48. Compare Nos. 46, 49, and 6. See Julien's No. 237, Vol. II, p. 122, Mich. Rep. The prevailing and typical variety of specular-iron schist (" slate ore "), composed of nearly pure sesquioxide of iron. Schistose, and slaty where the iron is micaceous, as in No. 46. Compact, homogeneous, showing under the lens a minute lamellar and sometimes finely fibrous structure, with high metallic lustre, and color of steel. Color of streak, brownish-red; and of powder, blackish-brown to glistening. A massive granular variety containing martite is less common. Often contains red (jaspery) quartz in minute laminæ, which in places prevail to the extent of constituting a banded ferruginous quartz schist, No. 37. Sp. Gr. 4.87 to 5.23. An average sample gave Chandler and Cairns: Fe^2O^3 93.75, Mn^2O^3 trace, Al^2O^3 .73, CaO .61, MgO .23, S .03, PO^5 .32, SiO^2 3.27, HO 1.09 = 100.03. For numerons analyses of these ores, see Vol. I, Chap. X, Mich. Rep.

Loc. Bed XIII. Jackson Mine. Similar ores occur in the New York, Cleveland, Barnum, Saginaw, and other mines herein mentioned in the Marquette region; but no identical ore has as yet been found elsewhere south of Lake Superior. Except at Iron Mountain, Mo., no equally valuable ore of this kind is at present produced in large quantities in America. It is very abundant and extensively mined, 526,000 tons of first-class specular ore having been produced in 1872 in the Marquette region from nine mines.

No. 46 (3046). — **Micaceous-iron schist** (specular slate ore). Similar to No. 49. Of a slaty structure, and the iron micaceous, but more firmly compacted, like No. 49, otherwise like No. 45. Sp. Gr.

5.09 to 5.56. An average sample gave Britton: metallic iron, 67.21; phosphorus, .03.

Loc. Bed XIII. Republic Mine. This is the prevailing ore, but beds of magnetite also occur. Extensively mined. See remarks under No. 39.

No. 47 (3047).—**Specular-iron schist.** Like Nos. 38, 48. Compare also Nos. 46, 49. Allied to Julien's No. 237, Vol. II, p. 122, Mich. Rep. Shows a cleavage structure oblique to the bedding and strong cross joints, otherwise like No. 45. Sp. Gr. 5.11 to 5.14.

Loc. Bed XIII. Jackson Mine. See remarks under No. 45.

No. 48 (3048).—**Granular specular-iron-schist.** Like Nos. 38, 45, 47. Compare No. 6. Allied to Julien's No. 237, Vol. II, p. 122, Mich. Rep. More fibrous, and containing numerous minute brown specks like No. 38 and the bird's-eye ore No. 6, otherwise like No. 45. Sp. Gr. 4.79 to 5.31. An average sample gave Chandler and Cairns: Fe^2O^3 86.70, Mn^2O^3 trace, Al^2O^3 1.64, CaO .57, MgO .24, S .02, PO^5 .14, SiO^2 9.82, HO .61 = 99.74.

Loc. Bed XIII. Lake Superior Mine. See remarks under No. 45. This mine was opened in 1858, soon after the Jackson and Cleveland, and has produced the largest aggregate of ore of all kinds, about a million and a half tons up to the end of 1875.

No. 49 (3049).—**Micaceous-iron schist.** Similar to No. 46. Compare Nos. 38, 45, 48. Differs from No. 46 in being less firmly compacted and more fissile. Made up of tiny scales. Magnet separates 5 per cent. Contains minute seams of a hydrous magnesian mineral. The splitting surface resembles No. 16 in high lustre and fish-scale appearance. Micaceous iron-ores occurring with magnetites always contain magnetite, giving up sometimes 25 per cent. to the magnet. Sp. Gr. 4.42 to 5.00. Average samples from this mine gave: Metallic iron, 63.55, phosphorus, .084.

Loc. Bed XIII. Champion Mine, No. 4 shaft. See remarks under No. 39. This mine produces both magnetic and slate ore in large quantities.

No. 50 (3050).—**Micaceous quartz schist** (Wichmann). Provisional name, gray ferruginous quartzite. Compare Nos. 138, 140. A gray, schistose, fine-grained quartzite, with scales of mica and micaceous iron, the latter apparently predominating. Splits into uneven flags. Sp. Gr. 2.74 to 3.03.

Loc. Bed XIV. Republic Mine, where this is a prevailing variety. Compare the micaceous conglomerate variety, No. 51, from the same bed at Washington Mine. A variety containing red mica (aventurine), sometimes conglomeritic, occurs in the same bed in the Menominee region, E. and N. of Lake Eliza. The micaceous quartz schists from bed XVIII in the same region are related.

No. 51 (3051). — **Micaceous conglomerate schist.** (Has been called gneiss with seggregations.) No allies. Compare Julien's No. 122, Mich. Rep., Vol. II, p. 66, from same bed. The matrix is micaceous and quartzose; many films of brownish-gray mica envelop irregular flattened nodules of quartz. Another more fibrous and schistose variety contained darker colored mica and considerable micaceous iron-ore, with grains of quartz, passing into a micaceous-iron conglomerate schist. The pebbles are white, smoky, and glassy quartz. Sp. Gr. 2.66 to 2.70.

Loc. Bed XIV. Washington Mine. This peculiar rock has only been observed in this bed, and is stratigraphically near the division between it and the underlying iron-ore. Red micaceous and specular conglomerate schists occur in the same bed in the Menominee region. Mica schists holding pebbles of quartz and feldspar have been observed in Belgium.

"A similar rock is one of the most characteristic in the series of alternating mica slates and conglomeritic gneisses in the Smoky Range of Western North Carolina. Safford first studied the extension of these beds into Eastern Tennessee (see Main Report on Geol. of Tennessee, pp. 383, 385, 408, 427), tracing the progress of the metamorphism of the Ocoee conglomerates, toward the N. C. line, with the gradual flattening and final obliteration of its pebbles. See also descriptions by Kerr (Geol. of N. C., Vol. I, pp. 136 to 139), Bradley (Am. Jour. Sci., 1874, p. 390, and 1875, pp. 279 and 370), and Julien (Geol. of N. C., Vol. II). Similar varieties are abundant in the tract of the Grandfather and Yellow Mountains, N. C." — Julien.

"Schists and conglomerates like Nos. 51 and 54 do not occur in the Swedish Archæan series, but may be found in the lowermost part of what we call the Dal-formation, a younger and more fossiliferous series, destitute of ores." — Törnebohm.

No. 52 (3052). — **Arenaceous magnetic quartz schist.** No allies. Compare Nos. 33, 40, also 37. See Julien's Nos. 358, 359. Vol. II, p. 183, Mich. Rep. Made up of irregular alternating layers of arenaceous magnetite, and white and gray friable sandstone. It is but an arenaceous form of such banded specular and jaspery schists as No. 37, which sometimes show martite. The quartzose layers differ from such quartzites as No. 137 only in being sandy, and the magnetite layers are like No. 40. It is not improbable that this rock, originally deposited as a sand and then indurated into a quartzite, may have been reconverted into its original condition. The arenaceous quartzite No. 139 is designated a sandstone by Dr. Wichmann. Sp. Gr. 2.89 to 3.08.

Loc. Bed XIII. Michigamme Mine. Laminæ of true quartz sandstone have only been seen in this bed on this range, where this rock takes the place of the banded specular jasper schists (No. 37) of the more easterly mines. A nearly identical rock is found W. of Commonwealth Mine and at Breitung's iron locations in Pine R. District, Wis., in bed XV.

No. 53 (3053).—**Mica schist** (Wichmann). Provisional name, talcoid schist. Compare Nos. 54, 74, 111. Under magnetic talc schist, No. 226, and porphyritic talc schist, No. 227, Julien describes closely related rocks. Vol. II, p. 116, Mich. Rep. Grayish-green, scaly, shining, unctious to the touch, often called talc schist, and sometimes clay slate. Fissile and slaty. It is not impossible that the micaceous mineral may be margarodite or paragonite, since such hydrous mica schists have often been called talcoid. Sp. Gr. 3.00 to 3.09.

Loc. Bed XIII. Republic Mine, where a thin layer divides magnetite above from specular ore, No. 46, below. A brown, less unctious, ferruginous variety occurs in the Champion magnetic deposit. A somewhat similar rock, No. 112, occurs in, or immediately over, the iron-ores in the Menominee region. This peculiar variety has not been seen except in small beds, and only in connection with iron-ore. See remarks under No. 55. Hunt has observed similar rocks in iron-ores in the Green mountains. Törnebohm says, "schists somewhat like these are found in the upper Euritic series of Sweden." The same may be said in regard to No. 56.

"In the thin section, magnetite (with some hematite ?) occurs abundantly in tiny black opaque and glittering plates, whose longer dimensions are mostly arranged parallel, in the schist plane. Their cross-sections appear as narrow rectangles. Minute ochreous films and scales sometimes occur. Muscovite abounds in small, clear and colorless scales, which polarize, but not strongly, between the crossed nicols. Tremolite is abundantly distributed in slender, colorless needles, with narrow rectangular cross-sections, which possess a fibrous structure when large, and polarize vividly between the crossed nicols."—Julien.

No. 54 (3054).—**Sericite schist** (Wichmann). Provisional name, mica schist and talcoid schist. Has also been called actinolite schist. No allies. Compare Nos. 53, 112, 74, 129, and Julien's No. 226, Vol. II, p. 116, Mich. Rep. Greenish-gray, with dark spots, blue to black elongated crystals, the axes of which lie in the splitting planes, but cross the minute corrugations. Shining, unevenly slaty schistose; in appearance between a talc and mica schist. A closely-related unctious feeling schist has been called chloritic. See remarks on hydrous mica under No. 53. Sp. Gr. 2.75 to 2.84.

Loc. Bed XIII. Old Washington Mine. A rare variety in iron-ore. See remarks under Nos. 53, 55, 89.

In thin section, colorless fibrous blades and slender needles abound, polarizing brilliantly between the nicols. A hydro-mica, however, predominates, in irregular and minute colorless scales, which in part polarize brilliantly and appear to consist of muscovite. Here and there are found elongated patches, made up of much larger clear scales, with a few inclusions of ochre and tremolite-needles. Magnetite occurs in rather large, irregular opaque cubes or hexagonal cross-sections, and hematite in a few scattered blood-red scales or films." — Julien. See Törnebohm's remarks on No. 51.

No. 55 (3055).—**Chlorite schist** (Wichmann). Gray feldspathic argillite (Julien). Compare Nos. 134, 13. Greenish-gray, and in appearance between a clay-slate and chloritic schist. Rutley found in a thin section of a similar rock, felsitic matter, grains of quartz and magnetite, and remarks its resemblance to some granulites. Sp. Gr. 2.76 to 2.89.

Loc. Upper part of Bed XIII, forming a heavy layer overlying the iron ore at Barnum Mine, and related to the several hydrous magnesian, hydro-micaceous and argillaceous schists (Nos. 53, 54, 89) which occur in this bed in the Marquette region, and also to similar rocks in the Menominee region. A dark reddish-brown variety, highly impregnated with iron, was observed at the Quinnesec Mine, and a more fissile and argillaceous variety in the same bed, VI, in the S. E. ¼ of Sec. 32, T. 40, R. 30. At this latter locality there also occurs, associated with the iron ore, a soft, ash-colored, shaly rock, which according to Dr. Wichmann contains microscopic crystals of tourmaline. See remarks under No. 89. The red chalk, common to many iron mines, may be regarded as a highly ferruginous variety of this rock, but not an ore.

"The groundmass is an aggregation of irregular grains of quartz, which in polarized light show different colors. Irregular green folia of chlorite are interwoven with this groundmass. Bluish-gray prisms of tourmaline occur, which are strongly dichroitic. Magnetite in black, irregular grains is present."—Wichmann. See also § 155 of his report.

"This rock is essentially composed of felsitic (or slaty) matter, angular and subangular grains of quartz, and crystals and aggregates of magnetite. There is a distinctly laminated structure in the rock — the grains of quartz lying in a brecciate manner in the felsitic substance, and forming well marked bands, divided by fine felsitic matter in which much smaller granules of quartz are disseminated. The magnetite crystals and patches evince here and there some tendency to lie in certain zones, but seem to be very freely scattered throughout the rock. It may perhaps be regarded as a granulite, although no mica is present. The rock attracts the magnetic needle."—Rutley. See Törnebohm's remarks under No. 13. "Is like those described on p. 233, Geol. of New Hampshire, Part IV." — Hawes.

No. 56 (3056). — **Mica schist?** (Wright). Provisional name, micaceous argillaceous schist. Compare Nos. 111, 114, 12. A dark greenish-brown micaceous slate, splitting somewhat unevenly, holding garnets, and intermediate in character between a clay slate and mica schist. Related to phyllite. Sp. Gr. 2.82 to 2.89.

Loc. Bed XV. Champion Mine Branch R. R. So far as observed, a local variety in this stratum of dark-colored, imperfectly cleavable clay slate. A pyritiferous, chloritic-looking rock, and a ferruginous clay slate, both from bed XVI? Menominee region, are related to this specimen. See Törnebohm's remarks under No. 53.

No. 57 (3057). — **Quartzose ochrey schist.** No allies. Compare Nos. 26 and 34, and also Julien's No. 157, Vol. II, p. 83, Mich. Rep. Smoky-gray, thin, irregular, quartz laminæ, and dirty-yellow ochrey layers, evidently an altered rock. Somewhat related to quartzose varieties of No. 35. Sp. Gr. 2.70 to 3.00.

Loc. Bed XVI. South of Champion Kilns. But little is known about this bed; this kind of rock seems to prevail. The ferruginous limonite schist, associated with the ore at Foster Mine, in bed X, is a related rock, but is browner and redder, indicating the presence of more hematite. Considerable amount of exploration has failed to find any part of this bed rich enough in iron to answer as an ore.

No. 58 (3058). — **Magnetic actinolite schist** (Wichmann). Anthophyllitic schist (Brush). Compare No. 59 from same bed, and Nos. 27, 130. Julien's No. 178 and Wright's No. 1032, Mich. Rep., Vol. II, pp. 92 and 223, where several varieties are described, are from the same bed. A striped rock, presenting on a fresh fracture bluish gray bands of a fine material, brownish at their contact with lighter colored, coarser grained and narrower bands, made up of the amphibolic mineral which characterizes this rock. It occurs in minute, translucent, light brownish and grayish blades, which often present a radial structure and suggest plumose mica.

Occasional brown and black layers occur, rich in manganese and magnetite, along which the rock splits into even flags which appear graphitic on their surface, marking paper black, but it is probably due to the pyrolusite. Professor Brush determined this mineral to be anthophylloidal, and suggested, with the approval of Prof. Dana, the name. He says: "By 'anthophyllite' is meant, not necessarily the restriction to the species 245 (page 231) in Dana's Mineralogy, but a fibrous, lustrous, difficultly-fusible mineral, belonging to the amphibolic group of bi-silicates, applying to both pyroxenic and hornblendic forms."

"Compact magnetic actinolite schist. A compact aggregation of colorless needles of actinolite. Into them are scattered many small ore-particles, partly belonging to the magnetite."—Wichmann. Sp. Gr. 3.04 to 3.34. A selected specimen afforded Dr. C. F. Chandler, 25.2 per cent. of metallic iron, and 4.37 per cent. of metallic manganese. Loses much water in a closed tube, and one specimen gave up 19 per cent. of the powder to the magnet.

Loc. Bed XVII. Mouth of Bi-ji-ki river, Lake Michigamme. This bed can be traced from a point E. of the Champion furnace, west along the N. shore of the lake for a distance of 8 miles. The eklogite, No. 27, of bed X, is a closely related rock, but contains no manganese. Similar, but more quartzose and ferruginous rocks occur in beds XIII and XV, in the Pine river district, Wisconsin, west of the Menominee (No. 130). The presence of manganese and of an easily fusible mineral in place of quartz, which is so common an ingredient in ferruginous rocks, renders it probable that some varieties of this rock, richer in iron, may have value as an ore.

"In thin section, the radiated variety of amphibole, antholite (possibly true anthophyllite), predominates in closely matted groups, made up of colorless to brownish (ochreous) fibres, which polarize strongly between the crossed nicols. Pyrolusite is found in considerable abundance and even predominates in some parts of the thin section, in tiny elongated plates between the fibres of antholite. Other tiny plates of hematite occur, which when thin are blood-red by transmitted light." — Julien.

No. 59 (3059). **Manganiferous anthophyllitic schist** (Brush). Compare No. 58, from same locality. See references under No. 58. A greenish-black, minutely glittering, fine-grained, highly magnetic and manganiferous variety of No. 58, which has been called pyrolusite. Sp. Gr. 3.16 to 3.60.

Loc. Bed XVII. Bi-ji-ki R. See under No. 58.

No. 61 (3061).—**Staurolitiferous mica schist** (Brush). No allies. Compare No. 107. Like Julien's No. 301, Vol. II, p. 155, Mich. Rep. Brownish-black, glistening, rather hard, finely fibrous mica schist, holding much grayish-white quartz and crystals of staurolite and often of andalusite and garnets, as determined by Professor Brush. The micaceous laminæ warp themselves around these crystals, giving the rock a nodular appearance. The crystals also appear on the brownish-gray weathered surfaces as wart-like protuberances. Sp. Gr. 2.58 to 2.79.

Loc. Bed XIX. Island in S. part of Michigamme Lake. The characteristic rock in this heavy and important bed, which maintains its lithological character very uniformly through the Marquette and Menominee regions, and intermediate country so far as observed. In the southern part of the Menominee region it becomes hornblendic, and is in places a typical hornblende schist, No. 125, of a variety not related to the greenstones, which have never been found in this bed.

"A common variety in western North Carolina, e. g., below Webster on the Hiawassee river, in Cherokee and Swain counties, etc." — Julien.

No. 64 (3064). — **Carbonaceous slate.** Provisional name, plumbaginous schist. Like No. 115. Under "Carbonaceous shale," "Quartzose carbonaceous slate," and "Graphitic shale," Julien has described similar rocks. See Nos. 246 to 251, Vol. II, p. 126, Mich. Rep. Grayish to brownish-black, soft and brittle, marks paper, and receives a high polish by a little friction. Contains sometimes quartz and ochre and often graphitic films. Is a carbonaceous variety of clay slate. Imperfectly fissile, and without oblique cleavage so far as observed. See Dr. Wichmann's Report, § 173. Sp. Gr. 2.10 to 2.17. An average sample gave Brush: C 20.86, earthy matter 77.78, moisture 1.37. Another sample contained several per cent. of iron-oxide.

Loc. L'Anse Iron Range, Sec. 9, T. 49, R. 33, in large quantity, associated with clay slate, and overlaid and underlaid by diabase, in the Lower Huronian. Has not been observed elsewhere in the Marquette region, except at the S. C. Smith Mine associated with clay slate; but it occurs at several points in the Menominee region in beds XV, XVIII and XVI, in the latter associated with clay slate allied to No. 114, and iron-ore, No. 135. In bed XV, N. of Lake Eliza, is a small mass in quartzite, appearing somewhat like artificial coke. So far as observed, it cannot be said to be abundant, but its soft nature would render it not likely to outcrop. Hunt says: "We have such in our Green mountains, but I do not feel sure of their place. Plumbaginous micaceous schists also occur in III in New Hampshire." Wapler compares them with a similar rock found at Reichenbach.

Saxony. Julien observed what he regarded as "imperfect fucoidal impressions."[1] See Vol. II, p. 5, Mich. Rep. So far as known the rock has no value. The somewhat general distribution of carbonaceous matter through the Huronian is interesting. It does not appear to be altered where it comes in contact with the greenstone.

No. 65 (3065).—**Protogine conglomerate** (provisional name). Compare No. 102 from same locality, and No. 3. A reddish gneissic rock, containing a hydrous magnesian mineral in place of mica, which in some varieties prevails to the extent of constituting a chloritic (?) schist, which holds pebbles (sometimes as large as the fist) of granite, gneiss and white quartz. Sp. Gr. 2.67 to 2.76.

Loc. Bed I. Falls of the Sturgeon, Sec. 8, T. 39, R. 29, below and conformable with the great quartzite, bed II. Associated with hydrous magnesian schists, quartzites and greenstones. Underlying this series on the north, apparently nonconformable, are unmistakable Laurentian gneisses. Conglomerates have so far only been observed in the Huronian and copper-bearing rocks of the Archæan, and are believed not to occur in the more highly metamorphosed Laurentian.

Mr. Rutley says: "This rock, under the microscope, resembles in some respects No. 55, being largely composed of quartz and slaty, felsitic material, together with crystals of magnetite; but it differs from it, in containing large patches of feldspar, some of which are unquestionably triclinic, showing by polarized light the characteristic twin-striation. Other patches may, however, be orthoclase. Under the microscope, the rock shows indications of a schistose structure. The hand specimen of the rock exhibits a great deal of what is apparently talc, or chlorite, and has red stains in places, which may be due to peroxidation of iron compounds. Some tolerably large, dark and, externally, reddish-brown cubes of pyrites project here and there on the surface of the specimen. The section examined was cut at right angles to the foliated or schistose direction, and consequently the talc or chlorite only presents thin edges of plates, and hence is difficult of recognition under the microscope. The rock attracts the magnetic needle." See Törnebohm's remarks under No. 3.

"A similar rock occurs abundantly in North Carolina, in the western Huronian belt (Kerr, Geol. of N. C., Vol. I), and in the Greensboro belt."—Julien.

No. 66 (3066).—**Gray fine-grained dolomite-marble.** Provisional name, ribbed and cherty marble. Compare No. 143, which

[1] These were examined by Dr. J. S. Newberry and the same opinion was expressed.
A. A. J.

is a variety of the same rock. See also Nos. 9, 141. Finer grained than Julien's No. 105, Vol. II, p. 57, Mich. Rep. Delicate pinkish and purplish gray, sometimes bluish, mottled and faintly striped, homogeneous, crypto-crystalline, semi-schistose, irregular fracture; a thin weather coating of dirty cream color; hard, apparently siliceous. Does not effervesce in cold acid. Another and common variety of the same rock which also occurs in the Marquette region, is banded with siliceous laminæ, scarcely distinguishable on fresh fracture, which make a rough ribbed surface from their better resistance to the weather. Where exposed they vary from brown, sandy, to gray and blackish, somewhat cherty laminæ, the latter often minutely corrugated. Occasionally siliceous veins of apparently the same material, and connected with them, cross the laminæ. Sp. Gr. 2.79 to 2.84. An analysis of a specimen from this bed gave Dr. Rominger: carbonate of lime, 61.00; carbonate of magnesia, 34.00, hydrated oxide of iron and manganese, 1.00; siliceous matter, .25.

Loc. Bed V. Sec. 11, T. 39, R. 29, Mich. The above are common varieties in this great marble bed. This rock is purer and more uniform and less mottled than the marble from the same bed of the Marquette region. There it contains a bed of novaculitic clay slate, and graduates into quartzite, which is not the case in the Menominee region. The cherty and ribbed limestones and dolomites of the Huronian of Canada, are believed to be closely related rocks. This rock is apparently richer in lime than that now used as a flux at the Morgan furnace, from the same bed. It would make a serviceable building material, and certain varieties possibly possess value as ornamental building stone.

No. 67 (3067).—**Earthy purple hematite shale.** Resembles No. 136. Compare with Nos. 2, 44. A soft, reddish-purple (pigeon-colored?), earthy, friable, homogeneous hematite shale or slate, closely related to the variety No. 136, which is richer in iron and more specular in appearance. Can be broken with the nail into a fine deep-purplish powder, which gives nothing to the magnet. Its homogeneity, absence of water, and totally different color, separate it from the earthy limonitic hematites of the Marquette region (Nos. 25, 34), to which it is related in its mode of occurrence; and its softness and lack of luster separate it from the specular ores, to which it is more nearly related in composition. Sp. Gr. 3.16 to 3.22. A richer and harder variety from this mine had the Sp. Gr. 4.90, and yielded E. T. Sweet with Prof. Daniels, Madison, Wis., the following constituents: Fe^2O^3 85.00, SiO^2 9.45, Al^2O^3 1.47, CaO .99, MgO 1.18, Mn^2O^3 .12, PO^5 .02, S .09, HO 1.77 = 100.09.

Loc. Bed VI. Breen Mine. See description of this stratum. Associated with several varieties of quartzose hematite flags. This ore is not found in the Marquette region in any quantity; but a related "blue hematite," apparently a disintegrated specular ore, has been produced to a limited extent at the New England Mine, in bed XIII. The explorations at this locality have revealed a workable deposit of this ore, but apparently not so rich on the average nor so extensive as those farther west in the same bed.

No. 68 (3068). — **Quartzose specular schist** (red flag ore). Compare Nos. 23, 6, 5. Dull reddish-blue, slightly shining, faintly banded, siliceous hematite flag, sometimes somewhat slaty. Nearly as hard as quartz. Closely related to the magnetic variety, No. 23, and the bird's-eye ore, No. 6, under which see remarks. Sp. Gr. 3.30 to 3.88.

Loc. Bed VI. Sec. 11, T. 39, R. 29, Menominee region. This is the prevailing rock in this formation; in it are deposits of purer and physically different ores, Nos. 67, 136, under which see remarks. See also remarks under No. 6.

No. 69 (3069). — **Gabbro** (Rutley, Wapler). **Saussurite or hornblende gabbro** (Pumpelly). Provisionally named, porphyritic speckled diorite. Compare No. 72. Coarse-grained, white to very light-green, compact feldspar, and a peculiar gray-green amphibolic mineral, in strong contrast. Massive to semi-schistose. Has much resemblance to some German gabbros. Some varieties have a serpentinoidal appearance, and are designated serpentine rocks in Foster and Whitney's Report, Part II, p. 25. Sp. Gr. 2.92 to 3.03.

Loc. Bed XV. Sturgeon Falls, Menominee R. This peculiar variety of greenstone is confined to this bed and the valley of the Menominee, where it forms a conspicuous ridge, associated with hydrous magnesian and greenstone rocks.

"I am inclined to think that this rock is a gabbro. The feldspars are too much altered to admit of determination, but the other principal component presents the appearance of diallage, both by reflected and by transmitted light. I cannot, however, speak positively on the subject." — Rutley.

"In the thin section, hornblende is abundant in large grains with good cleavages, and in parts even predominates, but chiefly in the colorless and often delicately-fibrous form (tremolite). A feldspar abounds in an altered condition, as colorless granulated masses, polarizing but not strongly. There are also clear and colorless veins of another material (sericite?) with thready texture, which envelop the other grains; between the crossed nicols they display only a very feeble polarization. Biotite is common but in small quantity, in brownish-yellow scales, of irregular form, sometimes presenting a network, and which are more or less dichroitic." — Julien.

"Saussurite-gabbro (or hornblende-gabbro): contains *saussurite diallage, hornblende.* Identical under the microscope with the coarser crystalline rock of Upper Quinnesec Falls." — Pumpelly.

No. 70 (3070). — **Decomposed diabase** (Wichmann). Chloritic schist? Has also been called a chloritic aphanite schist, and compact dioritic schist. Compare Nos. 55, 119, 91. Resemble Julien's No. 339, Vol. II, p. 174, Mich. Rep. This rock is a type of the obscure so-called greenstone, or dioritic schists, which is but one link in the chain of transition from hornblende rock through diorite, diabase, and this schist, to chloritic schist, and even to argillite. Dr. Hunt calls them chloritic diorites and says they are identical with rocks found in the Huronian of Canada. They are of various shades of green and gray-green, irregular schistose structure sometimes slaty, fine-grained, apparently chloritic, and have a dull, earthy, very uneven fracture, as if somewhat altered. Similar rocks are abundant in the Menominee region, especially in the hornblendic and chloritic bed XVII. They are believed to be much less common W. of L. Gogebic. Sp. Gr. 2.94 to 3.07.

Loc. M. & O. R. Road (Gorge). An extensive formation immediately below the quartzite V. Similar rocks can be traced from Marquette to N. of Teal lake. This rock resembles the aphanite from Zelle, near Nossen, Saxony. "The whole rock has been changed almost wholly into viridite, and this substance also is present in the fissures. Plagioclase, which has been kaolinized, represents a dust-like substance, which is greenish in consequence of the admixture of viridite. Newly-formed distinct crystals of augite occur in the viridite, while of the original individuals of augite, no trace is recognizable. Calcite, which has also been formed from the decomposition of the original augite, is colorless in appearance and often shows a distinct twin-lamellation in polarized light." — Wichmann. See also § 77 of his report.

No. 71 (3071). — **Micaceous hornblende schist** (Wichmann). Provisional name, quartzose chloritic diorite. Parts of the rock like No. 70. Grayish to dark-green with grain varying from crystalline to coarse, massive rock, related to the greenstones, and apparently contains quartz and chlorite. In places the weather surface is warty (presenting a conglomeritic appearance), from projections of crystalline grains. Sp. Gr. 2.90 to 2.93.

Loc. 20th mile-post, M. H. &. O. R. R. Age unknown, supposed to be Middle Huronian. Resembles the "greenstone" found between Bräunsdorf and Böringen near Rosswein, Saxony (Wapler).

"The green prisms of hornblende and the brown folia of biotite form aggregations, which are imbedded in a feldspathic groundmass. The hornblende shows the beginning of a change into viridite, in which substance some grains of epidote occur. A little calcite has formed in the fissures of the rock." — Wichmann. See also § 134, Wichmann's report.

No. 72 (3072).—**Diabase** (Wichmann). Provisional name, speckled diorite. Compare Nos. 121, 120, 122, 83, also 75 and 70. Gray-green, speckled, medium-grained, homogeneous, massive, apparently somewhat altered rock, related to No. 75, which is a diorite somewhat diabasic in character. Sp. Gr. 2.70 to 3.00.

Loc. Lower Huronian, Marquette Quarry, associated with related greenstones (often more or less decomposed) and schists represented in this collection.

Similar rocks have only been found in the L'Anse Iron Range. See No. 122. Resembles some Laurentian rocks observed west of L. Gogebic. See Julien's No. 309, Vol. II, p. 159, Mich. Rep. The serpentinoidal greenstone exposed at Sturgeon Falls and above on the Menominee river, which have been called diorites, gabbros, diabases (see No. 69), have more resemblance to this rock than any other in the southern region.

"A rock of similar composition, but differing in greater coarseness, etc., is found at various localities in North Carolina, but is not common. Sometimes it has been produced by the metamorphism of a gneiss adjacent to a dyke of eruptive diabase, e. g., near Charlotte. For description, see Report on Geol. of N. C., Vol. II."—Julien.

No. 73 (3073). — **Chloritic schist** (Rutley). Has also been called chlorite-potstone schist, and clay slate. No close allies. Compare Nos. 74 and 53. Julien calls it intermediate between his Nos. 340 and 341, Vol. II, p. 175, Mich. Rep. Light gray-green, soft, slightly unctious-feeling, irregularly splitting schist, with numerous veins of calcite. Another variety was harder, with a glistening splitting surface, and may be an altered hornblende schist. Sp. Gr. 2.53 to 2.68.

Loc. Quarry at Marquette, in small irregular beds or dyke-like masses in greenstone and related syenite — all Lower Huronian, probably below bed V. True dykes as to structure of related schists cross the quartzite V at the E. end of Teal lake, as well as the iron-ores of beds XII and XIII in the Jackson and New England Mines. The material filling the "fluccan" (fault) at the Washington Mine, is similar. Above Badwater village on the Menominee, is a similar chloritic schist associated with quartzite in bed XVIII, covered at high water.

Mr. Rutley says: "This rock appears to be a chloritic schist. The section shows one or two small veins of calc-spar, the individual crystals composing the veins exhibiting the usual twin striation. These calc-spar veins may also be seen quite well with the naked eye. The rock has an argillaceous odor when breathed upon, and is soft and sectile."

No. 74 (3074).—**Talc schist** (Wichmann). Has been called an unctious clay slate. No allies. Compare Nos. 73, 112, 53. Grayish, white, unctious feeling, apparently somewhat argillaceous slaty schist. Talc is a rare mineral in the Archæan, this specimen being the purest found; although unctious-feeling chloritic and hydro-mica schists are somewhat common, especially in the iron-ore strata. Many hydrous magnesian schists have been called talcose, which are chloritic. The same may be said of hydro-mica schists and sericites. Sp. Gr. 2.60 to 2.64.

Loc. At Grace Furnace, Marquette. A small bed associated with greenstones and related schists. Lower Huronian and probably below V.

"The white folia and scales are irregularly aggregated and appear as a felt-like mass. Minute grains of quartz occur now and then. Small grains of magnetite are present, but are surrounded by brown hydrated oxide of iron, in consequence of its alteration. Hexagonal folia of hematite, bluish-gray prisms of tourmaline and small crystals of zircon are recognizable."—Wichmann. See also § 164 of his report.

No. 75 (3075).—**Diorite** (Wright, Wichmann, Rutley). Compare Nos. 118, 71 and 30, and also No. 123. Blackish-green, medium-grained, tough, massive; contains a little epidote in thin seams. Sp. Gr. 2.96 to 3.08.

Loc. Light-House Point Quarry, Marquette. Lower Huronian, probably below V. Associated with other hornblendic rocks and related schists. The syenite, No. 116, apparently belongs to the same series, giving interest to the opinion of Mr. Rutley that this rock may contain orthoclase. See also No. 77. Nearly identical rocks in appearance occur in corresponding geological position in the Menominee region at falls of the Sturgeon river. With associated rocks, extensively quarried for filling cribs of breakwater.

"Microscopically this rock consists chiefly of hornblende and plagioclase. The hornblende is distinctly recognizable and is but little altered. The plagioclase is also rather fresh, and the characteristic twin lamellation always appears between crossed nicols. A little quartz is present in irregular grains, which contain many fluid-enclosures. Biotite forms brown, irregular folia. Titanic-iron is abundant, in association with which appears a grayish-white substance, which has been formed by the change of this mineral. Prisms and needles of apatite occur especially piercing the individuals of hornblende." — Wichmann. See, also, his report, § 87.

"Is composed of feldspars, both plagioclase and orthoclase, or plagioclase, some of which may have undergone alteration, and so may somewhat resemble altered orthoclase. This, however, is doubtful, as the specimen looks fresh and unweathered. The other components are hornblende, and some magnetite. The rock only very feebly affects the magnetic needle. It is either a diorite, or, perhaps, if orthoclase be present, as it seems to be, it would be more correct to regard it as a fine-grained syenite." — Rutley.

"Is no true diorite, as it contains small remains of augite. According to the newest nomenclature, it might be named proterobos." — Törnebohm.

No. 76 (3076).—**Hornblende schist** (Wichmann). Dioritic schist, with little feldspar and no chlorite (Wright). Compare Nos. 31, 103, and Julien's Nos. 182, 266 and 267, Vol. II, pp. 95 and 136, Mich. Rep. Chiefly made up of a blackish-green, somewhat lustrous mineral, resembling chlorite, but too hard and heavy. Structure almost slaty. Contains seams and veins of calcite. May be regarded as intermediate in character between hornblende and dioritic schist. Sp. Gr. 2.92 to 3.03.

Loc. Light-House Point Quarry, N. W. side of Marquette bay, associated with greenstones, syenites, and chloritic schists. See Nos. 75, 73 and allies. In Lower Huronian, probably below V.

"The groundmass is feldspathic in composition. Hornblende is present in green individuals, which are striated. Biotite is not infrequent. Numerous hexagonal folia of hematite appear. Calcite in irregular grains shows a distinct twin-lamellation in polarized light. Titanic-iron forms small grains, each of which is surrounded by a grayish-white substance. Minute folia and scales of muscovite occur." — Wichmann. See, also, § 137.

No. 77 (3077).— **Hornblendic syenite** (Wichmann). Porphyritic syenite (Rutley). Provisional name, porphyritic hornblendic diorite. Less feldspar than No. 116. See for varieties, Julien's Nos. 314 to 319, Vol. II, pp. 161 to 164, Mich. Rep. Composed chiefly of coarse tabular grains of green-black hornblende, with smaller and less numerous grains of reddish orthoclase, the minerals being but little changed on weathered surface, thus differing from diorite. Little or no quartz. Sp .Gr. 2.82 to 3.00.

Loc. Picnic Rocks, Marquette, Lower Huronian, probably below V. A similar rock (No. 116), most likely the same bed, occurs in the Marquette quarries associated with greenstones and related schists. A related rock in general character occurs south of the east end of Michigamme Lake, having some of the structural characteristics of an eruptive mass. Mr. Rutley says: "Is shown, under the microscope, to be mainly composed of hornblende and orthoclase, many patches of the latter mineral exhibiting crossed twin-striation in polarized light. Some quartz is also present. Here and there small clear and colorless transverse sections of hexagonal prisms are shown, which, between crossed nicols, become dark. These crystals are probably nepheline or apatite. Analysis of a moderate quantity of the rock would easily show to which of the two minerals they should be referred. These crystals are, however, very small and by no means numerous. The rock is apparently a porphyritic syenite."

No. 78 (3078).— **Serpentine** (Whitney). Has been called magnesian altered diorite and black trap. No allies. Compare Nos. 82, 83, 122. See Julien's black serpentine, No. 321, Vol. II, p. 165, Mich. Rep. Iron-black, slightly glistening, hard, compact, brittle, fine-grained rock, in which many facets of altered hornblende can be seen set in a serpentinoidal matrix. Sp. Gr. 2.80 to 2.92. The analysis of a similar rock from this locality (see Foster and Whitney's Report, Part II, p. 92) gave: SiO^2 38.24, MgO 14.83, Al^2O^3 1.48, CaO 1.42, HO 9.53, FeO^2, FeO and a little NaO 34.50=100.00; from which it was inferred that the rock was essentially a hydrous silicate of magnesia and the protoxide and peroxide of iron.

Loc. N. E. corner of Presqu' isle, Lake Superior, where it occurs in large, black, irregular, rounded masses, underlying nonconformably Lower Silurian sandstones. A short distance out in the lake are several islands of Laurentian granite. It may be eruptive, is probably of Huronian age, and related to some of the altered greenstones. Similar rocks, perhaps dykes, occur in the Huronian in Secs. 22, 28, 29, T. 42, R. 31, on the Michigamme river. Julien regards them as altered diorites. See Nos. 322, 323, Vol. II, p. 165, Mich. Rep.

At these localities the rock has been exposed to the waters of the lake or river, which may have produced the alteration, as is suggested under No. 120.

"An excellent example of pseudomorphs of serpentine after olivine. A great deal of the substance has already been changed into greenish serpentine. The change has taken place by an attack on the olivine along many fissures, that traverse it in every direction." — Wichmann. See also his report, § 59.

No. 79 (3079). — **Diabase** (Wichmann). Diorite with magnetite (Rutley). Provisional name, "Trap." Like No. 94. Compare Nos. 82, 83. A grayish-black, minutely glistening, compact, heavy, tough, hard, fine-grained, massive rock, with numerous irregular joint-planes, and conchoidal fracture. Quite a distinct variety in appearance from the several other varieties of diabase. Sp. Gr. 2.85 to 3.01.

Loc. From a vertical dyke at Washington Mine, 10 feet thick, which crosses the ore-bed XIII, and gives off branches. Such dykes have been observed at no other mine, and only one or two other similar, and very small ones, in the Huronian. Similar but much finer-grained dykes have been seen in the Laurentian, S. W. of L. Gogebic, but they are rare of this material, being usually coarse-grained and more dioritic. See Julien's No. 355, Vol. II, p. 182, Mich. Rep.

"Plagioclase is present in fine rod-like crystals, which in polarized light show the characteristic twin-lamellation. Very little orthoclase is recognizable. Augite shows a beginning of change into viridite. An interstitial substance occurs between the constituents of this rock. It has not been individualized, and must be considered as the remains of the original fluid magma of the diabase. Apatite is abundant. Biotite, which forms irregular brown folia is not unfrequent. Magnetite is present in sharply defined octahedra, and a little titanic-iron is also recognizable. Hematite appears in blood-red hexagonal folia." — Wichmann. See also § 72.

"Under the microscope, the section shows a meshwork of crystals of feldspar, some triclinic, together with much disseminated magnetite, and some very minute crystals and spiculæ of hornblende. It may be regarded as a diorite."— Rutley.

"The microscopic examination shows that the rock is not a diorite but an aphanitic diabase. It resembles pretty closely dykes in some of the Swedish mining districts, for instance, Norberg." — Törnebohm.

"Quite similar to Scotch and English dolerites." — Allpert.

"From my experience, I would say that this rock is eruptive." — Hawes.

No. 81 (3081). — **Roofing slate.** Provisional name, clay slate. Compare Nos. 20 and 113. A bluish-black, firm, argillaceous slate, with perfect oblique cleavage and very fissile. Said to be a good roofing slate. From the Huron Bay slate district. Age unknown, probably Lower Huronian, associated with quartzose rocks. Clay slates are generally distributed through the Huronian, but appear to be most abundant in the north and west parts of the Marquette region and in the Menominee region. Are often carbonaceous. See Nos. 64, 115 (2153). When associated with limestone, they are apt to have the character of novaculites. See Nos. 10, 12 and 13. See remarks on cleavage under Nos. 20 and 113. The first company for quarrying slate in this district was organized Jan., 1872, since which several have been formed and a considerable and growing industry is established.

No. 82 (913).—**Diabase** (Wichmann). No allies. Compare Nos. 79, 94. Several varieties are described by Julien as "Black Trappean Diorite" under Nos. 342 to 349, Vol. II, p. 176 to 179, Mich. Rep. Brownish and grayish black, speckled with whitish and brownish; glittering, hard, tough, compact, coarse, heavy, massive to semi-schistose rock, with very uneven fracture. Made up of about one-half black amphibolic mineral in irregular crystalline lamellar grains, the facets often of high luster, and one-half greenish and grayish feldspar in irregular tabular crystals. Weathers unevenly to a dirty brown and blackish green, and passes by disintegration into an angular sand, No. 99. Another variety contained blackish-brown hornblende, many minute fissures of which variety were occupied by a film of a yellowish-green color, apparently epidote.

Loc. L'Anse Iron Range, Sec. 9, T. 49, R. 33, in a bed underlaid by ferruginous schists and carbonaceous clay slates, probably Lower Huronian. See Mich. Rep., Vol. I, p. 152. No similar greenstone or related rock has been seen elsewhere in the Huronian or Laurentian. It differs in its external physical characters from No. 70 and similar rocks which Dr. Wichmann names diabases, as widely as possible; but it has similar stratigraphical characteristics. Evidence of non-conformability between greenstones and adjacent schists exist at this locality (See No. 122), and this rock may be eruptive.

"Resembles 107 B, Eagle R. section, Copper series."—Pumpelly. See Mich. Geol. Rep., Vol. I ,Part. II, p. 135.

"The individuals of augite are large and rather fresh and unaltered, yellowish-green in color and highly fissured. Plagioclase, in rod-like crystals, shows a beautiful twin-lamellation in polarized light. An interstitial substance occurs between these constituents. Titanic iron is present in fine crystals, which are aggregated. These aggregations represent the hexagonal forms of crystallization of this mineral."—Wichmann. See also his report § 71.

"From my experience, I should say after examination of this section, that this rock was eruptive."—Hawes.

No. 83 (911).—**Serpentine** (Wichmann). Provisional name, porphyritic greenstone. No allies. Compare with Nos. 122, 121, 78.

Described by Julien as No. 351, Vol. II, p. 180, Mich. Rep. Dark bluish-green, dull, with brown, glistening grains. A rather hard, brittle, compact, heavy, crystalline rock, made up of about one-third brownish to copper-colored grains of feldspar of good cleavage, in a dark, dull bluish-green, aphanitic paste. Fracture uneven. Weathers unevenly to reddish-brown. Julien regards No. 99 as the weathered product of this rock. It is more porphyritic in appearance than any other rock known to be Huronian.

Loc. Lower Huronian, L'Anse Iron Range, N. W. $\frac{1}{4}$ of Sec. 9, T. 49, R. 33. This rock is associated with No. 122 (under which see remarks), and may be a dyke.

"This serpentine shows well its metamorphic origin, as it chiefly consists of pseudomorphs." — Allpert.

No. 84 (1485). — **Banded jasper schist** (Pumpelly). Provisional name, red-banded chert. No direct allies. Compare Nos. 37, 85. Described by Julien as Nos. 166, 167, Vol. II, p. 87, Mich. Rep. Narrow bands of various shades of red, brown, and grayish jasper, speckled with red, and occasionally smoky-gray laminæ of chalcedony. The jasper layers are broken, displaced and bent by tiny faults filled by the brownish and more granular portions. This process, if carried far enough, would evidently produce the breccia, No. 85. See remarks on this origin of certain breccias, with figures, Mich. Rep., Vol. II, App. K. Fracture uneven, conchoidal. Too hard for file. Unchanged on weathered surface. Another variety was more brecciated, and contained small drusy geodes.

Loc. Sunday Lake outlet (Black R. series), W. side Sec. 18, T. 47, R. 45. Near the middle Huronian, associated with ferruginous slates, greenstones, and certain closely related gray and greenish-banded cherty rocks, which prevail here in these more typical forms, to a greater extent than at any other observed point in the Huronian. A homogeneous, blackish variety, called lydianstone by Dr. Wichmann, associated with related quartzose rocks, occurs on Black R., near center of Sec. 12, T. 47, R. 46 W. The dull to bright-red quartz laminæ, often jaspery, associated with the specular ores of bed XIII, Marquette region (see No. 37), are nearly related, and are near the same horizon. In the Cascade Iron Series, near the base of the Huronian, similar rocks are also found. The nearest related rock observed in the Menominee region occurs in bed XVI, at the falls of the Paint R., where it is associated with argillaceous and ferruginous rocks.

The quartzose laminæ occurring in the limestones, especially in the Menominee region, have not this cherty character, although chert in limestone is common in the Huronian of Canada.

No. 85 (1487).—**Chert-breccia** (Wichmann). Provisional name, schistose jasper breccia and banded, ferruginous cherty schist. No direct allies. Compare Nos. 84, 37. Described by Julien, Nos. 124, 125, Vol. II, p. 67, Mich. Rep. More or less angular, flattened fragments of green chert, in a greenish-gray, quartzose, crystalline matrix. Evidently a greenish variety of No. 84, in which the internal motion has been such as to completely break up and displace the quartzose laminæ. Weathered surface is brown and yellow, and extends to the depth of one-eighth inch. See under No. 84.

Loc. Sunday Lake outlet. W. side Sec. 18, T. 47, R. 45. See remarks under No. 84.

"The regular fragments of chert consist microscopically of aggregations of small grains of quartz. They contain numerous sharply defined rhombohedra of calcite, all of which possess a rough surface. The outlines of the fragments of chert are also surrounded by calcite. Fluid enclosures are abundant in some fragments; also sometimes small needles occur here and there. The substance which cements the fragments of chert seems also to be silicious. Only in some parts of a thin section it becomes transparent, and here we observe it consisting of quartz, which is filled with numerous grains of calcite. Besides these, a dust-like substance is present, in consequence of which the cement is not pellucid. Some irregular folia of chlorite occur and also a black opaque substance."—Wichmann. See also § 180 of his report.

No. 88 (1089).—**Black hornblende schist** (Julien). Compare No. 126, 18, 123. Described by Julien as No. 271, Vol. II, p. 140, Mich. Rep. Composed mostly of medium-sized, dark-green, tabular grains of hornblende. More schistose than Nos. 75 and 123. Differs from No. 77 chiefly in the feldspar, which is greenish-gray instead of red.

Loc. Bed. IX. Old Washington Mine, in which varieties of this rock, which have been called hornblende rock, hornblende gneiss, and diorites, prevail. Like the hornblende rock at Schmalzgrube near Marienberg in Saxony (Wapler).

No. 89 (729).—**Micaceous chlorite schist** (Wichmann). Pseudomorphous chlorite schist, and later, tremolitic mica schist (Julien). No allies. Compare Nos. 70, 134. Three varieties are described by Julien, Nos. 179, 180, 181, Vol. II, pp. 94, 95, Mich. Rep. Pumpelly has described another variety of the same rock under "pseudomorphs of chlorite after garnet," Am. Jour. Sci., Vol. X. July, 1875. Dark-green, soft, semi-schistose to massive, chloritic rock, containing numerous scales and octahedra, apparently pseudomorphs of chlorite after magnetite. Crystals of amphibole and pseudomorphs of chlorite after the same, also occur. The magnet separates several per cent. Effervesces slightly with acid. No equally well characterized chloritic rock has been elsewhere observed in large quantities.

Loc. Bed XIII. Spurr Mine. Occurs in lens-shaped layers in the upper part of the bed next the quartzite XIV, associated with pure magnetic ores. The scaly, obscure, chloritic slate, No. 55, occupies the same position in the Barnum Mine. See description of bed XIII and remarks under No. 55. Small lenticular masses and bunches of similar rock containing large garnets, occur at the Republic Mt. and elsewhere.

" This schist represents microscopically a tangled mass of green folia of chlorite. Biotite appears in the form of large brown folia, which are strongly dichromatic. They are, on an average, 0.4 millimetres in length, and 0.1 millimetres in breadth. Muscovite in colorless folia is not unfrequent. Many opaque grains and plates may belong in part to magnetite, partly to titanoferrite." — Wichmann. See also his report, § 159.

" In the thin section the predominant mineral, quartz is found in clear, colorless grains, containing minute biotite scales as inclusions. It is also rich in biotite, in tiny irregular but rounded scales, bluish-green, brownish-green to leather-brown in color; dichroitic, strongly so in cross-sections, and quite irregularly dispersed. Long rectangular sections consist of altered hornblende, colorless, cloudy, and rendered minutely granular by inclusions, whose arrangement often marks the original fibrous texture. Magnetite is found in a few minute plates, black and opaque, sometimes hexagonal in form." — Julien.

No. 90 (1252).—**Mica schist** (Wichmann). Fine-grained grayish-black gneiss (Julien). No direct allies. Described by Julien, No. 257, Vol. II, p. 130, Mich. Rep. Grayish-white, minutely speckled with black, glistening silvery brown mica-scales, hard, tough, compact, of a slaty schistose structure, somewhat like the German schiefer-gneiss. By a diminution and final disappearance of the other minerals, this becomes a soft, friable, mica schist with delicately corrugated surface, as seen below Cedar Portage.

Loc. Bed XIX. Long Portage, Lower Michigamme river, Secs. 32 and 33, T. 42, R. 31. Similar micaceous and hornblendic rocks, in places having granite veins, occur to the west at the portage in the Paint river, and have been traced east through the south part of T. 42, Rs. 30, 29, 28, as far as the meridian of Felch Mt. It cannot be positively asserted that all belong to bed XIX, but it is probable. A characteristic variety of this bed is the staurolitic mica schist, No. 61, which, however, is far less common in the Menominee than in the Marquette region.

No. 91 (1249).—**Clay slate** (Wichmann). Compare Nos. 132, 121, 70. Described by Julien as a chloritic feldspathic argillite, No. 209, Vol. II, p. 108, Mich. Rep. Resembles his No. 339, p. 174. Grayish-green, dull, compact, tough, homogeneous, of impalpable grain and rather schistose structure, apparently argillaceous and chloritic, contains veins of calcite and quartz. Closely related to rocks from the Marquette quarries called decomposed diabases by Dr. Wichmann. See remarks under Nos. 70, 120, 121.

Loc. Michigamme river, midway between Paint and Grand Portages. Huronian, age unknown. Is closely related in appearance to the fine-grained, altered, chloritic greenstones.

No. 94 (1110).—**Diabase** (Wichmann, Wright). Provisional names, black aphanitic diorite and "trap."

Like 79, and from same locality. Described by Julien as No. 354, Vol. II, p. 181, Mich. Rep., and by Wichmann, § 72, chap. V.

Hunt says: "Seems to be a fine-grained, compact dolerite." Pumpelly says: "True diabase, and resembles the ash-bed diabase, Eagle river section, copper-series, to judge from the thin section."

No. 96 (1228).—**Ferruginous granite.** Compare Nos. 7 and 101. Described by Julien, No. 253, Vol. II, p. 128, Mich. Rep. Reddish-gray mottled with light-brown, hard, tough, coarse, massive rock, with uneven fracture, consisting of feldspar (apparently orthoclase), quartz, micaceous-iron and a very little silvery mica. Resembles the eisen-granit of the Germans. The iron has its source undoubtedly in the unchanged walls of the dyke, which are quartzite highly charged with specular ore.

Loc. Felch Mt. Secs. 32 and 33, T. 42, R. 28. A dyke running north and south across the ferruginous quartzite II. A similar one was seen by Prof. Pumpelly eight miles west on Sec. 31, in the great iron-ore stratum of VI. No others have been observed in the Lower Huronian of the Menominee region, but in bed XIX, next the overlying granite, a number occur. No unmistakable granite dykes or veins have been seen elsewhere in the Huronian (See No. 7), although they are numerous in the Laurentian. One of the proofs of non-conformability. Very much resembles the granite of Hitteröe in Norway (Wapler). A corresponding rock (so-called "itabyrite") is found in North Carolina (Geol. of N. C., Vol. I, p. 251, and Vol. II.)—Julien.

No. 97 (984).—**Ferruginous crystalline limestone.** No allies. Described by Julien as No. 101, Vol. II., p. 55, Mich. Rep. White to red and blackish, mottled. Irregular grains of calcite, separated from each other by a brown harder matrix, constituting less than one-half the mass, which Julien calls siderite. The calcite grains have dissolved out on the weathered surface, leaving it roughly pitted. Effervesces briskly in cold acid, thus differing from the common dolomitic variety.

Loc. Sec. 28, T. 51, R. 31. Huron Bay slate district, in a small, irregular and vein-like mass, associated with ferruginous minerals. Has not been observed elsewhere.

No. 98 (1428).— Provisionally named **chloritic diorite-wacke,** and later, **turgite schist** (Julien). Closely related to Nos. 121, 122. Described by Julien as No. 325, Vol. II, p. 167, Mich. Rep. A very fine-grained, reddish-gray schist, rather soft to the knife, and with brick-red streak. Under the loupe, it seems to consist of rather hard, black, rounded grains, slightly shining, rarely one-eighth of an inch in length, enveloped in a soft, ochreous cement of brownish-red to brick-red color. The seams and fissures are reddish-black and shining. Fragments of the rock decrepitate in a closed tube, sometimes quite briskly. The powder loses, on ignition, 6.3 per cent. of its weight.

Loc. W. line of Sec. 18, T. 47, R. 45, on Sunday Lake outlet. Black river series, west of Lake Gogebic. Precise age undetermined, probably middle Huronian. Associated with other greenstones, jaspery and cherty (Nos. 84, 85), and magnetic schists. Similar rocks occur in the vicinity of Marquette, and on the L'Anse iron range. See remarks under Nos. 121, 122.

No. 99 (887).— Probably a completely decomposed **diabase** (Wichmann). Provisional names, brown wacké and greenstone sand. Compare Nos. 122, 82 and 83. Described by Julien as No. 352, Vol. II, p. 180, Mich. Rep. Reddish-brown mottled with dirty light-yellow, dull and earthy; from an angular sand to a friable decomposed rock, produced apparently by the weathering of No. 82, or perhaps of rocks related to No. 83. Both the feldspar and hornblende are altered, but can be distinguished.

Loc. Lower Huronian, L'Anse Iron region. Same locality as No. 82, forming the lower portion of that bed, and apparently a disintegrated and altered variety of the same. This variety is found on the south side of the ridge and near the contact with the underlying limonitic siliceous schist.

No. 101 (1715).— **Granite** (Wichmann). Compare No. 96 from vein, and No. 7. Light flesh-red orthoclase, an unusually large amount of blackish mica, and white quartz. Medium-grained, massive. The micaceous mineral does not appear on the reddish weathered surface, where the quartz is much more conspicuous than on a fresh fracture.

Loc. Bed XX? Near corner of Secs. 20 and 28, T. 42, R. 32, Paint River district. This bed, recently determined as the youngest known Huronian so far as observed, is chiefly granite, often, especially south of the great Quinnesec Falls, coarser-grained, lighter colored and less micaceous than this variety. In places it is gneissic, and one variety, No. 117, is a well characterized hornblende gneiss. These gneisses all conform with the underlying hornblendic and micaceous schists of bed XIX.

"The irregular granules of quartz contain many fluid-enclosures in their water-clear substance. The feldspar-constituent is chiefly represented by othoclase, which has been altered. A little plagioclase is also present. Biotite forms large brown folia, which are strongly dichromatic. Small prisms of quartz occur. Some individuals of augite, which appear now and then, are nearly colorless and highly fissured." — Wichmann. See also § 60 of his report.

No. 102 (1641). — **Mica gneiss** (Wichmann). Provisional name, protogine. Resembles No. 3. Compare No. 65. Brownish-gray gneiss, mottled with reddish and white grains of feldspar and quartz, which are often scattered through the somewhat uniform and rather finely-grained gray matrix, giving the rock a sort of conglomeritic appearance. It is associated with the protogine conglomerate No. 65, and is probably a variety of that rock.

Loc. Bed I. Falls of the Sturgeon, Menominee region. See remarks under No. 65, with which rock this is associated. Quartzose bed V, of the Marquette region, graduates into a somewhat similar rock. See No. 3. The rocks have considerable resemblance to certain chloritic gneisses from the Laurentian. See remarks under No. 3.

"The water-clear grains of quartz are filled with rows of fluid-enclosures, and also contain numerous long bristle-like microlites. The crystals of orthoclase are much altered, and in consequence of this their substance is dull in appearance. Muscovite occurs in colorless scales and folia; besides this, biotite is present in isolated brown folia. Magnetite is present in large, sharply-defined octahedra 0.12 millimetres in length and breadth." — Wichmann. See also § 96 of his report.

No. 103 (2090). — **Feldspathic mica schist** (Wichmann). Provisional name, arenaceous greenstone schist. No direct allies. Compare Nos. 70, 120. Grayish-green, inclining to black, very fine, even grained schist. Uneven fracture. Thin weathering coat of dirty gray-brown. Schistose structure is imparted by mica, which appears on the splitting planes. The rock is not gneissic in appearance, but seems an obscure fine-grained greenstone. See Wichmann, § 116.

Loc. Bed XIX? One-half mile below Islands Rapids, Menominee river, Sec. 18, T. 40, R. 19, Wis. A rare variety in this bed; probably altered by the waters of the Menominee river, which sometimes cover it. Similar rocks are occasionally seen.

No. 104 (1102).—**Mi a schist** (Wichmann). Compare Nos. 56, 132, 134. Described by Julien as a micaceous feldspathic slate, No. 204, Vol. II, p. 106, Mich. Rep. Blackish-gray, minutely sparkling, very fine-grained, homogeneous schist; containing scales of black to grayish-white mica, quartz, and apparently feldspar. Weathers mottled brownish-gray. This obscure rock seems to be a transition between the argillaceous, micaceous, and chloritic families, varieties related to it having been placed in each class.

"The groundmass consists of an aggregation of small grains of quartz. Biotite in form of brown laminae, which are strongly dichroitic. Muscovite colorless. Magnetite in numerous crystals."—Wichman. See also § 113 of his report.

East end of Washington Mine. Middle Huronian, exact age undetermined. This rock and its varieties, while it does not characterize any particular bed, is more or less distributed, especially in the western part of the Marquette region. A closely related rock, No. 132, occurs in the Huron Bay slate district.

" All the common varieties of mica schist occur in North Carolina, with muscovite, biotite, and hydrous micas."—Julien.

No. 105 (2207).—**Mica schist with actinolite?** (Wichmann). Provisional name, actinolite schist. Compare Nos. 129 and 54, also 134, 107. Dark grayish-green, fine crystalline texture, glistening, presenting a broken semi-fibrous schistose structure. Uneven fracture. Weathers greenish-gray and stained reddish-brown on seams. Altered by the waters of the Pine R., which sometimes covers it. Seems more nearly related to actinolite schists than to micaceous.

Loc. Bed XVII or XVIII. 1370 N., 640 W., Sec. 22, T. 39, R. 17, Wis., associated with hornblendic and micaceous quartz schists (No. 140). Somewhat similar rocks are occasionally found in the Menominee and Marquette regions, associated with greenstones and related chloritic rocks.

No. 106 (2212).—**Hornblendic mica schist** (Wichmann). Provisional name, porphyritic hornblende rock. Compare No. 127. The base is blackish-gray, has an aphanitic, slightly sparkling texture, and is porphyritic with numerous black slender crystals of hornblende. Uneven, conchoidal fracture, massive and very jointed. Golden-brown mica on splitting planes. Weathers to a light greenish drab.

"Calcareous groundmass. Biotite the chief rock constituent. Hornblende in form of beautiful bluish-green prisms. Quartz, with little fluid-enclosures. Magnetite."—Wichmann. See also § 114 of his report.

Loc. Bed XII? 1475 N., 900 W., Sec. 35, T. 40, R. 17, Wis. A rare variety associated with greenstones and anthophyllite schists, and not with micaceous rocks. Its lithological affinities seem rather with the hornblendic than micaceous family. Diorites very similar in appearance except as to color, have been observed in the Marquette region.

"Such rocks as 2212, 2222, 2255, 2254, 1100, 1101, 327, are of the same character as the altered slates collected close around the edge of Land's End granite."—Allpert.

Hawes describes similar rocks from Cornish, N. H., in the Geol. of N. H., Part IV, p. 231.

No. 107 (1170).—**Micaceous augite schist** (Wichmann). Provisional name, micaceous diorite schist. Compare No. 61. Irregular wavy laminæ of blackish mica in large scales, and bunchy, thicker laminæ of a fine-grained, dark grayish-green, somewhat hard rock, related to the greenstones. The micaceous portion has considerable resemblance to the mica schist No. 61, but its affinities on the whole are with the so-called chloritic greenstones and the related micaceous looking rocks of bed XI. This rock is interesting as illustrating the transition of greenstone into chloritic and micaceous schists.

Loc. Bed XI. Champion Mine. A more chloritic-looking variety occurs south of Lake Angeline mine in the same bed. A dark-green variety from Republic Mt. was designated mica schist by Dr. Hunt. In bed XIII, at the Little Quinnesec falls, Menominee river, is a similar rock associated with hornblendic diorite.

"Augite light green, often showing the characteristic cleavage, but not in form of distinct crystals. Biotite in very numerous folia. Magnetite, quartzose groundmass."—Wichmann. See also § 153, Chap. V.

From a microscopic examination of another thin section of the same rock, Mr. Hawes says: "In this section, the mineral in its optical behavior is like hornblende. Dichroic, weakly polarizing. I can find no place where a satisfactory cleavage can be found. I do not mean to doubt the determination that may have been made on more or better material. I only suggest that I should doubt it from this section."

No. 108 (2220).—Provisional name, **Garnetiferous chloro-mica schist** (Wright). No direct allies. Compare with Nos. 90, 128, from same bed. Grayish-green and light-gray; indistinct, broken lamination; fine-grained; containing in places numerous crystals of red garnets, larger than peas. The rock is decidedly gneissic in appearance and contains pyrites.

Loc. Bed XIX. 1775 N., 500 W., Sec. 25, T. 39, R. 17, Wis., on Pine river. A somewhat exceptional variety in this hornblendic and micaceous bed. Garnets, which are abundant in the same bed in the Marquette region, have only been observed at this point in the Menominee region.

No. 109 (2087).—**Mica schist** (Wichmann). Provisional name, magnetic chloritic schist. No direct allies. Compare 110, 134, also with 16. Greenish-black, sprinkled with glistening specks, very fine grained, even texture; cleaves readily on bedding planes into thick slates, the surfaces of which are covered with a shining, bronze-colored, micaceous mineral. Strongly magnetic. Some varieties have been called gneisses.

Loc. Believed to be from between beds II and V. From the S. E. corner of Sec. 6, T. 41, R. 30, Menominee region, where it occurs in a considerable isolated bed. Similar rocks have not been observed elsewhere in the Huronian. The arenaceous and magnetic character and black color distinguish it. A related banded rock occurs in the Laurentian south of L. Gogebic. See Julien's No. 213, Vol. II, p. 110, Mich. Rep., a rock possessing much interest on account of the rarity of iron-ore in the Laurentian.

"Aggregations of irregular small grains of quartz form the groundmass, in which the brown folia of biotite have been imbedded in great numbers. These folia have all formed parallel to the schist plane. Magnetite is abundant either in distinct octahedra or in irregular grains."—Wichmann. See also § 113, Chap. V.

No. 110 (2236).—**Blackish-gray mica slate** (Julien). Provisional name, micaceous chloritic slate. Compare Nos. 111 and 134 (2075, 2227). Compare Julien's No. 210, Vol. II, p. 108, Mich. Rep. Dark grayish-green, very fine grained, splits into thickish slates along bedding planes, which have a shimmering luster. Has been called slaty gneiss.

Loc. Bed XVII. Lower fall, Pine R., 1200 N., 1400 W. Sec. 28, T. 39, R. 18, Wis., associated with banded arenaceous quartzose schist.

"In the thin section the predominating mineral is biotite, chiefly as leather-brown to fawn-colored plates, brownish-yellow in cross-section and strongly dichroitic. These plates, and also smaller rounded or irregular scales and slender blades and needles, are in general loosely scattered about and isolated, but are also concentrated in certain laminæ. An apparently chloritic mineral (perhaps a form of biotite) also occurs in small irregular brownish-green scales, usually near or intimately mixed with the brown scales of biotite, and occupying their interstices; it is more or less dichroitic. Quartz is abundant, and even predominates in some laminæ in clear and colorless irregular grains, brought out distinctly in polarized light. Minute black scales of hematite, rarely blood-red by transmitted light, are scattered pretty uniformly through the micaceous layers, and in dusty groups through the quartz. They are often hexagonal, octagonal, etc., in cross-section, and present polished surfaces in reflected light."—Julien.

No. 111 (2075).—**Micaceous clay slate or phyllite** (Wichmann). No allies. Compare Nos. 56, 110, 81, also 10, 114. A light slate-colored, fine-grained, hard, eminently fissile slate, without oblique cleavage, the splitting planes of which are often wavy and which glisten from micaceous laminæ, giving it an entirely different luster from the ordinary clay slate.

Loc. Bed XI. At the Four-foot Falls, Menominee R. In it are occasional thin seams of gray quartz, containing veins of glassy quartz. A related rock, less fissile (No. 56), occurs locally in the clay-slate stratum XV, of the Marquette region. Certain Laurentian (?) slates which occur on the W. branch of the Ontonagon R., are closely related, but were regarded by Prof. Pumpelly as chloritic. See Julien's description of No. 219, Vol. II, p. 113, Mich. Rep.

"This class of slates finds a large development along the western and southwestern border of North Carolina. They generally abound in staurolite, kyanite, garnet and ottrelite. (See Geol. of N. C., Vol. I, pp. 131–139, etc., and Vol. II.)"—Julien.

No. 112 (2077).—**Sericite schist** (Wichmann). Provisional name, talcose schist. Compare Nos. 74, 73, 53, 54. Light pea-green to gray, weathering red; unctious feeling, and irregular, warped, schistose structure. The reddish-gray splitting planes have somewhat of a satin luster. It seems intermediate in character between the talcose schist No. 74 and the mica schist No. 53.

"In a quartzose groundmass, small yellowish folia and scales of sericite. Round granules of quartz. Tourmaline, mostly in form of broken crystals. Some hydrated oxide of iron."—Wichmann. See also § 118, Chap. V.

From a test-pit near south quarter post of Sec. 25, T. 40, R. 31, bed VII, or the upper portion of the iron-ore bed VI. A rare rock, closely related to the hydrous magnesian and hydro-micaceous schists which occur in the iron-ore bed XIII, Marquette region. At the Big Quinnesec Falls is a similar schist in bed XV.

"Is like some that I have described as argillitic mica schist."—Hawes.

No. 113 (2253). — **Clay slate.** Compare Nos. 20, 81, 10. Between Nos. 20 and 81 in character and color. Bluish-black, aphanitic texture, imperfect slaty structure, producing rough surfaces. Oblique cleavage. Bedding planes are marked by faint oblique bands forming every angle with the cleavage planes, which are constant in strike and dip.

Loc. Bed IX or X. South of L. Hanbury, 1750 N., 30 W., Sec. 16, T. 39, R. 29, Mich. Alternating in thin layers with the arenaceous quartzite No. 139. This bed affords the only clay slates with oblique cleavage observed in the Menominee region, the fissile character of the others in beds XI and XVI being apparently due to lamination, as they conform with the bedding. Carbonaceous matter seems confined to this latter class. Oblique cleavage, so far as observed, is always present in clay slates alternating with beds of limestone or quartzite, and usually absent when the slate constitutes the whole bed or is associated with other rocks. True (oblique) cleavage planes of clay slates in the Menominee and Marquette regions, generally, if not always, dip at a high angle in a southerly direction, the prevailing strike of the rocks being E.-W. Cleavage too uneven and irregular to afford valuable slates.

"Similar slates abound in certain parts of central North Carolina, especially in the great belt west of Raleigh, assigned to the Huronian by Prof. Kerr. (See Geol. of N. C., Vol. I, pp. 131–132, and Vol. II.)" — Julien.

No. 114 (2179). — **Argillaceous slate.** Provisional name, chloro-argillaceous slate. Compare Nos. 10, 81. A greenish slate color, faintly shining on splitting planes, greenish-black and dull on cross-fracture. Destitute of oblique cleavage. Splits into moderately thin and tolerably even slates of small size on account of numerous joints. Appears to be somewhat chloritic. Several varieties as to shades of color and perfection of cleavage, occur.

Loc. Bed XVI. Extensively developed, probably forming bed of river, at large island in Brulè R., on E. line of Sec. 15, T. 40, R. 18, Wis., where, in going N., every transition through chloritic and related greenstone schists to nearly massive greenstone, could be found. Similar slates are exposed in the same bed at Twin Falls. In other portions of this bed, this slate becomes ferruginous and carbonaceous (No. 115), and contains masses of hematite ore (No. 135). Farther up the Brulè, related slates, less fissile, apparently more chloritic, and presenting often minute corrugations on the splitting planes, which are sometimes warped, occur. The absence of all appearance of oblique cleavage distinguishes these argillaceous rocks from the true clay slates represented by No. 113 and allies. The nearest related rock of the Marquette region is that of bed XV, extensively developed at L. Michigamme.

No. 115 (2153). — **Carbonaceous clay slate.** Provisionally called graphitic schist. Similar to No. 64, differing in splitting less evenly, containing apparently more carbon, and in its glistening graphitic (?) surfaces.

Loc. Keyes and Fisher's Location, 675 N., 1900 W., Sec. 21, T. 40, R. 18, Wis., associated with clay slate, iron-ore and ferruginous quartz schist, in bed XV.

No. 116 (1720). — **Syenite** (Wichmann). Provisional name, porphyritic diorite. Compare the hornblendic variety, No. 77, from same series. The hornblende grains are smaller, and the proportion of red orthoclase is much larger than in No. 77. It contains also irregular veins of orthoclase.

"Greenish hornblende in form of good crystals, often showing distinctly its characteristic prismatic cleavage (angle = 124° 30′), dichroitic. Orthoclase, also a little plagioclase. Titanite in form of wedgelike yellow crystals. Quartz, biotite, apatite."—Wichmann. See also § 61, Chap. V.

Loc. Marquette Quarry. Lower Huronian, probably below V. See remarks under Nos. 77 and 75.

No. 117 (2211). — **Syenite gneiss** (Wichmann). Hornblende-gneiss (Wright). Compare Nos. 90 and 128. Dark-gray sprinkled with light-gray, fine-grained, hard, tough, flaggy schistose structure, with corrugated splitting planes which glisten.

"Greenish hornblende in form of large rods or crystals, often penetrated by needles of apatite, biotite, orthoclase predominating among the feldspathic constituents. Plagioclase recognizable by its twin-lamellation; quartz; magnetite." — Wichmann. See also § 103, Chap. V.

Loc. Bed XX. 500 N., 1700 W., Sec. 27, T. 39, R. 17, Wis., on Poplar river. This variety of gneiss was not observed elsewhere in this bed. It has more lithological affinity with XIX. The prevailing rock in bed XX is granitic, of which one variety is No. 101. Somewhat similar rocks are found in the greenstone strata south of the Washington Mine.

"A rock of this character, rich in plagioclase, and always of slaty structure, attains an enormous development in N. C. (See Geol. Report.") — Julien.

No. 118 (192).— **Quartz diorite** (Wichmann). Compare with Nos. 71, 75; also with No. 126. Gray-green, coarse-grained, with tabular crystals of hornblende, massive, tough, weathering brownish-gray. Numerous joints stained brown. Graduates into fine-grained and schistose varieties, which, in turn, graduate into a chloritic schist. Differs from the coarse-grained hornblende rock, No. 126, chiefly in containing pale, greenish-gray feldspar. Foster and Whitney give the following analysis of a similar rock from the same bed (see their report, Part II, p. 93): SiO^2 46.31, Al^2O^3 11.14, FeO 21.69, CaO 9.68, NaO 6.91, HO 4.44, Mg. trace $= 100.77$, from which they concluded the rock to be a mixture of pyroxene and labradorite, together with water.

Loc. Bed XI. Near center of Sec. 2, T. 47, R. 27. Associated with schistose varieties, sometimes chloritic. It constitutes the greater part of this bed in the Negaunee district. Similar rocks occur in the Menominee region, in bed XV.

"Compare with the series of North Carolina diorites. Geol. of N. C., Vol. I, pp. 123–125, and full descriptions in Vol. II." — Julien.

"A rather altered rock. The twin-lamellation of plagioclase well observed. Hornblende partly changed into a greenish-fibrous, often radiated mineral, called viridite. In this viridite are found as new production beautiful crystals of augite. Titanic-iron also altered and surrounded by a grayish-white mineral, produced by its change. Quartz in form of small grains." — Wichmann. See also § 91, Chap. V.

"The thin section contains much epidote (not noticed in Wichmann's description). The rock is identical with the ones described on p. 227 of my New Hampshire Report, Part IV. It especially resembles the one from Littleton. Differs only in containing a little quartz. This rock, from my experience, should say was doubtless metamorphic." — Hawes.

The presence of epidote in quantity was fully verified by Mr. Hawes on a second examination, and he remarks that this mineral is quite characteristic of the metamorphic diorites of New Hampshire.

No. 119 (2118).— **Chlorite schist** (Wichmann). Provisional name, chloritic diorite. Compare Nos. 70, 76, 91. Dark grayish-green, fine grained, even texture, jointed and schistose, slightly shining. Weathers mottled brownish-gray. Is apparently identical with rocks often called dioritic schists and chloritic diorites.

Loc. Bed XVI. Near S. qr. post of Sec. 10, T. 38, R. 20, Wis., Little Quinnesec Falls, Menominee R., associated with massive greenstones and related schists. Similar rocks in appearance, and called chloritic schists, occur in beds XVIII and XV, Menominee region, and in the greenstone strata of the Negaunee district.

No. 120 (827).—**Decomposed diabase** (Wichmann). Provisional name, micaceous greenstone schist. Compare Nos. 121, 82 and 122. Described by Julien, No. 336, Vol. II, p. 173, Mich. Rep. Dull grayish-green, slightly glistening, apparently somewhat decomposed rock, related to No. 121, but harder and more schistose. Minute scales of a reddish-brown micaceous mineral are dispersed through it. Effervesces in acid. Somewhat serpentinoidal in appearance.

"In consequence of the alteration of the rock, the plagioclase is dull and seldom recognizable by its twin-lamellation. Augite has been totally changed into viridite. In the viridite, small crystals of augite have been formed as result of new-production. Quartz, titanic-iron, apatite. In some cavities calcite."—Wichmann. See also § 81, Chap. V.

South of Northwestern Hotel, Marquette, associated with obscure greenstones and related schists, all believed to be older than bed V, and having more or less the appearance of having been altered as if by water, which character is lost as they are followed westward on higher ground. These rocks may have formerly been covered by the waters of Lake Superior, above which they are now elevated only a few yards. This hypothesis would not however apply to the similar rocks (No. 122) of the L'Anse Range, which are nearly 1000 feet higher.

No. 121 (821).—**Decomposed diabase** (Wichmann). Provisional name, calcareous greenstone schist. Compare Nos. 122, 120, 99. Described by Julien as No. 331, Vol. II, p. 170, Mich. Rep. Olive-green mottled with chocolate-brown, compact, fine-grained, somewhat soft, and serpentinoidal in appearance. Fracture uneven, following irregular fissures, which renders it difficult to obtain a fresh fracture. Effervesces decidedly in acid. Is plainly a finer-grained and somewhat less altered variety than No. 122. See Chap. V, § 80.

Loc. North of Northwestern Hotel, Marquette, having position and associations of No. 120.

"Nos. 121, 120, 83, 122, diabases, are too much altered to determine whether they had any resemblance to Keweenawan (copper series) diabases or not; their alteration is in the direction of quartz, chlorite and carbonates, which is unusual in the copper series."—Pumpelly.

"Nos. 121, 120, 70, 122, are very highly altered, and are in every way analogous to our Lower Silurian diabase of North Wales, which I take to be simply altered dolerites and gabbros."—Allpert.

No. 122 (889).—**Altered quartz diabase** (Wichmann). Provisional names, altered greenstone and serpentine. Compare Nos. 121, 99, 83. Described by Julien as No. 345, Vol. II, p. 177, Mich. Rep. Chocolate-brown, irregularly banded with green. A soft, fine-grained, compact, massive, apparently altered rock, made up largely of reddish, altered hornblende, and soft, greenish and grayish feldspar. The rock appears to be intermediate in character between the unaltered rock No. 82, and the disintegrated variety, No. 99, but it is not known whether it came from exactly the same locality. See Chap. V, § 77.

Loc. Lower Huronian, L'Anse Iron Range. Very similar rocks, if not this specimen, occur in a dyke-like mass, apparently crossing at a very acute angle with the bedding planes, strata of ferruginous, quartzose and argillaceous rocks. Related rocks occur in the Lower Huronian at Marquette, and also in the Black R. series, but have not been seen on the Menominee R.

No. 123 (2167).—**Hornblende rock** (Wright and Wichmann). Resembles Nos. 18, 22 and 30. Compare the diorite No. 75, and also 127. Greenish-black, fine-grained, tough, massive rock, composed chiefly of hornblende, with little feldspar. This rock is not so black, and weathers less like the diorites than those of the Marquette region. Chap. V, § 126.

Loc. On the Brulè river, 1040 N., 470 W., Sec. 9, T. 40, R. 18, Wis., in bed XVIII, associated with clay and chloro-argillaceous slates.

"The white portion of the section I have is largely triclinic feldspar. It resembles the rocks described on p. 229, Geol. of N. H., Part IV, as quartz-diorite. It contains epidote also, in addition, and not very much quartz. It is a metamorphic quartz-diorite."—Hawes.

After a second examination of this rock, Mr. Hawes says: "In regard to section No. 123, which I have again examined, allow me first to call your attention to the opening remarks under the head of amphibolite, on page 230 of the Geol. of N. H., Part IV. You will then see that the difference between the determination of Dr. Wichmann and myself is not so great, except that in the printed list that accompanies these sections, no mention of triclinic feldspar is made in the diagnosis of the section, and it is certainly present in considerable quantity in the section that I have. As Dr. Wichmann did not observe it in his sections, and as the rock is just one of those referred to in my report as being on the dividing line, I should refer it to the amphibolites. I regard the existence of just such rocks as this as quite conclusive proof of the possibility of quartz-free diorites among the metamorphic rocks; for among variable sedimentary deposits, if some undoubtedly schistose or interstratified rocks are near diorite in composition, it is not strange that sediments of just the composition of basic diorites should occur near by. Then why need this very simple explanation be passed over, and the eruption or the tuffaceous product of associated eruptive masses, which is always referred to for the explanation of the green dioritic rocks, be always relied upon."

No. 124 (2201).—**Hornblende schist** (Wright, Wichmann). Compare Nos. 123 and 127. Banded, dark greenish-gray, fine-grained, with numerous laminæ or seams of calcite, which, by their destruction on the weathered surface, produce corrugations. Contains, also, minute irregular veinlets of calcite. Sp. Gr. 2.93.

"Has a quartzose groundmass. Contains hornblende, numerous granules of garnet, titanite and magnetite."—Wichmann.

Loc. Bed XVII or XVIII. Near N. qr. post, Sec. 22, T. 39, R. 17, Wis. Overlaid by quartzose rocks. Hornblende schist strongly banded with calcite, has not been observed elsewhere. Similar rocks are described by Hawes, Geol. of N. H., Part IV, p. 231.

No. 125 (2124).—**Hornblende schist** (Wright and Wichmann). Compare No. 128 from same bed, also Nos. 31 and 134. Dark grayish-green, crystalline, very fine-grained, splitting evenly into thin flags. Another variety contained laminæ of mica, and another, seams of quartz and apparently a little chlorite, having a gneissic appearance. Chap. V, § 130.

Loc. Bed XIX. Near W. quarter-post of Sec. 15, T. 38, R. 20, Wis. This bed contains granite dykes in this vicinity and is overlaid by the granite of bed XX. This stratum, which is decidedly hornblendic in the southern part of the Menominee region, is highly micaceous in the northern part.

Hawes describes similar rocks in Geol. of N. H., Part IV, p. 231.

No. 126 (2200).—**Hornblende rock** (Wright). Much finer-grained are Nos. 123, 18 and their allies. Blackish-green, very coarse-grained, massive and jointed, presenting numerous large tabular crystalline facets on fresh fracture.

"The groundmass consists of an aggregation of quartz-granules. Hornblende, a little feldspar, biotite and magnetite are present."—Wichmann.

Loc. Bed XVII or XVIII. 1900 paces N. and 1000 W. from S. E. corner Sec. 22, T. 39, R. 17, Wis. Its lithological affinities are with XVII, but it is much coarser grained than the prevailing varieties. Finer-grained and more schistose varieties overlie this. These very coarse-grained hornblendic rocks have not been observed in the Marquette region, and they have nowhere been seen constituting heavy beds.

Mr. Hawes says this "hornblende rock contains scarcely any triclinic feldspar. The presence in the set of all shades between hornblende schist and real diorite, by the introduction of plagioclase and elimination of quartz, indicates that you have the same series of rocks as have been studied in the Pyrenees (see p. 230, Geology of N. H.), and also in New Hampshire and elsewhere. It may be interesting to read my chapter in N. H. Reports, on the greenstones in connection with these rocks."

No. 127 (2182).—**Micaceous hornblende schist** (Wichmann). Provisional name, diorite. Compare the hornblendic (porphyritic) mica schist, No. 106; also Nos. 123 and 126. Dull greenish black, massive, uneven fracture, appears like an altered diorite. The fresh surface shows bright elongated crystalline facets. Weathers brown. Sp. Gr. 2.80.

"Quartzose groundmass. Hornblende in form of small needles. Biotite in numerous folia. Some orthoclase. Titanite."—Wichmann. See also § 136, Chap. V.

Loc. From bed XVII. 750 N., 1375 W., Sec. 17, T. 41, R. 31, on Brulè river. A rare variety in this hornblendic stratum.

Hawes says: "The section I have has much plagioclase and little quartz; it is almost a dioritic schist."

No. 128 (2245).—**Micaceous hornblende schist** (Wichmann). Resembles No. 125 from same bed. Compare No. 117. Blackish-green, fine-grained, holding laminæ of dark-brown mica, splitting into thin, uneven flags, and faintly striped on weathered surface. Splitting planes sparkle from leaves of mica. A slaty gneissic variety contains laminæ of brownish-green and yellow mica, over the surface of which are scattered in somewhat fan-shaped forms, slender crystals of black-brown hornblende, which are sometimes collected in bushy bunches.

Loc. Bed XIX. High ledge, 1500 N., 0 W., Sec. 12, T. 39, R. 16, Wis.

This rock unites in itself the hornblendic and micaceous character of this stratum, which is almost entirely made up of hornblende schists, mica schists, and closely related rocks.

No. 129 (2238).—**Actinolite schist** (Wichmann, Wright). Compare Nos. 105, 54. Silvery greenish-gray, very coarse, fibrously radiated, crystalline texture. The fan-shaped bunches of actinolite are often an inch or more in length. Very soft, hardening on exposure to the air. Reddish ochre in seams and cavities.

"Contains large prisms of actinolite, colorless and highly fissured. Between them is a chloritic substance." — Wichmann. See also § 120, Chap. V.

Loc. Bed XVI. 1200 paces N. and 1000 W. of S. E. corner, Sec. 28, T. 39, R. 18, Wis., below Lower Fall, Pine R. Overlaid by clay slate. A finer-grained, firmer variety occurs 2 miles W. of Loon lake, near N. quarter-post of Sec. 34, T. 40, R. 17, supposed to belong to XVIII. See remarks under the micaceous variety No. 105. Well characterized rocks of this kind are only found in the Menominee region and west of the river. Certain obscure fine-grained hornblendic greenstones of bed XI, Marquette region, have received this name.

"Like the actinolite schists from Pittsburg, N. H., lacking the pretty rutile crystals. See Geol. of N. H., Part IV, p. 232." — Hawes.

No. 130 (2186). — Provisionally named **Magnetic anthophyllite schist** (Brush), and magnetic anthophyllite-actinolite schist (Wright). Compare Nos. 27, 58. See references under Nos. 27 and 58. A fresh fracture presents irregular bands of different shades of silvery and greenish-gray, sparkling with minute elongated facets of the amphibolic mineral. Schistose and strongly magnetic. Brush says: "It appears to be a mixture of some blackish hornblendic mineral with a mineral resembling anthophyllite." This mineral exists in minute fibres and blades, generally radial and often in beautiful star forms. The splitting planes have a brown weather-surface, which often extends one-fourth of an inch into the rock. It often contains laminæ of arenaceous quartz. Sp. Gr. 4.00. A highly ferruginous specimen, banded with laminæ of white quartz sandstone, gave E. T. Sweet with Prof. Daniells, Madison, Wis.: Fe^2O^3 44.06, FeO^2 19.62, SiO^2 18.98, Al^2O^3 7.82, CaO 2.54, MgO 1.66, Mn^2O^3 .20, PO^5 .12, S .21, HO 4.32 = 99.53.

Loc. Bed XV. 400 paces N., 500 W., from the S. E. corner Sec. 25, T. 40, R. 17, Wis. It occurs close by in the same, associated with much iron, both magnetite and hematite.

In the Marquette region a related manganiferous variety, less quartzose, forms bed XVII. See Nos. 58, 59. It is not improbable that workable beds of ore may be found with this rock. See remarks under No. 58.

No. 131 (221). — **Magnetic actinolite schist** (Wichmann). No allies. Compare Nos. 27 and 28 from same bed, also Nos. 58 and

148. A dark-gray, faintly banded, fine-grained, magnetic schist. Uneven semi-conchoidal fracture. Does not split along striping. Weathers brown. Contains a large percentage of some other mineral besides magnetite, which does not give fire with steel and is apparently amphibolic. Nos. 15, 19 and 23 are related in the amount of iron they contain, but differ in being highly siliceous and giving fire with steel. Chap. V, § 121.

Loc. Bed X. S. W. qr. of N. E. qr., Sec. 13, T. 47, R. 27, where it is associated with other ferruginous rocks and greenstones. This variety has not been observed elsewhere. Nos. 27 and 28 from same bed, although differing widely in their physical characters, are believed to be related to this rock, especially the former. Dr. Wichmann also finds an amphibolic mineral in the magnetic ore of Penokee Gap, Wis., which however gives fire strongly with steel, and is black and more compact than this rock. A variety intermediate between this specimen and No. 28 has been observed.

No. 132 (982). — **Feldspathic chlorite schist** (Wichmann). Provisional name, argillaceous schist. Compare Nos. 134, 55, 104. Described by Julien as gray, feldspathic argillite, No. 200, Vol. II, p. 104, Mich. Rep. Cast-iron gray, slightly glistening, compact, fine-grained, slaty schist, with an uneven fracture. Weathers blackish-gray. A rock similar in appearance, No. 104, has been called mica schist. See remarks under No. 104. This rock appears to be a transition variety between micaceous, argillaceous and chloritic rocks. Chap. V, § 158.

Loc. Huron Bay slate region. Probably Lower Huronian. Not a common variety.

No. 133 (2091).— **Micaceous chlorite schist** (Wichmann). Compare Nos. 132, 134, 70. Dark greenish-gray, fine-grained, somewhat jointed, irregular schistose structure. The fresh surface of this rock has a peculiar delicately shining luster. Golden-mica scales in joints. Chap. V, § 160.

Loc. At the "Point," N. E. corner of Sec. 18, T. 40, R. 18, Wis., on the Menominee R., in bed XVIII. Associated with this is a variety of the same rock containing numerous irregular seams of calcite. On the north side of the river are massive to schistose, greenish-gray, quartzose rocks, belonging to the same bed. The chloritic quartzose series constituting this stratum are best exposed at the Islands Rapids, one mile above.

No. 134 (2227). — **Actinolitic chlorite schist** (Wichmann). Chlorite schist (Wright). Related to No. 55. Compare Nos. 132, 109 and 128. Dark-grayish-green, very fine-grained, even texture, slightly glistening. Splitting planes unevenly corrugated. Thin greenish-gray weather-coating. Next to No. 89, the best characterized chloritic rock. It is more nearly related in character to the so-called chloro-argillaceous slates (without oblique cleavage) of beds XVI and XVIII of Lower Brulè. See No. 114.

Loc. Bed XIX. Upper Falls, Pine R., Sec. 30, T. 39, R. 18, Wis., associated with hornblende schist and underlaid by quartzose schist, believed to belong to XVIII. A rare variety, particularly in this bed, which is usually micaceous and hornblendic.

"Quartzose groundmass. Greenish chlorite, therein small prisms of colorless actinolite. Some grains of magnetite." — Wichmann. See also § 133, Chap. V.

No. 135 (2154). — **Red hematite.** Compare Nos. 24, 35. Purplish-brown, without luster, aphanitic texture, with a few irregular, broken, quartzose laminæ. Breaks irregularly. This ore apparently forms a lithological connecting link between the soft earthy hematites and limonitic ores of the Marquette region, like Nos. 24, 35, and the rich hard specular varieties, like No. 45. Sp. Gr. 3.60 to 4.32. An average sample gave E. T. Sweet: Fe^2O^3 75.47, FeO^2 trace, SiO^2 14.28, Al^2O^3 4.31, Mn^2O^3 .23, CaO .88, MgO .43, PO^5 .08, S .09, HO 3.94 = 99.71.

Loc. Bed XV. Keyes' and Fisher's location, 725 paces N. and 10 W. of S. E. corner Sec. 20, T. 40, R. 18, Wis., associated with banded ferruginous quartzose schist and clay slate, often carbonaceous, which are the prevailing rocks in this bed.

A similar association of rocks, believed to be the same horizon, has been traced along the Brulè and the line dividing ranges 32 and 33, T. 42, to the falls of the Paint R. in Michigan, and ore similar to this is found at several points.

No. 136 (2284). — **Soft purple hematite slate.** Resembles No. 67. Compare with Nos. 44, 49. Has some points of resemblance with Julien's magnetite schist, No. 229, Vol. II, p. 118, Mich. Rep. Differs from No. 67 only in possessing a higher luster, approaching some of the dull varieties of specular ore, due to its greater richness in iron. It is of a bluish slate or pigeon-color. Under the lens the ore seems to be entirely composed of exceedingly minute grains of specular hematite, only slightly compacted into a slaty, friable, iron (somewhat porous) sandstone. Hence, while in physical character it is essentially different from the specular ores of the Marquette region, it is chemically nearly identical. If we suppose the silica to be dissolved out of such associated flag-ores as No. 68 by alkaline waters, this ore would result; and if the process were continued to the hydration of the iron-oxide, we may suppose the associated earthy limonitic ores similar to Nos. 25 and 34 to be produced. Sp. Gr. 4.90. An average sample gave E. T. Sweet: Fe^2O^3 90.20, FeO^2 .76, SiO^2 4.24, Al^2O^3 3.81, Mn^2O^3 trace, CaO .36, MgO .09, PO^5 .11, S .03, HO .57, =100.17.

Loc. Bed VI. Quinnesec Mine, Sec. 34, T. 40, R. 30; associated with hematitic quartzose flags and ferruginous argillaceous schist. An identical ore, except in being disintegrated to a specular sand in some instances, occurs at the quarter post between Secs. 9 and 10, T. 39, R. 29, imbedded in hematitic quartz-flags, No. 68. A harder variety occurs, apparently in small quantities, at the Breen. Extensive explorations have proved the existence at this point, as well as on Sec. 10, T. 39, R. 29, of workable deposits of this excellent ore, which are only awaiting railroad facilities to be introduced into the market.

No. 137 (2083).—**White quartzite.** Compare Nos. 21 and 50. Julien describes varieties under Nos. 126 to 135, Vol. II, pp. 68 to 72, Mich. Rep. Grayish white, arenaceous, semi-saccharoidal texture, dull vitreous luster, massive to semi-schistose structure, often jointed, resembling a highly indurated sandstone. The bedding is often very obscure, being sometimes marked by a faint indistinct striping. Green actinolite, brown mica and specular iron occur as accidental minerals, but are not common. Sp. Gr. 2.68.

Loc. It constitutes bed II, at the S. qr. post of Sec. 17, T. 41, R. 30, where there is an exposed thickness of 500 feet. A nearly identical rock occurs in beds V, VIII and XIV, Marquette region, and is generally distributed, being found in the Huron Bay district, west of L. Gogebic, and on the Penokee Range. Quartzites, especially red, are apparently more abundant in the Huronian of Canada, than in Michigan. This rock is frequently plainly ripple-marked on bedding planes. The false stratification of the original sandstone can often be seen. See fig. 2, p. 109, Vol. I, Mich. Rep. The Felch Mt. specular ore deposit, somewhat like No. 37, is believed to be a highly ferruginous part of this quartzite bed II.

"Similar quartzites abound in the Huronian belts which Kerr has distinguished in North Carolina. (Geol. of N. C., Vol. II, pp. 131-139, and Vol. II.)"—Julien.

No. 138 (2093).—**Chloritic quartzite** (Wright). Compare Nos. 50, 139. Dark-green, sprinkled with light-gray, medium-grained, arenaceous, even texture, strongly jointed, uneven fracture, weathers brown. Made up of different sized crystalline grains of white, glassy and smoky quartz, in a greenish-gray matrix, which seems to be chloritic and micaceous. A fine-grained, exceedingly tough, variety occurs at the mouth of the Michigamme river.

Loc. Bed XVIII. Center of Sec. 23, T. 41, R. 31, associated with chloritic schist, which rocks graduate into each other and constitute the bulk of this bed. A similar, but more arenaceous rock, is found in bed V, Marquette region, near the Cascade Mines.

No. 139 (1621).—**Dark-gray arenaceous quartzite** (Dr. Wichmann calls it a sandstone). No allies. Compare with Nos. 52 and 138. Dark-gray, sometimes mottled brown, arenaceous quartzite, or compacted sandstone, with numerous minute veins and bunches of white quartz, and a deep weather-coating up to one inch, of brown, friable sandstone. The quartz veins are perpendicular to the bedding planes, and present distinct white reticulations on the brown weathered surface. The dark color, tendency toward decomposition, quartz veins, and its evident fragmentary character, distinguish this quartzite.

"Irregularly shaped or round granules of quartz. In the greater part, calcite fills up the intervals. Numerous black particles belong to coal."—Wichmann. See also § 136, Chap. V.

See description of white sandstone laminæ under No. 52. This particular variety of quartzite has not been observed elsewhere.

Loc. Bed IX? South of Lake Hanbury, Menominee region, associated with clay slates having oblique cleavage.

No. 140 (2205).—**Micaceous quartz schist.** Resembles No. 50. Compare No. 51. Medium to dark-gray, specked with light-gray, fine-grained, glittering on splitting planes, and to a less extent on cross fracture with scales of mica, containing also small bunches of brown mica. Unevenly schistose, the planes sometimes presenting fine indistinct corrugations, such as are often seen in mica schists, but rarely in quartzites. Weathers whitish, to a depth of less than one eighth inch. In other varieties the material is in part cryptocrystalline and almost cherty.

"The grains of quartz are intermingled with brown strongly dichroitic folia of biotite and such belonging to the muscovite, which are colorless. All the mica is placed parallel to the schist-plane." Wichmann. See also § 45, Chap. V.

Loc. Bed XVIII. 1500 paces N. and 850 W. of S. E. corner, Sec. 22, T. 39, R. 17, Wis., near junction of Pine and Poplar rivers, where these rocks prevail, constituting the greater part of this bed. In the same bed on the Upper Menominee and tributary streams, occur dark greenish-gray granular varieties, associated with chloritic schists (No. 138). Identical rocks, graduating into micaceous-iron conglomerate schists, occur in bed XIV. Menominee, and somewhat related conglomeritic micaceous rocks (Nos. 50, 51), occur in the same bed, Marquette region. Conglomerates, however, do not occur in bed XVIII, Menominee region. Identical rocks have not been observed elsewhere.

No. 141 (1744).—**Siliceous limestone** (Wichmann). Compare Nos. 9, 142, also the quartzite No. 8. See references under No. 9; also Chap. V, § 36. Grayish-white, mottled and sprinkled with red, composed of grains of glassy quartz in a crystalline matrix of limestone, probably dolomitic. Schistose, and containing numerous joints stained brownish-yellow. The quartz grains project from the dirty yellowish-green weathered surface, appearing like angular grains of sand, having a general parallelism in their longer axes.

"Irregular shaped grains of quartz containing little fluid-enclosures. Some grains of feldspar, which mostly are triclinic. The intervals filled up with calcite, which shows very distinctly the characteristic twin-lamellation."—Wichmann. See also § 36, Chap. V.

In some particulars the rock has considerable resemblance to the quartzite No. 8, which is believed to be from the same bed (Republic Mt.), but eighteen miles distant N. N. E.

Loc. South line of Sec. 33, T. 44, R. 31, W. of quarter post, associated with ferruginous, quartzose, and chloritic rocks, and in places ribbed like No. 66. Pumpelly observed in a neighboring outcrop of marble, a bed of "fissile chloritic slate" several feet thick; and another outcrop showed a variable amount of finely disseminated quartz, and of quartz in seams or threads. These facts all point towards the equivalency of this quartzose marble bed with the marble-bearing quartzite of the Marquette region, and still more strongly towards its equivalency with the same bed in the Menominee region.

No. 142 (2086).—**Saccharoidal dolomite-marble.** Provisional name, tremolitic white marble. No allies. Like Julien's No. 103, Vol. II, p. 56, Mich. Rep. Grayish-white; granular, crystalline texture; massive; uneven, conchoidal fracture; ragged blackish weathered surface, due to the projecting crystals of tremolite, which is irregularly dispersed in the direction of bedding in bladed crystals one-eighth to over one inch long, and which appear, where weathered, somewhat like fragments of clay slate.

Loc. Bed X? 800 paces N. and 600 W. of S. E. corner Sec. 34, T. 42, R. 30. This bed, which has only been observed in the northeast part of the Menominee region, is characterized by the presence of tremolite; otherwise much like V, as developed in the vicinity.

Wright finds a similar rock in a corresponding position in the Penokee series. See Chap. V, § 35; also, remarks under No. 66.

"A similar dolomite from North Carolina has been referred to by Kerr (Geol. of N. C., pp. 133–138) and Bradley (op. cit.). See also Geol. of N. C., Vol. II."—Julien.

No. 143 (1626).—**Dolomite** (Wichmann). A variety of No. 66. Bluish-gray to grayish-blue, semi-schistose to massive, numerous joints. Weather coating is dirty cream color, sandy, and shows ribs like No. 66. In another sandy variety, the siliceous laminæ were not thicker than paper, even, and presented a beautiful fine purple parallel striping on fresh surface.

"Aggregations of irregular granules of dolomite. Calcite recognizable by its twin lamellation. Quartz in form of small grains or veins with many fluid-enclosures, also often containing crystals of dolomite."—Wichmann. See also § 40, Chap. V.

Loc. Bed V. N. W. qr. of S. W. qr., Sec. 11, T. 39, R. 29, on Pine creek, Mich. See remarks under 66, 9, and 141.

No. 144 (21).—**Micaceous limestone** (Wichmann). No allies. Compare Nos. 143, 66. Gray, fine-grained rock, glistening with facets of calcite. The eminently schistose structure seems to be imparted by scales of mica. It effervesces with acids much more readily than the dolomites, to which it does not seem related either in appearance or stratigraphy. Thin yellowish weather-coating, which does not penetrate the rock. See Chap. V, § 37.

Loc. S. W. qr. of N. E. qr., Sec. 13, T. 47, R. 28, near M. H. and O. R. R. Age unknown; supposed to be Middle Huronian. Has only been observed at this locality.

No. 145 (718).—**Quartz conglomerate.** Compare No. 51 from same bed, also No. 65. See Julien's descriptions, Nos. 114 to 118, Vol. II, p. 63, Mich. Rep., of several varieties of this rock. Blackish to grayish-green, mottled, tough, hard, compact, made up of round pebbles of arenaceous quartz, and angular masses of milky and smoky-quartz, often containing blackish-green scales of a soft chloritic mineral. Fracture uneven streak greenish to grayish white. Weathered surface but little changed, but generally roughened by the projection of the harder portions, which have better resisted the influence of the weather.

Loc. Bed XIV. Spurr Mt. Sec. 24, T. 48, R. 31, where this bed is in part a true conglomerate, as it is also near the Washington Mine, and on the Saginaw Range. A bed of quartz conglomerate is also found in the Cascade series below V. In the Menominee region, specular and occasionally micaceous conglomerates related to No. 51, are found in bed XIV, west of the river. But the best characterized and most interesting conglomerate is the gneissic schist holding pebbles of granite, gneiss, and quartz, at the base of the Huronian on the Sturgeon R. See No. 65. A similar rock is found in the N. E. qr. of N. E. qr. of Sec. 1, T. 45, R. 32, associated with ferruginous rocks.

"Slate and jasper conglomerates" are very common in the Huronian of Canada.

No. 146 (2234).—**Mica gneiss** (Wichmann). Provisional name, micaceous quartz schist. Compare No. 140. The augen gneiss 157 is a variety. Speckled light and dark-gray, fine-grained, crystalline mass, apparently made up of quartz and feldspar, in which are numerous minute lenticular or gash seams of black mica, which impart to the rock a schistose structure and give the cross fracture a broken striped appearance. Shows little disposition to break in the plane of the mica lenses. Contains seams of white calcite, and weathers dirty greenish-gray.

Loc. From bed XVII, 825 N., 0 W., Sec. 24, T. 39, R. 17, Wis., associated with micaceous quartzose rocks related to No. 140, which constitute a heavy E.–W. bed, which is believed to be the equivalent of the gneiss series on north side of the Menominee, near head of Big Quinnesec, where an augen variety (157) is seen. Wichmann, § 100, Chap. V.

No. 147 (2271). — **Sericite gneiss** (Wichmann). Provisional name, feldspathic protogine. Has been called feldspar porphyry schist. No allies. Compare No. 65. Flesh-red on cross fracture, fine-grained, slaty schist, splitting readily into small, thin, uneven flags, the feldspathic laminæ being separated by exceedingly thin layers of a hydrous magnesian mineral, apparently chlorite. No distinct crystals can be recognized with the loupe. Contains iron pyrites. Effervesces slightly in acids. Fuses at 4.5 to a white pearly glass. Chap. V, § 107.

Loc. Bed XVII. Below Sturgeon Falls, Menominee region, 1225 paces N., 850 W. of S. E. corner, Sec. 27, T. 38, R. 21, Wis., in a considerable bed. A related rock, but coarser grained and more gneissic, and graduating into a granitoid variety, occurs in an E. and W. belt about 18 miles north; probably same horizon. Has not been observed elsewhere.

No. 148 (1732).—**Hornblendic, quartzose magnetite schist** (Wichmann). No allies. Compare Nos. 131, 28; also 17. Iron-gray, very fine-grained, homogeneous, very hard, tough, heavy rock, splitting into small slabs with rectangular terminations, due to joints.

Weathers black. Highly magnetic. The presence of an amphibolic mineral in this ore, as determined by Dr. Wichmann, is interesting, since this is rarely the case with the rich ores of the Marquette region.

Loc. Penokee Gap, Bad river, Wis., in the Upper (?) Huronian. Forms the most northerly exposure of iron to be observed, being near the north face of the ridge, constituting a bed say 200 feet thick. This appears to be a part of the great Penokee magnetic iron range, which can be traced for many miles east and west of this gap, forming usually the crest of the ridge. No identical ores have been observed elsewhere, but certain rocks in bed X, Marquette region (see Nos. 27, 28, 131), and the ore from the Magnetic Mine (No. 17), are closely related.

No. 149 (3149).—**Chiastolitic slate** (Wright). Compare No. 28. A micaceous clay-slate holding numerous crystals of chiastolite.

Loc. Upper Huronian, Bed XIX? Penokee range, 1200 paces N., and 1,600 W., of S. E. corner S. 11, T. 44 N., R. 3 W., Wis. I have not seen this rock in place in the U. P. of Michigan, nor in the Menominee range of Wisconsin.

No. 150 (2417).—**Garnet rock** (Pumpelly). Compare Nos. 27, 152. Gray to brown, medium-grained, crystalline, somewhat magnetic, schistose.

Loc. Bed IV? Near N. E. corner of Sec. 7, T. 41 N., R. 30 W., Mich., associated with magnetic mica schist, No. 109. At no other point in the Huronian has so highly a garnetiferous rock been found in quantity. The eklogite bed (X), Washington mine, Marquette region, and in T. 39, R. 17 E., Wis. (151), are nearest related. Garnet as an accessory mineral is quite common, especially in the chloritic schists of XIII, and mica schists of XIX, Marquette region. This rock is believed to be equally rare in other portions of the Huronian.

No. 151 (2819).—**Eklogite** (Julien). Resembles 27. Compare 150. Contains acicular tremolite or actinolite, with small red garnets, and is schistose in structure.

Loc. Bed XIII? 175 paces N., 300 W. of S. E. corner, Sec. 13, T. 39 N., R. 17 E., Wis. One of the series of thin beds represented by Nos. 2814 to 2822, underlying the great quartz conglomerate (XIV). This rock is rare, and may perhaps be regarded as a local garnetiferous variety of actinolite schist.

No. 152 (2686).—**Magnetic actinolite schist.** Closely related to No. 58. Compare Nos. 130, 59, 129, 153. Garnetiferous varieties? (which have been called eklogite) are 27, 151.

Loc. Bed XVIII? 625 N., 1150 W., Sec. 35, T. 40 N., R. 17 E., Wis., constituting a broad and, in places, highly contorted and altered belt of rock, with N. W.–S. E. trend. What appear to be pseudomorphs of hematite, which is sometimes changed into magnetite after the actinolite, are common. In No. 153, the change is complete, resulting in iron ore schist. The Breitung ore, Sec. 28, T. 39 N., R. 18 E., is lithologically the same, and may be in the same horizon.

No. 153 (3394).—**Actinolitic flag iron ore.** Compare 130, 152. A shining, coarse-grained, blue-black ore, with brown weathering. It splits into even thin flags with rough surfaces. The iron seems to be a pseudomorph after actinolite.

Loc. Upper Huronian. 1,400 paces N. and 2,000 W. of S. E. corner Sec. 27, T. 40 N., R. 17 E., Wis., in a test pit. It is the purest ore observed west of Lake Eliza, but the quantity was not made out. It may be regarded as a highly ferruginous variety of the actinolite schist of this district [152], which usually contains more or less iron.

No. 154 (3450).—**Granular specular iron ore.** Martite, massive, rich in iron. Iron pyrites occurs in parts of the deposit.

Loc. Bed XV. 250 paces N. and 1,750 W. of S. E. corner Sec. 32, T. 40 N., R. 18 E., Wis., on the Commonwealth Iron Co.'s land, and known as "Sec. 32" Mine of the Commonwealth range. This ore closely resembles the massive granular specular ores of the Marquette region, and is unlike any other one yet found in quantity in the Menominee region. It differs from the specular slate ore of the Cyclops Mine, Michigan, in being more slaty and finer grained. The association of chloritic schists and banded cherty schists is like the Marquette iron series.

No. 155 (2996).—**Kersantite mica trap** (Julien). Provisional name, greenstone schist. Compare Nos. 70 and 120.

Loc. Bed XVIII or XIX. 700 paces N. and 1125 W., S. E. corner Sec. 7, T. 38 N., R. 20 E., Wis. Belongs to the Big Quinnesec series, and to a large family of rocks, usually denominated greenstone or diorite schist. If Mr. Julien's provisional name be sustained by further examinations, it is probable that several specimens may be embraced under it, now included under diabase and greenstone.

After a preliminary microscopic study of a thin section, Mr. Julien says: "It consists of two minerals. 1st. Minute grains of colorless and clear feldspar, polarizing brightly with crossed nicols, and sometimes showing twin structure. 2nd. Predominates and is present in two forms, as bluish-green, irregular scales, decidedly dichroic, and also of fibrous blades of greenish shades of color, and colorless needles varying in size down to minute microlites. The latter appear to represent original blades of hornblende, but rarely display its strong dichroism. The green scaly mineral appears to be intermediate between biotite and chlorite. Apparently a mica trap."

No. 156 (2650).— **Granulated biotite schist** (Julien).

Loc. 1750 paces N. and 300 W. of S. E. corner Sec. 2, T. 39 N., R. 17 E., Wis. Several varieties of this schist occur at this point, forming a considerable bed associated with pyritiferous chlorite or clay slates. Actinolite schists occur to the west and greenstones east, the structural relations not being fully made out. At Sand Portage is a similar rock [2106] in or near this horizon.

No. 157 (2912).— **Augen-gneiss** (Julien). A variety of No. 146 which is supposed to be from same bed. Gray and typical in appearance. The mica is biotite, and the feldspar triclinic, with large and rare crystals of orthoclase, (Pumpelly).

Loc. Bed XVII. North side of upper basin at Big Quinnesec Rapids, near center of S. W. qr. of Sec. 7, T. 39 N., R. 30 W. Mich., constituting a variety of the gray gneiss which prevails here, and which is associated with chloritic varieties and hornblendic schist. A closely related rock, believed to be of the same horizon, is extensively exposed in an E.–W. belt across the center of Sec. 24, T. 39, R. 17 E., Wis. (146). This rock has no lithological equivalent in the Marquette series. Rocks believed to belong to this bed in its eastward prolongation are chloritic and sericite schists and gneisses. See general maps.

No. 158 (3200). — **Porphyrite** (Julien). Compare 158 to 162.

Loc. Peminee Falls, Sec. 17, T. 36 N., R. 22 E., Wis. This rare rock in the Huronian is believed to belong to one of the upper beds (XX ?), and is associated with granitiod rocks more or less porphyritic. No. 160 is closely related, and in all probability came from the granite bed XX. Neither having been found within the limits of the survey, could not be thoroughly investigated. Compare the porphyries Nos. 161, 162, from Buffalo and Baraboo, Central Wisconsin, described by Mr. Irving. See remarks under (160). This rock resembles in many particulars the characteristic porphyrite of Ilfeld, Germany.

After a preliminary microscopic study of a thin section, Mr. Julien remarks: "The minute scales in the base appear mostly brownish-green, and display strong dichroism, like biotite. The feldspar crystals are well marked and slightly altered, and are sometimes penetrated with long needles of amphibole. Under crossed nicols they display brilliant striations and evidently consist of a plagioclase-feldspar. In the base a few water-clear granules appear to consist of quartz."

No. 159 (3204). — **Porphyrite** (Julien). Compare Nos. 158 to 162.

Loc. Peminee Falls, Sec. 8, T. 36 N., R. 22 E., Wis. See remarks under 158.

After a preliminary microscopic study of a thin section, Mr. Julien says: The base differs from (3339) in the abundance of colorless microlites and needles. The green color of the chlorite scales is less conspicuous. Small crystals of an altered feldspar abound, sometimes twinned, always clouded milk-white by minute (kaolinic) inclusions. Their outlines are remarkably sharp, and in polarized light they display rather decidedly a system of parallel lines (twin-lamellation?).

No. 160 (3339). — **Porphyrite** (Julien). Compare Nos. 158 to 162. No. 101 from same horizon has been called granite.

Loc. Bed XX. 1500 paces W. of S. E. corner, Sec. 21, T. 42 N., R. 32 W., Mich. This is the uppermost Huronian rock, the eruptive (?) granite, 101. It is not established that the Peminee Falls rocks (158, 159) are of the same age, but it is probable. See remarks under porphyry in preceding chapter.

After a preliminary microscopic study of a thin section, Mr. Julien remarks: "Certain dark grains of irregularly rectangular form, visible in the section to the naked eye, seem to represent altered blades of hornblende, consisting usually of a mixture of decolorized and very minute scales of chlorite, and of particles and granules of brownish-red ochre; in one case a dark-green mass is thus produced, and exhibits dichroism. Under higher power the granules of the base appear often angular and of but a single mineral, probably feldspar."

No. 161.—**Black quartz-porphyry** (Irving). Observatory Hill, Buffalo, Marquette county, Wis. See Geol. of Wis., Vol. II, p. 519, Spec. 762.

No. 162.—**Red quartz-porphyry** (Irving). Baraboo Narrows, Sauk county, Wis. See Geol. of Wis., Vol. II, p. 513, specimen 1244. See remarks under (160). Prof. R. D. Irving assigns these porphyries, which occur in immense beds of several varieties, to the Huronian period. Their entire absence, so far as observed, in the Marquette and Penokee regions, their occurrence in small quantity and not typical in the Menominee region, and prevalence in Central Wisconsin, is interesting in connection with the great prevalence of related rocks in the iron-bearing Archæan of Missouri, showing a regular increase to the south.

CHAPTER V.

MICROSCOPICAL OBSERVATIONS

OF

THE IRON BEARING (HURONIAN) ROCKS FROM THE REGION SOUTH OF LAKE SUPERIOR.

BY ARTHUR WICHMANN, PH. D., LEIPZIG, 1876.

PREFATORY NOTE.

Under date January 22, 1875, Professor Zirkel wrote, in answer to my inquiries if he would undertake the microscopic investigation of the crystalline rocks for my survey, that it was impossible, on account of the U. S. 40th Parallel work then in hand. "But," he added, "my assistant, Dr. Wichmann, a young gentleman largely experienced in microscopic investigations, has expressed his readiness to undertake the work, under my control and revision. So you may send the thin-sections, and be quite sure they will be examined and described as carefully as possible."

It is unjust to Dr. Wichmann, who receives no compensation for his work, and unfortunate for the science of lithology, that the publication of his valuable paper has unavoidably been delayed so long.

All of the Wisconsin specimens collected in 1874, and over one thousand of the most interesting of my Michigan collection, including those described by Julien (Mich. Report, 1873, Vol. II), were in Dresden in 1875-6, and Dr. Wichmann saw them all. Thin sections were prepared from about five hundred specimens. My collection is now in Am. Museum of Nat. History, N. Y.

T. B. B.

I. THE MICROSCOPICAL STRUCTURE OF THE MINERALS CONSTITUTING THE ROCKS DESCRIBED.

§ 1. A. Quartz.

Quartz is the most widely spread mineral as a constituent of rocks. Microscopically it is very easily recognized. In a thin section, it shows a substance clear as water, in which many fissures may often be observed, but never the beginning of change into another mineral. Quartz appears in bright colors by polarized light. It is also characterized by the abundance of other enclosed minerals. Colorless needles of apatite are often found in it (Spec. 137), also folia of mica (Spec. 732), hematite (Spec. 1085), crystals of magnetite (Spec. 734), etc., and fine, long needles, called "microlites" (Spec. 1641). The numerous fluid-enclosures found in all specimens which contain quartz, are very interesting. These fill up a cavity in the mineral with a fluid, which consists of water, of a solution of salt, or of liquid carbonic acid. A bubble is always found in such fluid-cavities, which often moves rapidly, and then turns into fluid. By heating the object to about 31° Centigrade, such a bubble disappears, to appear again with its motion, when the quartz cools. It is beyond all doubt that in this case the fluid consists of carbonic acid (Specs. 1085, 137, 527). Cubes of *halite* could be observed in some fluid-enclosures (Spec. 2105), and then the fluid probably consists of a solution of this substance. The forms of the fluid-enclosures are mostly rounded and egg-like, but sometimes they are very irregular. Generally the fluid-enclosures are ranged in the quartz in rows like a string of pearls. Pores, often found in quartz without any fluid, are called "vapor cavities."

As a constituent of rocks, quartz does not appear in distinct, regular forms, but is always represented by irregular grains.

Quartz constitutes the following rocks: quartzite (Specs. 361, 732, etc.), siliceous schist (Specs. 1436, 1500), jasper schist (Spec. 1196), and chert schist (Spec. 1510).

As chief constituent it appears in granite (Specs. 1715, 1749), in gneiss (Spec. 1641, etc.), in the siliceous limestone (Spec. 1744), and in many crystalline schists, such as hornblende schist, mica schist, chlorite schist, etc.

It is observed in the diorite (Spec. 192), in the diabase (Spec. 827), in the syenite (Spec. 1720), etc., as an accessory constituent.

The quartz shows a peculiar constitution in the so-called "crystalline schist," usually constituting the ground-mass of the rocks. This aggregation is only recognizable in polarized light. Each irregularly-shaped grain appears of another color, for the individuals are mixed together, and their optical axes lie in different directions. The other constituents are imbedded in such a ground-mass.

§ 2. B. Feldspar.

Feldspar is abundant in the rocks of the Iron region. We distinguish, in relation to its physical properties, two varieties of feldspar: orthoclase (monoclinic-feldspar) and plagioclase (triclinic-feldspar). As we shall see in §§ 3 and 4, these two varieties are quite distinguishable by microscopical examination.

§ 3. a. *Orthoclase.*

Orthoclase appears as a chief constituent of granite, syenite and gneiss. As an accessory, it can be recognized in many other rocks. In general it forms distinct crystals, and twin-crystals are not unfrequent. These twin-crystals are formed according to the Carlsbad law, the plane of junction running parallel to the clino-pinacoid, and a line divides the crystal into two parts, which in polarized light show different colors.

The substance of orthoclase is seldom completely fresh and clear. We observe mostly the beginning of an alteration starting from the fissures, which cross the crystals in all directions. In these parts, the substance is dull and changed into a snow-flake-like aggregation, well observed by crossed nicols. The fresh and unaltered parts appear in bright colors in polarized light.

The red color of some orthoclases is probably due to oxide of iron. We observe in a thin section streaks and clusters of a reddish dust-like matter strewn through the colorless substance of orthoclase. Under a high objective this apparent dust dissolves into small granular individuals. Zirkel[1] expressed the opinion that these small grains are oxide of iron, and that they were formed simultaneously with the feldspar. They never occur in quartz which is associated with orthoclase, nor in the plagioclases which are associated with orthoclase.

The oldest rocks very rarely contain the glass-like, cracked variety of orthoclase, called "Sanidin." It was observed with all its characteristic properties, in the form of tabular crystals with lustrous faces in a diabase (Spec. 2072), where it was colorless, highly fissured, glass-like in appearance, and contained some vapor cavities.

In general, no fluid enclosure or vapor cavity is to be found in orthoclase, but needles and prisms of apatite, hexagonal folia of hematite, and needles of hornblende, etc., often occur. In the fissures, delicate membranes of hydrated oxide of iron, some viridite, etc., sometimes appear. In a gneiss (Spec. 944), small needles, which belong to an unknown mineral, were observed in the orthoclase, crossing one another at an angle of 60°.

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[1] Mikroskopische Beschaffenheit der Mineralien und Gesteine Leipzig, 1873, page 126.

In Spec. 192, orthoclase is associated with quartz, and is microscopically in appearance like "Lapis hebraicus."

In some hornblende-schists and rocks orthoclase forms the ground-mass, and then it appears in aggregations of irregular grains, sometimes mixed with grains of plagioclase. In many cases the beginning of alteration is recognizable.

§ 4. b. *Plagioclase.*

Plagioclase is, microscopically, very easily distinguished by its characteristic twin-lamellation. It appears principally as a rock-constituent in diorite, diabase, and diorite-gneiss, but it is also found in all rocks in which orthoclase is present, and then it is generally associated with the latter. Plagioclase comprises the triclinic feldspars, all of which contain silica and alumina; but one has, in addition, soda — a soda feldspar, another lime — a lime feldspar, and others both soda and lime. The physical characters of these varieties are generally so alike that they are not distinguishable by them, nor by a microscopical examination (their inclination to form twin-crystals characterizing them all), and therefore only a chemical analysis can determine whether a given triclinic-feldspar is albite, labradorite, or anorthite, etc. According to the theory of Tschermak,[1] all varieties of the triclinic-feldspar are only to be considered as mixtures in different proportions, and this fact is easily explained. In consequence of this, the name "plagioclase" is always used.

In the different rocks, plagioclase forms well-shaped crystals, mostly in the form of small rods. The crystals are also sometimes tabular. Irregular grains of plagioclase appear in a diorite-gneiss, the outlines of which depend upon the associated minerals.

In opposition to orthoclase, the plagioclases are characterized by a twin-lamellation, where the plane of junction is the brachy-pinacoid $\infty \breve{P} \infty$. This twin-lamellation is often to be recognized under the microscope in common light by its parallel lines, and in polarized light the laminæ always show different colors. No other mineral is characterized by a twin-lamellation of such a color. The single laminæ are often only 0.001 millimetre in breadth, and a crystal is sometimes composed of 30 and more, of such laminæ. This twin-lamellation always appears if the section is cut at any angle to the brachy-pinacoid.

A second law of twin-crystallization is known especially in labradorite. The plane of the junction is the base oP. and this law is called the "Pericline-law." These two above-named laws appear in combination, and so we observe two systems of twin-lamellation crossing one another at an angle of 86° 40′. This phenomenon is clearly seen in grains occurring in a siliceous limestone (Spec. 1744).

A triclinic feldspar, which occurs in a dolomite from Pine Creek, Michigan (Spec. 1626), is probably albite, for this variety is also often seen in such rocks of other countries.[2]

The plagioclase in granite, syenite and gneiss, is considered to be oligoclase. There, it forms well shaped crystals, or irregular grains. In most cases it only represents an accessory constituent. Orthoclase and oligoclase have often been found grown together, and then the plane M. is mutual if the main axes are parallel. These two feldspars are always distinguishable by an examination with crossed nicols.

Plagioclase is a chief constituent in diorites and diabases, where it always appears in the form of rod-like crystals, partly as oligoclase, and it may also occur partly as labradorite.[3]

Enclosures are not frequent in plagioclase. Fluid enclosures have not been recognized. In some places small black needles, some folia of hematite, small prisms of apatite, etc., are microscopically perceptible.

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[1] Sitzungsberichte der Wiener Akademie, Dec., 1864.

[2] Zirkel, Lehrbuch der Petrographie, 1866, Vol. I, page 237.

[3] Foster and Whitney's Report, part II, page 92. Michigan Geological Survey, chap. III, page 101.

In consequence of the decomposition, the twin-lamination is not always recognizable in polarized light. Sometimes the alteration has reached a state where no twin-lamellation is observed. The decomposition starts from fissures which cross the crystals. Its beginning is also recognizable on the lines which represent the plane of junction of the twin-crystals. In diorites and diabases, plagioclase often seems to have been changed into viridite.[1]

§ 5. C. Mica.

Muscovite, a potash mica, and biotite, a magnesia mica, are the two members of the mica group which usually appear as constituents of rocks. In general, these two species are plainly discernible by a microscopical examination, but it is uncertain whether other members of this group occur in the rocks of the iron region.

§ 6. a. *Muscovite.*

Bi-axial mica, muscovite, forms colorless folia and scales, which appear in bright colors in polarized light, in whatever direction the section may be cut. In sections parallel to the cleavage plane, muscovite generally appears as irregularly shaped folia, showing sometimes rhombic forms. This species chiefly constitutes some mica schists (Specs. 2239, 2222, 442, 1085, 2225), but those composed of biotite are more frequent. Small laminæ of muscovite appear as an accessory in gneisses (Spec. 1641), magnesian-mica schists (Spec. 2255), hornblende schists, etc. In association with biotite, beautiful and characteristic folia of muscovite were observed in a chlorite schist of Spurr mine (Spec. 729). The muscovite is always very fresh and clear, with no enclosures.

§ 7. b. *Biotite.*

Uni-axial mica. Biotite is abundant in the rocks of the iron region. It generally appears in the form of dark-brown folia, characterized by its very strong dichroism when tested by a single nicol's prism. These folia are ragged and irregularly shaped. In a section parallel to the main axis, biotite is composed of parallel laminæ, which are fringed at the ends. Now and then they are accompanied by magnetite. When a lamina lies parallel to the base, no dichroism is recognizable, and, in polarized light, darkness will occur. Biotite constitutes many mica schists (Specs. 1100, 2087, 2212, etc.). As a chief constituent it appears in gneiss (Spec. 146), granite (Specs. 1715, 1749), micaceous limestone (Spec. 21), micaceous quartzite (Spec. 732), micaceous augite schist (Spec. 1170).

As an accessory, it is observed in diorite (Spec. 3075), syenite (Spec. 1409), diabase (Spec. 1501), chlorite-schist (Spec. 729), hornblende schist (Spec. 3029), etc. In consequence of this fact, we may say that biotite is to be found in nearly all rocks. Biotite is enclosed sometimes in quartz, augite, hornblende, etc., and, with the latter mineral, is often grown together. While muscovite has never been observed in a state of decomposition, we sometimes find biotite altered and changed into viridite. This is the case in some diabases, while in the crystalline schists it always appears fresh and unaltered.

§ 8. D. Sericite.

Sericite occurs in the form of twisted scales with a fibrous structure. Its color is a grayish-white, and the folia are sometimes nearly colorless. The dichroism is very feeble and generally not perceptible. In relation to its chemical composition, sericite is very similar to muscovite, but in relation to its microscopical structure, these two minerals are different. The scales of sericite are often arranged in clusters, and form a felt-like mass. Sericite composes chiefly the sericite-schists (Specs. 2071, 2077).[2]

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[1] See § 64.

[2] See § 118.

§ 9. E. Talc.

Talc consists of white fibrous scales and folia. Aggregations of such scales compose the talcy-schists. No distinct crystals appear. The structure of its individuals is generally a very fine, scaly one. The scales are often fringed at the ends. Talc composes principally the talc-schist (Spec. 3074).

§ 10. F. Amphibole.

Among the minerals which belong to the amphibole group, actinolite and hornblende are of the first importance in relation to the composition of rocks. The other varieties represent, for the most part, only accessory constituents. All members of this group crystallize in monoclinic prisms at an angle of 124° 30′.

§ 11. a. *Tremolite.*

This variety was only observed in a limestone (Spec. 2086, see § 35).

§ 12. b. *Actinolite.*

Actinolite composes especially the actinolite-schist, but also occurs as a constituent of some other rocks. Its individuals are partly visible to the naked eye, and they are only partly perceptible under the microscope. In a section parallel to the main axis, actinolite represents long colorless, or nearly colorless prisms, the ends of which, owing to the prisms protruding unequally, are ragged and uneven, having somewhat the appearance of a fringe. Sections cut perpendicularly to the main axis are not frequent, but show perfectly the characteristic angle of 124° 30′ made by the two prism faces. The crystals of actinolite are formed very simply, only the prism ∞ P, is observed.

The prismatic cleavage, which is very characteristic in the members of the amphibole-group, is not expressed in the actinolite fissures intersecting each other under the prismatic angle, as in hornblende. Sometimes twin crystals of actinolite are seen even in microscopic individuals. The plane of junction is parallel to the ortho-pinacoid, and is characterized by a line, which divides the crystal into two parts, which in polarized light show different colors. This line is not always straight (Spec. 2240). The absorption of light is very feeble, and in general not recognizable when tested with a single nicols prism.

Actinolite contains few enclosures. Now and then some grains and octahedra of magnetite appear, also small crystals of zircon and brown folia belonging to an unknown mineral (Spec. 2198), which Rosenbusch[1] also observed in an actinolite from Pontresina.

Actinolite composes the actinolite-schists (Specs. 2198, 2238, 221, 1116, 1155, 308), but only Specs. 2198 and 2238 are typical, whilst the other specimens have not preserved their character, in consequence of the admixture of other minerals.

We find actinolite as a chief constituent of eklogite (Specs. 3027, 109) in which it appears in association with garnet and magnetite. As a constituent of magnetic schist, it appears in Spec. 2240, and of limonite in Spec. 222. It seems that actinolite is microscopically also abundant in the ore beds of other countries. In a quartz-schist (S. E. of old Washington Mine, Spec. 1088), beautiful crystals of actinolite occur.

In all these specimens Brush has proved the existence of this mineral, and named it "anthophyllite," except in Specs. 2198 and 2238. According to my investigations this mineral cannot be identified with anthophyllite. Microscopically, the latter named mineral[2] is characterized by a brown color, is dichroitic and fibrous. It contains many brown needles which lie parallel to the main axis. There occur many specimens of anthophyllite which are similar to hornblende, but not to actinolite. Finally anthophyllite crystallizes in orthorhombic, and actinolite in monoclinic-prisms.

[1] Physiographie, page 308. Strassburg, 1873.

[2] Rosenbusch, Physiographie, 1873, p. 263. Tschermak, Mineralog. Mittheilungen, 1871, Vol. I, p. 37.

§ 13. c. *Hornblende.*

In general we distinguish two varieties of hornblende: the common hornblende, which is of a green color, and the basaltic hornblende, which is brown. In these rocks only the common variety occurs. In thin sections, parallel to the main axis we observe a striation parallel to it, similar to sections of biotite. To mistake the one for the other, however, is not possible, for the optical principal sections of these two minerals have a different position. The ends of the prisms are generally ragged and uneven. Sections cut perpendicularly to the main axis are characterized by many fissures corresponding to the prismatic cleavage of the hornblende, parallel to the prism ∞ P., showing perfectly the characteristic angle of 124° 30′, while the angle made by the two prism-faces of augite is 87° 6′. A very good criterion for hornblende is its strong dichroism, which augite never shows, or only very feebly.

Tschermak was the first who called attention to this property.[1] If a dichroscopic loupe is placed on the ocular and turned till the difference between the two images has reached the maximum, the hornblende always shows two very different colored images, while augite shows images differing very little in color. Instead of the dichroscope we can make use of one of the two nicols prisms, and then we observe the tones of color, one after another, by turning it. The use of the lower prism is to be preferred. The nearer the section is parallel to the plane of symmetry, the more remarkable is the dichroism. When hornblende is pale green, its dichroism is very feeble. With regard to the dichroism, hornblende might be mistaken for biotite and tourmaline, but these two minerals become nearly black, when tested by a single nicols prism — and besides this, the directions of their optical principal sections are different.

Hornblende occurs as a constituent of different rocks in the form of well defined crystals, or in crystalline aggregations. In sections perpendicular to the main axis we observe not only the prism ∞ P., as is the case with actinolite, but mostly the clinopinacoid ∞ P ∞ appears, and sometimes also the orthopinacoid ∞ P ∞. For the most part the individuals of hornblende are not sharply defined at the ends, which have somewhat the appearance of a fringe, especially in the schistose rocks.

Hornblende, unlike augite, has much more inclination to form microlites. These microlites then run through the whole rock in the form of fine single needles, or they compose irregular aggregations. Some hornblende-schists consist nearly entirely of aggregations of such microlites (spec. 2051). In some diorites the crystals of hornblende are composed of such small needles.

In some rocks the individuals of hornblende contain numerous inclosures. The occurrence of water-clear prisms and hexagons of apatite, which pierce the crystals of hornblende in every direction, is remarkable. Magnetite appears in irregular grains, or in the form of distinct octahedra. When associated with hornblende, biotite always appears in the form of brown folia.

Hornblende composes the hornblende-schists and rocks. As a chief constituent it appears in syenite (Specs. 1409, 1724, etc.), diorite (Specs. 464, 37, etc.), hornblende-gneiss (Specs. 1757, 1762, 2211, etc.). As an accessory, we observe hornblende in mica-schist (Spec. 2212), and in diabase (Spec. 884), etc.

§ 14. G. Pyroxene.

Pyroxene crystallizes in the monoclinic system with a prism of 87° 6′. Among the members of this group, augite and sahlite are especially observed in the rocks of the Iron region of Lake Superior, as constituents. These minerals are generally only to be determined by the aid of the microscope, and therefore it is easy to explain why they have not been observed heretofore in the rocks of that region.[2]

[1] Sitzungsberichte der Wiener Akademie, 59, 1869, p. 1.

[2] See the notes of Julien, Mich. Geol. Survey, Vol. II, p. 193. 1873.

§ 15. a. *Augite.*

In the different rocks, augite forms mostly distinct crystals. In a section perpendicular to the main axis we always observe the characteristic angle of 87° 6′ made by the two prism faces. Its imperfect prismatic cleavage is expressed by indistinct fissures in contrast with hornblende, which is characterized by its distinct cleavage. Twin crystals are microscopically abundant, and the orthopinacoid $\infty P \infty$ is the plane of junction. They are only recognizable in polarized light, and then the two parts of the twinned crystal show different colors. Augite is of a yellowish-green or pale-green color, showing very little or no dichroism.

Augite in association with plagioclase, composes diabase, a rock which is abundant in the Iron region. As an accessory it appears in some diorites (Spec. 37, etc.). In association with biotite and quartz, it forms an augite-schist, at the Champion mine (Spec. 1170). In this rock augite is represented by irregular individuals, which sometimes are twinned (see § 153).

Augite gives rise to some secondary minerals. In the diabases we observe in its fissures the beginning of a change into a fibrous mineral called viridite. Sometimes the alteration has reached a state in which augite is no longer recognizable. But sometimes a change from augite into hornblende is observed (see Uralite, § 17).

§ 16. b. *Sahlite.*

Sahlite belongs to the group of lime-magnesian-iron pyroxene,[1] and was proved microscopically by Dr. Kalkowsky, a short time ago, to be a constituent of Archæan rocks.[2] It is therefore interesting to observe that this mineral is also found in the Huronian rocks of Lake Superior.

Kalkowsky first mentions its occurrence in the hornblende-schists of Silesia. Sahlite there appears in the form of small, thin prisms, with pyramidal ends, and passing by gradual transitions into thicker ones. Many individuals are irregularly shaped. In the larger prisms, and grains, a basal cleavage is recognizable. Besides the basic cleavage, a cleavage parallel to the orthopinacoid is also characteristic of sahlite. The size is very variable. The microlites are 0.05 millimetre in length, and .007 millimetre in breadth. Those individuals which occur as delicate membranes on the schist-plane are mostly 0.05 millimetre in length.

In a thin section sahlite is colorless or of a pale-green color. It never shows any absorption of light or dichroism, but is highly refracting, and in consequence of this it appears with bright colors in polarized light. Sahlite is with difficulty fusible by the blow-pipe. With a solution of cobalt it does not assume a blue color. With fluxes it gives reaction for iron. Its chemical analysis shows a considerable amount of magnesia and lime, and second to these, iron and traces of alumina.

Sahlite is generally fresh and unaltered, but in some rocks it is dull in appearance, and a little decomposed. Fluid-enclosures are not unfrequent, but very small. Minerals are not enclosed in sahlite, but it is often enclosed in feldspar, and also in quartz and hornblende. It occurs especially in association with hornblende and chlorite, but without these minerals in quartzite (see Spec. 2083).

In gneisses sahlite is mostly observed in the form of small rods; those which are intermingled with quartz appear in the different rocks in the form of irregular grains.

Kalkowsky proved sahlite to be a constituent of the gneisses and hornblende-schists from Silesia, of gneiss from St. Gotthard, of quartzite from Haslau, near Eger, in Bohemia, and of hälleflinta from Dannemora in Sweden.

I observed sahlite in some gneisses, mica-schists, hornblende-schists and granite.

[1] Dana, A System of Mineralogy, 5th ed., p. 115.
[2] Ueber den Salit als Gesteinsgemengtheil, Tschermak Miner. Mitthlg., 1875, p. 45.

§ 17. H. Uralite.

Uralite is a mineral possessing the physical properties of hornblende, but showing the forms of augite. It is a metamorphosed augite. The individuals of hornblende lie parallel to one another and to the main axis of augite.

Although uralite is rare in occurrence in the rocks which have been examined (I observed it only in Specs. 37 and 464), it may be mentioned in this place. It is remarkable that uralite could not be determined in any of the diabases. In these rocks augite is always present in a state of change into viridite.

Specs. 37 and 464 are diorites containing accessory crystals of augite which show distinctly the change into hornblende, and are in a word uralite.

Under the microscope the original forms of augite are distinctly recognizable. The interior of the crystals also consists of augite. The outlines of the individuals have been changed into hornblende, which consists of small needles. These aggregations of needles pierce the augitic substance and change it gradually into a hornblendic one.

§ 18. J. Epidote.

Epidote occurs as a constituent of some diabases, and is often observed in syenite. It is not an original mineral, but is formed in consequence of the decomposition of augite or hornblende. Epidote appears in the form of yellowish-green grains, which sometimes are clustered together. Generally no distinct forms are perceptible, but the characteristic basic-cleavage is always to be recognized. Its dichroism is not very strong. Spec. 1724.

§ 19. K. Chlorite.

Chlorite is characterized by its pale-green and bluish-green color. In the rocks examined, it appears only in the form of folia or scales. It is very variable as regards its optical proprieties, some folia showing a distinct dichroism, while this is not observed in others. This fact may be dependent on the position of these folia in the schists, for if a scale or lamina is cut parallel to its base, no dichroism can be recognized, also by crossed nicols darkness will occur in this case. If a lamina is cut parallel to the main axis, dichroism will be very distinct, and by the crossed nicols colors of polarization will occur. Rosenbusch[1] has expressed the opinion that bi-axial chlorite is present as a constituent of some rocks.[2] This fact is difficult to establish, for the individuals are very small, and, therefore, it is not easy to determine whether a lamina has been cut parallel to its base. Besides, they occur mostly with quartz, which mineral appears with bright colors in polarized light.

Chlorite composes especially the chlorite schists, which, in their typical specimens, represent aggregations of folia of chlorite (Spec. 729). Chlorite is chiefly imbedded in a quartzose groundmass. As a principle constituent it is found in chlorite gneiss (Spec. 3003), in chloritic quartzite (Spec. 432), and in mica schist (Spec. 2254). In our hornblende schists no chlorite is found.

The "chloritic" constituent of greenstones does not belong to this mineral, for a great difference is remarked with regard to its physical properties and its chemical constitution.

§ 20. L. Olivine.

Olivine is only present in serpentine and some diabases, according to my investigations (see Specs. 876, 1247, 3078, § 59).

Microscopically olivine is easy recognizable. Its substance appears in thin sections of a pale-green color, or it is colorless. Between crossed nicols it appears with bright col-

[1] Physiographie, page 241.

[2] The general impression is that the rock constituting chlorite is uni-axial and hexagonal.

ors. The rough surface, which this mineral always shows, is very characteristic. In consequence of this fact, olivine can be readily distinguished from other minerals. The individuals of olivine are always highly fissured. These fissures traverse the crystals in every direction, and from them a change takes place into serpentine. Olivine is the most decomposable of minerals, and the different varieties of serpentine are especially the results of its change.

§ 21. M. Calcite.

Calcite is colorless in appearance and forms in general irregular grains. The larger ones are always twinned, and in polarized light they show a distinct twin-lamellation. The rhombohedral cleavage is also recognizable. The smaller grains show generally no twin-lamellation, and in this case they are not distinguishable from those of dolomite. In polarized light the grains of calcite are milky-blue in appearance.

The limestones are composed chiefly of calcite (Spec. 1744, etc.) In dolomite (Spec. 795) its grains are to be recognized by the characteristic twin-lamellation.

In mica-schists and hornblende-schists calcite sometimes forms the groundmass, and it then consists of an aggregation of irregular grains (Specs. 1100, 1724).

Calcite is often present in diabases where it is mostly the result of the decomposition of augite. The lime of augite has been formed into calcite, while the other elements have induced the formation of viridite. This calcite has been deposited in the cavities of the rock. There are instances in which calcite appears to occur as an original constituent in diorite, diabase and syenite.

§ 22. N. Dolomite.

Dolomite constitutes especially the rock "dolomite" and is also present in some limestones. It forms small irregular grains, which are never twinned. Rhombohedral cleavage does not often appear. Rhombohedra of dolomite are present in some veins of quartz which cross the dolomite rock. In other rocks no dolomite could be found.

§ 23. O. Apatite.

In sections parallel to the main axis, apatite forms long, colorless needles and prisms. In cross sections the crystals show distinct hexagonal forms. Apatite pierces other minerals, and is found especially in quartz, feldspar, and hornblende (Specs. 1409, 1724, etc.). Sometimes the center of the prism is filled with a dust-like substance (Spec. 1453).

The brilliant appearance and the distinct forms of crystallization are characteristic, and by these properties apatite is easily recognized.

§ 24. P. Garnet.

In thin sections garnet forms irregular grains, which are of a light-red color, or colorless, and brilliant in appearance. The crystals are mostly rounded and imperfectly formed, though regular hexagonal and rectangular forms are sometimes perceptible, and both of these forms comport themselves in polarized light as perfectly isotropic bodies.

The individuals are highly fissured and enclose different minerals, such as magnetite, hornblende, etc. The surface of the sections of garnet is rough.

Garnet is a chief constituent of eklogite (Specs. 1091, 3027), forming sharply defined, rhombic dodecahedra, or irregular grains. They contain numerous needles of actinolite, and crystals of magnetite.

As an accessory garnet occurs in quartzite in the form of rounded grains of a pale red color (Spec. 1722); it is also present in hornblende schist (Spec. 2201).

The substance of garnet is mostly fresh and unaltered, only in its fissures has a change sometimes taken place. This fact is evident in polarized light. Between crossed nicols darkness occurs, for garnet is isotropic, but along the fissures a play of colors is observed; the alteration products are probably small scales of chlorite.

The excellent pseudomorphs of chlorite after garnet, occurring in the Spurr Mountain Iron Range, have been described by Pumpelly.[1]

Finally we may mention the occurrence of a metamorphosed garnet-rock (Spec. 2189). The greater part has been changed into actinolite.

In a thin section of this rock, only traces of garnet are recognizable; the other part consists of actinolite. A gradual transition of the latter mineral into the former is not observable. The individuals of actinolite represent fibrous, radiated, and ice-flower-like aggregations composed of single fine needles. A glance at a section shows that the change has taken place from an attack on the garnet from the outside. The crystals of actinolite penetrate the substance of garnet, and in this manner, going from without into the interior, the garnet will finally be totally changed.

§ 25. Q. Zircon.

Not long ago there were observed under the microscope in the granulites of Saxony,[2] and in the eklogites from Fichtelgebirge in Bavaria, small brownish-yellow needles and prisms which Dr. Zirkel thought might belong to zircon. This opinion is probably correct, as Sandbergen[3] had already determined zircon with the naked eye in eklogite from the Fichtelgebirge.

These prisms appear to belong to the tetragonal system, and are terminated by a pyramid. Twin-crystals are not unfrequent. Often the individuals have been crippled. This mineral refracts light strongly, and this fact is in accordance with the opinion expressed by the high authority alluded to on the refraction of zircon.

I observed this mineral in the form of well-shaped prisms in actinolite-schist (Spec. 2198), in mica-schist (Spec. 2222), in talc-schist (Spec. 3074), in chlorite-schist (Spec. 137), in granite (Spec. 1749, etc.).

According to a note by Dr. Zirkel,[4] zircon is abundant (microscopically) in the Archæan schists of the territories of Nevada and Utah.

§ 26. R. Tourmaline.

Tourmaline has been observed microscopically only in one specimen (from the north of the Dead river);[5] nevertheless this mineral is microscopically widely distributed through many of the schistose rocks.

In thin sections, tourmaline appears in the form of long or short prisms of a bluish-gray color. The extraordinary strong dichroism is very characteristic. The ends of the prisms show the basic-pinacoid or a rhombohedron, if the crystal be not broken at that place. Sometimes the individuals show a distinct hemimorphism. In this case the basic-pinacoid appears at one end, and a rhombohedron at the other. This fact has already been established by Dr. Auger.[6]

Distinct crystals of tourmaline are abundant in some clay-slates (Spec. 2067). The individuals have been generally broken into several pieces, but the pieces of each crystal are generally found near together. The basic cleavage is recognizable. The occurrence of tourmaline within the clay-slates seems to be of importance, for probably they may represent the crystalline constituent instead of the "clay-slate needles," which are abundant in Devonian and Silurian clay slates.

Numerous individuals of tourmaline appear in sericite-schists (Spec. 2077), in chlorite-schist (Specs. 3055, 2082), in mica-schist (Specs. 2162, 2239), in talc-schist (Spec. 3074), etc.. They are present also in actinolitic-quartzite (Spec. 1088.)

[1] American Journal of Science and Arts, Vol. X, July, 1875.
[2] Mikrosk. Beschaffenheit der Min. u. Gest., 1873, p. 466.
[3] Neues Yahrbuch f. Min., etc., 1867, p. 476.
[4] N. Yakrb. f. Min., 1875, p. 628.
[5] Mich. Geol. Survey, Vol. II, p. 195.
[6] Tschermak, Mineralog. Mittheilungen 1875, p. 163.

§ 27. S. Titanite.

Titanite is observed as an accessory constituent of hornblendic rocks; it appears especially in syenite.

In thin sections, titanite is characterized by a yellow or yellowish-brown color. Its substance is often not very transparent, having an almost pearly appearance; but it is always free from any enclosure, and, in general is highly fissured. The monoclinic crystals are mostly of a wedge-like form, and, in consequence of this, easily recognizable.

Good crystals of titanite appear especially in syenite (Spec. 1720)

§ 28. T. Magnetite.

The greater part of the small, black grains, which appear in the different rocks, belong to magnetite. This mineral forms either sharply defined octahedra, or irregular opaque grains. The octahedra compose sometimes fine aggregations consisting of joined lines. Such aggregations appear in some diabases, but not frequently in schists (Spec. 2254). The irregular grains are also abundantly dispersed throughout many rocks, or grouped together in clusters.

Although magnetite is readily soluble in acids, it is mostly fresh and unaltered. Sometimes, the single crystals and grains are surrounded by a brownish amorphous substance, which is hydrated oxide of iron, and results from the decomposition of magnetite.

In association with quartz or other minerals, magnetite composes the magnetite-schists (Specs. 80, 1741, 2240).

It is a chief constituent in magnetic quartzite (Spec. 734), in magnetic mica-schist (Spec. 1101), in eklogite (Spec. 3027), etc. As an accessory, magnetite is found in most rocks, especially in gneiss, granite, syenite, diabase, diorite, hornblende-schist, etc.

§ 29. U. Hematite.

Hematite is microscopically characterized by pale-red, blood-red or blackish plates, which generally are hexagonal in form. The different colors depend on the varying thickness of the plates and folia. Sometimes these folia are irregularly shaped and then, whenever they are opaque they are with difficulty distinguishable from magnetite.

In hematite-schist (micaceous-iron-schist, Spec. 3016), the constituents are mostly not transparent, but distinct hexagonal forms often appear.

In feldspar and quartz, folia of hematite are inclosed, and are mostly of a blood-red color; also in syenite (Spec. 1409), in mica-schist (Spec. 185), in hornblende-schist (Spec. 3076) and in diabase (Spec. 3076).

§ 30. V. Titanic iron.

Titanic-iron forms tabular crystals in sharply defined hexagonals, or in narrow rods. Sometimes the individuals appear in irregular forms. It is always opaque, and therefore sometimes not distinguishable from magnetite, and hematite. In such circumstances it is necessary to etch the section with hydrochloric acid; magnetite and hematite will be dissolved, while titanic-iron will not be affected.

Sometimes fine aggregations of titanic-iron appear, repeating in their forms the hexagonal crystals (Spec. 310).

Very often it is changed into a grayish-white substance. By this peculiarity titanic-iron is unmistakably recognized, for neither magnetite nor hematite show such a form of decomposition. This grayish-white substance, which is not amorphous, surrounds the grains and crystals of titanic-iron, and sometimes only a trace of the original mineral is left intact. The forms of crystallization are always recognizable. The chemical constitution of this grayish-white substance is unknown up to this time. We will return to this mineral in § 69.

§ 31. W. Limonite.

Microscopically observed, limonite represents a brownish-amorphous substance. It composes principally the limonitic ores (Specs. 222, 542, 549, etc.), in which it sometimes appears in association with quartz, actinolite, etc.

It often happens that it is the result of decomposition of magnetite, and in that case limonite surrounds the individuals of the former mineral.

Further, limonite is to be found in many rocks, where it appears in the fissures, and there forms delicate brownish membranes. But it is a mistake to suppose that the cavities within the rocks are filled with this substance.

§ 32. X. Pyrite.

Pyrite, microscopically observed, forms irregular grains or isometric crystals, which in the latter case appear in the form of cubes. This mineral is recognizable in reflected light, by its metallic luster, and its brass-yellow color. In the different rocks it is only present as an accessory constituent. Sometimes the cubes or grains are surrounded by a brownish hydrated oxide of iron, which results from the decomposition of pyrite. We observed this mineral in syenite (Spec. 1724), in diabase, and in clay slates.

II. DESCRIPTIVE LITHOLOGY.

§ 33. A. Non-fragmental rocks.

This class of rocks was formerly named "crystalline rocks," but in consequence of the fact that many of them contain an amorphous, non-crystalline substance, Dr. Zirkel[1] proposed the name "non-fragmental rocks." The Huronian rocks of the iron region of Lake Superior belonging to this class, all show a crystalline structure, with the exception of some diabases.

The non-fragmental rocks may be classified as follows: a. *simple rocks*—limestone, dolomite, quartzite, magnetite-schist, hematite-schist, serpentine; b. *massive rocks*—granite, syenite, diorite, diabase; c. *schistose rocks*—gneiss, mica-schist, hornblende-schist, chlorite-schist, augite-schist, talc-schist, sericite-schist and eklogite.

§ 34. 1. Limestone.

Pure limestone consists of an aggregation of grains of calcite, but generally it contains accessory minerals, such as quartz, mica, dolomite, magnetite, etc. According to the size of the grains we distinguish granular limestone (marble) from compact limestone. Limestones are more or less dolomite in the iron region of Lake Superior.

§ 35. a. *Granular Limestone.*

Spec. 2086. Bed X. Mich., T. 42 N., R. 30 W., Sec. 24, 800 N., 600 W.,[2] Menominee region.

The granules of calcite are irregular and always twinned. Besides the twin-lamellation, the rhombohedral cleavage is in general quite recognizable. The twin crystals are formed according to the well known law in which the plane of junction is the rhombohedron —½ R, which occurs in all granular limestones. In polarized light the different laminæ generally appear with different colors. The position of the twinned laminæ is independent of that in the neighboring grains. The individual laminæ are of 0.03 millimetre in length, and of 0.01 millimetre in breadth. The presence of numerous fluid enclosures, in some granules, is remarkable.

[1] Mikrosk. Beschaffenheit der Min. & Gesteine, p. 290, 1873.

[2] Such expressions as "800 N., 600 W.," mean 800 steps north and 600 steps west from the S. E. corner of the section, that being the uniform method of noting locations adopted by Messrs. Brooks and Wright.

Aggregations of small irregular grains of dolomite, which are not twinned, occur. Tremolite is recognizable with the naked eye. The colorless individuals are striated parallel to the main axis. Irregular fissures cross the substance in every direction. In the fissures we observe the beginning of alteration into a fibrous mineral. Sharply defined crystals of tremolite are not present. Magnetite presents itself in the form of octahedra, or irregular grains; we also observe water-clear particles of quartz, with strings of fluid enclosures. In some places, films of hydrated oxide of iron are recognizable.

§ 36. b. *Siliceous limestone.*

Spec. 1744, Bed V?, Mich., T. 43 N., R. 31 W., Sec. 4, 2000 N., about 1200 W.

This is a limestone which contains numerous granules of quartz. The two minerals (quartz and calcite) are present in nearly equal quantities. By a gradual addition of quartz, a quartzite would finally arise. T. B. Brooks says, in his paper on the lithology of the iron region of Lake Superior:[1] "The association of this rock (marble) with the lower quartzite, or rather the transition of the latter into marble, has been mentioned. This transition is seldom complete, the marble being always more or less siliceous. As is usual in such cases, the change is gradual, producing all varieties, from calcareous quartzite to siliceous marble."

The water-clear quartz-grains are filled with many fluid enclosures. They are generally composed of an aggregation of smaller grains, a fact only recognizable between crossed nicols, where the individuals which compose the quartz-grains appear in different colors. The sharply-shaped rhombohedra of calcite which occur in the quartz are remarkable. This is a proof that calcite and quartz have been formed at the same time.

Calcite appears in the form of irregular grains, which everywhere show the characteristic twin lamellation.

The presence of numerous grains of feldspar is very interesting. It seems to be mostly triclinic, and is probably labradorite. The individuals are twinned according to the Albite-law, and Pericline-law. With the former, the brachypinacoid is the plane of junction, and, according to the latter, the base. In consequence of this, we observe two systems of twin lamellation, crossing at an angle of 86° 40′ (see § 3).

§ 37. c. *Micaceous limestone.*

Spec. 21. Mich., T. 47 N., R. 28 W., Sec. 13, S. W. qr of N. E. qr.

This fine-grained rock appears, to the naked eye, of a dark-gray color, and glistens with facets of calcite.

The larger grains of calcite show perfectly, under the microscope, the characteristic twin-lamellation. The smaller ones are irregular, and no twinned individuals are to be recognized. In this case, they are not to be distinguished from those of dolomite.

Numerous folia of brown biotite are imbedded in the rocks, always showing a strong dichroism when tested with a single nicol's prism. They are often aggregated in clusters.

Titanic-iron is frequent in occurrence. It forms irregular opaque grains, which are generally surrounded by the known grayish-white substance, by which this mineral is everywhere recognizable.

§ 38. 2. Dolomite.

In general the dolomitic rocks are characterized by the same microscopical structure as limestones. They consist of an aggregation of small irregular grains of dolomite. Chlorite and quartz occur as accessory constituents.

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[1] Mich. Geol. Survey, Vol. I, p. 109. 1873.

§ 39. a. *Dolomite.*

Spec. 795. Chocolate marble quarry, S. of mouth of Carp, L. S. Spec. 1635. Bed V, Mich., T. 39 N., R. 20 W., Sec. 7 (?).

Dolomite and limestone are not easily distinguishable by the naked eye. But, although dolomite and calcite crystallize in nearly the same forms, they show in general, under the microscope, different characteristics. Tnostranzeff[1] was the first to observe that calcite, whenever it appears as a constituent of rocks, shows the characteristic twin-lamellation, while dolomite only forms simple—untwinned—grains. In consequence of this fact, the variable quantity of lime in dolomite is explicable, and also the occurrence of the different proportions of magnesia to lime. Dr. Zirkel[2] remarks the fact, that in compact limestones calcite does not show any twin-lamination, and, therefore, in such cases, dolomite and limestones are only to be recognized by a chemical analysis.

In these specimens calcite can be easily recognized. The irregular grains of this mineral are mostly aggregated.

Dolomite forms small, irregular grains, but sometimes, I observed in cavities of the rock, distinct rhombohedra characterized by a zonic formation. The different zones are limited by hydrated oxide of iron (Spec. 795). Black particles of coal are also present in Spec. 795.

§ 40. b. *Siliceous dolomite.*

Spec. 797, Chocolate marble quarry. Spec. 1626, Mich. Bed V, T. 39 N., R. 29 W., Sec. 11, E. ½, Pine creek.

The individuals of dolomite appear in the same forms as we have mentioned in § 39. Calcite is less abundant than in the before-named specimens.

Quartz appears in very small grains, which are disseminated throughout the whole rock. It also occurs in the form of small veins, which cross the rock in every direction. These veins consist of an aggregation of small grains, as is to be seen in polarized light. In the quartz are numerous fluid enclosures; we also observe sharply defined rhombohedra, which doubtless belong to dolomite.

In Spec. 1626 a triclinic feldspar was recognized, which, as we mentioned before (see § 4), may be albite, a mineral which occurs elsewhere in dolomites.

§ 41. 3. Quartzite.

Quartzite is one of the most abundant rocks in the iron region of Lake Superior.[3] It consists generally of a compact aggregation of quartz-grains, and is characterized by its extreme hardness, and by its shaky cleavage. The rocks called "quartzite" can be recognized, with the aid of a microscope, as being partly sandstones. Such rocks cannot be considered as quartzite, because the single quartz-grains have been cemented by another substance, and they belong to the class of fragmental rocks. These specimens we shall mention under that head. (See §§ 175–179.)

Quartzite is usually associated with different minerals, which often give peculiar characters to the rock. These minerals are especially: mica, magnetite, actinolite, garnet, chlorite, etc.

The quartz-grains composing quartzite represent a water-clear substance, which appears in bright colors in polarized light. These grains sometimes consist of smaller ones, as may be seen between crossed nicols.

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[1] Tschermak, Minerolog. Mittheilungen, 1872, p. 45.

[2] Mikroskop, Beschaffenheit, p. 297.

[3] T. B. Brooks, Mich. Geol. Survey, Vol. I, p. 106.

With a lower power the individuals of quartzite seem to be filled with a dust-like matter. Under a strong power this dust is found to consist of numerous fluid enclosures, each containing a bubble which often moves. The specimens described in § 42 are the typical varieties of quartzite.

§ 42. a. *Quartzite.*

Spec. 361. Bed. V. Mich., T. 48 N., R. 26 W., Sec. 31, W. side of N. E. qr. of N. E. qr.

Spec. 891. Mich., T. 49 N., R. 33 W., Sec. 9, center of N. W. qr.

Spec. 1174. Bed X. Mich., Champion Mine, T. 48 N., R. 29 W., Secs. 31 and 32.

Spec. 1629. Lower quartzite, Mich., T. 39 N., R. 23 W., Sec. 7, 1250 N., 600 W.

These specimens consist almost entirely of an aggregation of colorless granules of quartz. Some grains contain many fluid-enclosures; others are filled with bristle-like microlites. Small colorless folia and scales of mica are sometimes present. The reddish appearance of some quartzite (Spec. 1174) is due to numerous microscopic films of hydrated oxide of iron, which lie between the individuals of quartz. They are probably of secondary origin. Some small prisms and grains of sahlite are present in Spec. 1629.

I have sometimes observed colorless crystals and microlites with clinobasic ends (Spec. 1174), without being able to determine the mineral to which they belong.

An opaline substance mentioned by Julien,[1] could not be found in Spec. 891. On the contrary, this rock consists wholly of crystalline substance.

§ 43. b. *Magnetic quartzite.*

Spec. 734. Bed VIII, Mich., Spurr Mountain mine, T. 48 N., R. 31 W., Sec. 23.

Besides quartz, magnetite is abundant in this rock. Only a little of the magnetite occurs in well-shaped octahedra. The irregular grains are mostly aggregated in the form of numerous rounded clusters. The quartz grains contain fluid-enclosures and some blood-red folia of hematite.

§ 44. c. *Garnetiferous quartzite.*

Spec. 1722. Quarry near Cleveland Dock, Marquette. According to a personal communication from Major T. B. Brooks, this rock forms a small vein in a diorite.

Although this rock represents a hard quartzite, it is rich in foreign substances.

One mineral occurs especially in the form of rounded and often fissured grains, which comport themselves in polarized light as perfectly isotropic bodies. It is garnet, which is present in great abundance; but is not visible to the naked eye.

Small green acicular prisms are distributed throughout the rock, and belong to hornblende.

Reddish-brown particles of hydrated oxide of iron are quite recognizable.

§ 45. d. *Micaceous quartzite.*

Spec. 732. Bed XIII, Mich., Spurr Mountain mine, T. 48 N., R. 31 W., Sec. 23.

Spec. 2205. Bed XVIII, Wis., T. 37 N., R. 17 E., Sec. 22, 1520 N., 850 W., T. 4.

Spec. 732 is especially filled with biotite, which appears in the form of brownish folia. Besides this mineral, we observe opaque octahedra of magnetite, some folia of hematite, some microlites and few fluid-enclosures.

In Spec. 2205, the quartz is mixed with biotite and muscovite, the folia of which lie parallel to the schist-plane.

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[1] Mich Geol. Survey, Vol. II, p. 79.

§ 46. E. Actinolite-quartz-schist.

Spec. 1088. Bed X., Mich., S. E. of old Washington mine.

Grains of calcite are aggregated with the irregular quartz-grains. The individuals of calcite are numerous, but sometimes the characteristic twin-lamellation is not recognizable.

In this calcareous quartz-substance, single prisms of actinolite occur, which show all the characteristic properties of this mineral, already mentioned in § 12. Besides these single individuals, we observe aggregations of actinolite. The prisms lie confusedly together and are often broken and crushed. In sections perpendicular to the main axis the prismatic cleavage is recognizable. The appearance of tourmaline in this schist is remarkable. The prisms have often been broken into different pieces. The individuals are of a bluish-gray color and show a strong dichroism. Julien[1] has called this rock brownish anthophyllitic-quartz-schist.

§ 47. f. *Chloritic quartzite.*

Spec. 432. Bed. V, Mich., T. 47 N., R. 26 W., Sec. 30, S. W. qr. of N. W. qr. This rock seems to have been formerly a fragmental one. It is composed of angular quartz-grains, which are filled with numerous fluid enclosures. Between these grains we observe a substance which consists of an aggregation of green folia of chlorite. Besides these, strong brown dichroitic folia of biotite occur, and some muscovite is also present.

This rock, microscopically observed, resembles much a sandstone, except that the cement consists of crystalline elements. The formation of chlorite may possibly have taken place by metamorphic processes.

§ 48. 4. Jasper schist.

Spec. 1196. Huronian boulder. This rock consists of parallel bands of jasper, in which zones of micaceous iron are intercalated.

Under the microscope, jasper consists of colorless quartz, filled with a reddish-brown substance, which gives to the rock its characteristic color. We observe that the quartz is composed of an aggregation of small grains, which appear in a bluish-gray color of different shades, in polarized light. The granular reddish-brown substance seems generally to consist of hydrated oxide of iron. It appears often as a dust-like substance, but sometimes it forms clusters in such a quantity that the quartz becomes opaque. These grains are very small, and seem to be amorphous. Small blood-red folia of hematite are present.

The limits between the bands of jasper and of micaceous iron are sharply defined. The latter contain a quartz groundmass, in which distinct crystals and folia of hematite are imbedded. A little magnetite is also probably present.

§ 49. 5. Chert-schist.

Spec. 1510. Mich., T. 47 N., R. 45 W., Sec. 8, N. side of S. E. quarter.

This rock is made up of laminæ of different colors (grayish-white and grayish-green). In a thin section some bands become colorless and transparent. They consist of a colorless hornstone, composed of an aggregation of small grains of quartz. Therein are imbedded single rhombohedra, which possess a rough surface, and are probably calcite. Small needles are abundant, and form small bunches, or star-like aggregations, Sometimes black opaque grains are regularly surrounded by such needles. A dull, dust-like substance is distributed throughout the whole rock.

The dark-colored bands are filled with numerous clusters of grains of calcite, which are aggregated. The irregular grains and rhombohedra are all characterized by a rough

[1] Michigan Geol. Survey, Vol. II, p. 91.

surface. The dust-like substance is also present here in great quantities, and, owing to this, the bands appear, to the naked eye, with a grayish-green color. Black, irregular particles, are coal dots. In the fissures of this rock, reddish-brown films of hydrated oxide of iron sometimes appear. In some parts of the rock irregular red folia of hematite are present.

This rock, microscopically observed, resembles very much a siliceous-schist, with the exception that the latter rock is generally very rich in particles of coal (plumbago).

§ 50. 6. Siliceous schist.

As regards their composition, the siliceous schists correspond to chert, only they contain more foreign substances, and therefore generally possess a dark gray or blackish color.

It would be advantageous to call quartzose-schists, which are contaminated by other substances, siliceous schists.

§ 51. Spec. 1436. Mich., T. 47 N., R. 46 W., Sec. 12, center of S. hf.

This specimen is filled with a dull, dust-like substance, which is distributed throughout the whole rock. The particles of this substance, which have not been individualized, are often clustered together. There often appear gray and brownish-gray shreds. All these seem to be remains enclosed at the time of the formation of the rock. Some irregular dots of coal are present.

This siliceous-schist is crossed by minute veins of quartz, which are composed of small grains, as may be seen in polarized light. They contain numerous sharply-defined hexagons, which doubtless belong to hematite. In the fissures a brownish limonite occurs.

§ 52. Spec. 1500. Lower Bed, Mich., T. 47 N., R. 45 W., Sec. 18. Sunday Lake outlet, W. side.

Spec. 1441. Mich., T. 47 N., R. 46 W., Sec. 12, center of S. hf.

The water-clear substance of quartz is only recognizable in some places, and shows, in polarized light, the characteristic mosaic-like composition of small quartz-grains. These specimens are filled especially with particles of carbonate of lime. The larger grains are round, colorless in appearance, and show distinctly the rhombohedral cleavage. The smaller individuals are characterized by a rough surface, and are often aggregated in clusters. Sometimes its rhombohedral forms are perceptible. They contain, in many cases, a dust-like substance or brown particles of hydrated oxide of iron. Irregular small coal dots are not unfrequent.

In some places we observe pale-green, irregular particles, which comport themselves, in polarized light, as perfectly isotropic bodies. Probably this substance represents an amorphous silicate of protoxide of iron, or it may be an opaline substance.

§ 53. Spec. 1683. Mich., T. 42 N., R. 32 W., Sec. 30, S. W. qr.

This rock consists partly of water-clear bands of quartz, which represent an aggregation of small grains. In some places they are filled with numerous fluid-enclosures. Numerous grains, and rhombohedra of calcite appear, and coal dots are not unfrequent; we also find numerous sharply-defined octahedra of magnetite, and particles of dust-like substance.

The dark-colored bands are rich in calcite, the individuals of which are often aggregated in clusters. They are often of a brownish-color in consequence of the presence of hydrated oxide of iron. In the fissures of this rook, particles of this substance are also not unfrequent. Dots of coal appear in great number and form irregular masses.

§ 54. 7. Magnetite schist.

The magnetite-schists have hitherto been very little investigated by the microscope. They do not consist of magnetite alone; this mineral being associated with others, especially with quartz; these varieties we call, simply, magnetite-schist. § 55.

§ 55. a. *Magnetite schist.*

Spec. 80. Mich., T. 47 N., R. 27 W., Sec. 27, N. W. qr. of N. W. qr.

Spec. 1741. Mich., T. 44 N., R. 31 W., Sec. 33, S. E. of S. E.

These two specimens represent a mixture of quartz-grains and magnetite. Wherever magnetite occurs in single individuals, it forms regular octahedra, in consequence of which its sections are quadratic. Twin-crystals are sometimes present. The grains of magnetite are generally aggregated, and then distinct forms of crystallization are not recognizable. The single individuals are generally 0.03 to 0.04 millimetre in length and breadth. The substance of magnetite is opaque, but sometimes surrounded by a brownish material, which is hydrated oxide of iron, produced by the decomposition of magnetite.

Quartz is abundant in this rock and is always recognizable by its characteristic properties. It consists of a water-clear substance, and appears in bright colors between crossed nicols. It consists of an aggregation of smaller grains, as is the case with most crystalline schists. The irregular grains contain small fluid enclosures, and besides these, we observe numerous crystals of magnetite, small hexagonal folia of hematite, and small, narrow, transparent needles, which may possibly be rutile. Under a high power we recognize the dust-like substance with which the quartz is filled to be fluid-enclosures.

§ 56. b. *Actinolitic magnetite schist.*

Spec. 2240. Bed XV, Wis., T. 39 N., R. 18 E., Sec. 28, 1500 N., 1050 W.

The presence of actinolite in ore beds is known, and we know further, that this mineral occurs as a microscopical constituent of magnetite-schist. Dr. A. Knop [1] had already observed actinolite in the magnetite-schist of Askersûnd in Sweden, with the aid of the microscope.

Magnetite is present in the form of irregular grains, which are aggregated in clusters. Distinct crystals are not frequent.

Actinolite forms long, colorless needles, and prisms, but sections perpendicular to the main axis are also recognizable. The crystals are very simply formed, and in consequence of this, on the prism ∞ P. can be observed. In the cross-sections twin crystals are remarkable. The plane of junction is the orthopinacoid, and characterized by a line dividing the crystal into two parts, which, in polarized light, show different colors. This is also a proof that this mineral cannot be "anthophyllite," as determined by Prof. Brush.

§ 57. 8. Hematite-schist.

(Micaceous iron-schist.)

Spec. 3016. Bed VI, Mich., Cannon mine, T. 47 N., R. 30 W., Sec. 28.

Hematite-schist is a schistose aggregation of quartz and micaceous iron. Micaceous iron is a scaly variety of hematite.

Hematite appears in the form of opaque or blood-red folia, according to its thickness. It occurs in hexagonal forms, but the outlines are often not equal, and in consequence of this, we sometimes observe rhomboidal forms. Numerous irregular folia and scales of hematite are also present. The characteristic metallic luster is recognizable by reflected light, whenever the section is cut parallel to the schist-plane. The folia of hematite are often aggregated.

Water-clear particles of quartz are abundant. This mineral forms the groundmass in which the folia of hematite are imbedded. Besides hematite, some fluid-enclosures and microlites are present in quartz.

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[1] Studien uber Stoffwandlungen im Mineralreich, 1873, p. 120.

§ 58. 9. Limonite.

Spec. 222. Bed X., Mich., T. 47 N., R. 27 W., Sec. 13, N. E. qr. of N. W. qr.

Spec. 549. Bed VIII., Mich., T. 47 N., R. 27 W., Sec. 12, N. W. qr. of N. W. qr.

Spec. 893. L'Anse Iron range, Mich., T. 49 N., R. 33 W., Sec. 9, N. W. qr.

The limonitic iron ores consist, microscopically observed, of limonite, and besides this they often contain quartz, magnetite, actinolite and carbonate of lime.

Spec. 222 is an actinolitic limonite. In a thin section a brownish substance appears, which is not homogeneous, and in which octahedra and irregular grains of magnetite are imbedded. A granular, dull substance is also present. With the limonite a colorless amorphous substance occurs, which may possibly be opal, or an opal-like substance. Actinolite forms small colorless prisms and needles, which are generally aggregated. There is no proof that limonite has been formed in consequence of the decomposition of magnetite, for the grains of this mineral never show the beginning of any alteration.

In Spec. 549 limonite contains irregular grains and rhombohedra of calcite, which possess a rough surface. Magnetite is widely distributed throughout the whole rock, in the form of small grains. The substance of the rock is filled with small needles. The mineralogical nature of these needles cannot be established, but it is possible that they belong to actinolite. The substance of the limonite is highly fissured.

Spec. 893. In a thin section this rock is not transparent; only in some places, a brownish substance (limonite) is recognizable. This contains black irregular particles, which probably represent a manganiferous substance.

§ 59. 10. Serpentine.

Spec. 876. Dyke, Mich., E. side of Presqu' Isle, L. S.

Spec. 1247. Mich., T. 42 N., R. 31 W., Sec. 22.

Spec. 2263. Bed XIV., T. 39 N., R. 29 W., Sec. 27, 1670 N., 500 W.

Spec. 3078. Presqu' Isle, Lake Superior. N. E. corner.

Serpentine shows generally a greenish black or dark-green color, a fissured cleavage, and appears in faint colors.

It has long been known that serpentine is not an original rock, but a production of the decomposition of other rocks. This opinion is based on the occurrence of pseudomorphs of serpentine after other minerals, as well as on the transition of serpentine into other rocks. Notwithstanding this fact, the microscopical investigations proved that a change from olivine into serpentine is principally to be recognized, and therefore olivine is present nearly always in real serpentine.

The presence of olivine is easily recognized with the aid of the microscope. In a thin section, this mineral is colorless, or of a light-green color, and is especially characterized by a rough surface. Distinct crystals of olivine occur, and even when they have been totally changed into serpentine, their forms are quite distinguishable. Traces of fresh olivine are usually observed in serpentine, and then these remains have the form of rounded granules.

The change begins on the outlines of the crystals or grains, and progresses by following the fissures that streak the olivine in all directions. Thus begins a state in which the individuals of olvine appear to be disjointed into numerous small grains, which are surrounded and cemented by the substance of serpentine. We observe a green net of serpentine, the meshes of which are filled with olivine. This mesh-like structure is very characteristic of the microscopical nature of serpentine. It is also recognizable whenever no trace of olivine is present.

The secretion of magnetite and hydrated oxide of iron is remarkable, and these minerals occur in association with the phenomenon, which brings out the change into serpentine. These irregular grains fill especially the veins and strings of the first produced substance of serpentine, which now becomes untransparent by the presence of these substances. Upon these strings we observe green veins of serpentine crossing each other, which, under strong power, show a fibrous structure perpendicular to the direction of these veins.

In these sections, serpentine appears of a green or yellowish brown color. In polarized light, it shows a crystalline structure and is found to be composed of an aggregation of small fibres. In consequence of the individuals being very small, and irregularily grouped together, their optical properties are recognized with difficulty.

Dr. Hermann Credner[1] and Julien[2] mention the occurrence of serpentine among the rocks from the iron-region of Lake Superior.

Specs. 876 and 3078 are very typical, and only consist of olivine, serpentine and magnetite.

Spec. 1247 is very much decomposed, and only a little olivine is recognizable. Some augite is present, which also seems to have been changed into serpentine. Augite sometimes shows a fibrous structure, and this mineral very much resembles diallage.

Spec. 2263 is a light-green serpentine. No trace of olivine is perceptible. Magnetite appears abundantly. The augite present shows also the beginning of change into a greenish serpentine-like substance.

§ 60. 11. Granite.

Spec. 1715. Bed. XX?, Mich., T. 42 N., R. 32 W., cor. of Secs. 20, 21, 27, 28.
Spec. 1749. Mich., T. 42 N., R. 30 W., Sec. 13, near center of N. W. qr.
Spec. 2129. Bed XX?, Wis., T. 33 N., R. 19 E., Sec. 12, 500 N. 0 W.

Granite is a massive rock, consisting of quartz, feldspar, and mica.

Quartz always occurs in the form of irregular grains, and is easily recognizable in a thin section by the appearance of its water-clear substance, which never shows the beginning of any decomposition. The presence of numerous fluid-enclosures which, under low power, have the appearance of a dust-like substance, is very characteristic. Under strong power, each fluid-enclosure is recognizable, and each contains a bubble which often moves about. The form and size of these enclosures are very different, this also being the case with the size of the bubbles. Distinct relations between the size of the fluid-enclosure and that of the bubble are not observable. In Spec. 1749 we observed some of the so-called double fluid enclosures. Such an enclosure appears to contain two fluids, and in the interior we also find a bubble. This is the opinion expressed by Sorby[5] and Brewster,[4] while Vogelsang[5] and Zirkel[6] lean to the opinion that the exterior zone is not liquid, but is a solid substance. Sometimes granite contains in its quartz-grains, fluid enclosures in which cubes of halite are not unfrequent. Some vapor cavities occur now and then.

The minerals which have been enclosed in quartz are apatite (in the form of small, colorless prisms), hematite (which is represented by blood-red hexagonal folia), mica, and numerous microlites. The quartz-grains are composed of aggregations of smaller ones.

Feldspar is generally a little dull in appearance in consequence of the beginning of the decomposition. The change proceeds from the fissures, which agree with the cleavage of this mineral, and therefore are placed parallel to the clinopinacoid. $\infty P \infty$ On these fissures the substance of orthoclase becomes dull and gradually the whole individual will finally decompose. Thin films of hydrated oxide of iron which occur in the fissures have arisen from infiltration.

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[1] Zeitschrift der deutschen geolog. Gesellschaft. Plate X, fig. 4, 1869.
[2] Mich. Geol. Survey, Vol. II, pp. 165 and 166.
[3] Quarterly Journal of the Geol. Soc., 1858, XIV, p. 473.
[4] Transact. of the Royal Soc. Edinburgh, X, 1826, p. 407.
[5] Pogg. Ann. C. XXXVII, 1868, p. 265.
[6] Mikrosk. Besch. d. Min. Gest., 1873, p. 65.

Fluid-enclosures and vapor cavities are sometimes recognizable in the water-clear and unaltered parts of orthoclase. Some folia of mica are also sometimes present. Twin crystals, twinned according to the Carlsbad-law, are not unfrequent.

Plagioclase is not of rare occurrence in granite. It is generally associated with orthoclase. As a constituent of this rock it belongs probably to oligoclase, as is the case in most of the granites. The characteristic twin-lamellation is always quite recognizable in polarized light, although its individuals have been a little altered.

The mica constituent of these rocks is nearly always represented by biotite, which, in the form of brown folia, is recognizable by its strong dichroism. The sections are mostly cut parallel to the main axis, and they therefore show a fibrous structure. The outlines of biotite are often supplied (surrounded)[1] by small grains of magnetite, and sometimes its folia are pierced by needles of apatite.

Spec. 1749 contains very little biotite, and this mineral is only perceptible by the aid of the microscope. A little muscovite is also present. Such varieties of granite, which are nearly free from mica, are called "aplite," and this specimen resembles very much the aplite[2] from Meissen and Gottlaube in Saxony.

The occurrence of small yellowish-brown needles, and prisms of zircon in Spec. 1749 is remarkable.

A pyroxenic constituent is present in Spec. 1715. The colorless individuals, which are highly fissured, belong to sahlite.

§ 61. 12. Syenite.

Spec. 1720. Quarry near Cleveland dock, Marquette. Spec. 1724. Quarry near Cleveland dock, Marquette.

Massive rocks, which consist of hornblende and orthoclase belong to the class of syenite. In association with these constituents, there are to be found plagioclase, quartz, biotite, titanite, apatite, hematite, magnetite and titanic iron.

Orthoclase is generally much altered, and represents a dull substance. The unaltered parts appear in bright colors in polarized light, while the changed grayish-white substance is composed of an aggregation of small particles, which show different colors by crossed nicols. The change mostly proceeds from the fissures, which, especially in their course, are parallel to the clinopinacoid. The occurrence of small blood-red hexagonal folia of hematite is very characteristic of orthoclase and of syenite. Small prisms of apatite are also often inclosed in it.

Plagioclase, which is not unfrequent, has generally grown together with orthoclase. The individuals are mostly fresh and unaltered, and always recognizable by its characteristic twin-lamellation, which appears in polarized light.

The greenish hornblende forms more or less distinct crystals, which in many cases are much altered. The fresh and unaltered parts are strongly dichroitic, and show the prismatic cleavage expressed by its fissures. Apatite is abundant in this mineral. The hexagonal prisms and needles pierce the individuals of hornblende, and remain in the parts where the hornblende is totally decomposed.

In the first state of the decomposition of hornblende, we observe the change as proceeding from the outlines into a green, fibrous mineral, called "viridite." This change also proceeds from the fissures. By this, the individuals of hornblende are often wholly changed into viridite, but the original forms of the decomposed mineral are sometimes still recognizable. In the viridite small individuals of epidote begin to arise. They are of a yellowish-green color, and a little dichroitic. A direct change from hornblende into epidote never could be observed; the occurrence of viridite always represents an intermediate state.

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[1] Surrounded is probably meant. T. B. B.

[2] Zirkel, Petrographie, Vol. I, p. 495.

Quartz is never entirely wanting in the greater number of the specimens of syenite. It always forms irregularly-shaped, water-clear granules, which are filled with fluid-enclosures, and microlites. By a gradual addition of quartz into syenite a syenite-granite appears, which consists of quartz, orthoclase and hornblende. In one hand-specimen (1724), we can recognize the transition of syenite into syenite-granite (hornblende-granite) by the naked eye.

Titanite is one of the most characteristic constituents of syenite. In both specimens, this mineral is not unfrequent, and quite recognizable by the wedge-like form of its crystals. It is remarkable that titanite is nearly always present only in association with hornblende rocks.

Biotite is not unfrequent, and mostly associated with hornblende. It forms brown folia, which are strongly dichroitic.

We have already mentioned the occurrence of apatite in the orthoclase and hornblende of syenite. It is remarkable that this mineral always resists any alteration, although it is easily soluble in acids.

Calcite is distinctly recognizable in some places. Till lately the opinion was expressed that calcite, wherever it appears as a constituent of massive rocks, was of secondary origin.[1] Behrens[2] was the first who observed the calcite in some diorites in a situation which removed all doubt that this mineral was formed at the time of the formation of the rock. Zirkel proved the original formation of calcite in kersanton, and Dr. Kalkowsky[3] mentions the occurrence of original calcite in syenite. Although it is possible that some calcite may have arisen here in consequence of the change of hornblende into viridite, it is beyond all doubt that this mineral also appears in an original state. Grains of calcite, especially, are enclosed in quartz. We also observe grains into which individuals of hornblende reach.

Pyrite forms irregular grains, which are recognizable by their metallic luster, which especially appears by reflected light.

§ 62. Spec. 1409.[4] Boulder, Mich., T. 47 N., R. 45 W., Sec. 18.

Orthoclase only shows the beginning of decomposition in this rock. Quartz is rare in occurrence, and whenever it appears it is composed of an aggregation of small grains. Hornblende is quite fresh and unaltered. Biotite is abundant. The presence of titanite could not be proved, and apatite is also rare in appearance. Pyrite is present in small particles.

This rock is a syenite in relation to its lithological composition, but resembles much more the rocks which belong to the class of "crystalline schists" in relation to the structure and presence of its constituents.

§ 63. 13. Diabase.

Before the microscope was used in the examination of rocks, geologists could only try to investigate the mineralogical nature of the trappean rocks and greenstones by chemical analysis, or by observations with the unaided eye. Until lately the composition of these old basic rocks was not exactly known, but now their constituents are distinctly recognizable with the aid of the microscope. We can, in consequence of the results of these investigations, subdivide the so-called greenstones, diorites, trap-rocks, etc., into diabase and diorite. The diabase mostly prevails among these rocks, which are abundant in the iron-region of Lake Superior. They consist chiefly of augite and plagioclase, while diorite consists of hornblende and plagioclase. Diabase embraces all

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[1] Neues Jahrb. f. Miner. etc., 1872, p. 462.

[2] Berichted Konigl. sachs Gesellschaft d. Wissenschaften, 1875, p. 200.

[3] Neues Jahrb. f. Miner. 1876, p. 488.

[4] Mr. Allpert says: "It is interesting to note that the syenite 1409 and several of the hornblende rocks — hornblende gneisses — are wonderfully like some of the hornblende rocks of Queensland."

rocks of such constitution, which have been formed up to the end of the Paleozoic period.

The name "Diabase" was first used by Alex. Brongniart,[1] for rocks consisting of hornblende, and a white feldspar; but as Hauy[2] had already applied the name "Diorite," the former name therefore would signify nothing. In consequence of this, Hausmann[3] accepted the name "Diabase" for rocks which consist of pyroxene and a triclinic feldspar (labradorite), and up to this time nearly all authors have adopted this name. Dana[4] alone makes an exception, and names "Diabase" "massive hornblende rocks, which are like diorite in composition, excepting that the feldspar is less abundant, and is either labradorite or oligoclase." We can neither agree with such an opinion, nor justify the placing diabase with dolerite, for we can only apply the latter name to eruptive rocks of the tertiary age.

§ **64.** The chief constituents of diabase are plagioclase, augite, and magnetite or titanic-iron. Besides these, quartz, orthoclase, hematite, hornblende, apatite, pyrite, etc., are found now and then.

Plagioclase is either represented by labradorite or by oligoclase, which fact can be only established by a chemical examination. This mineral nearly always forms rod-like crystals. The characteristic twin-lamellation is always perceptible in polarized-light, if the crystals are fresh and unaltered. In the coarser grained varieties of diabase, plagioclase is readily visible to the naked eye (Specs. 912, 913).

The lamellæ which compose such a crystal are sometimes present in great numbers. In Spec. 913, from L'Anse Iron Range, some individuals are composed of more than 40 lamellæ, which by crossed nicols show different colors. The lamellæ are generally twinned according to the Albite-law, where the plane of junction is the brachy-pinacoid; but also the Pericline-law sometimes appears, which labradorite especially follows, and in which the plane of junction is the base. Where these two-systems of twin-lamellation are combined, they cross each other at an angle of 86° 40′ and therefore show in polarized light a grate-like structure.

In consequence of the alteration of plagioclase the twin-lamellation often begins to disappear. The decomposition mostly proceeds from the fissures, which cross the crystals in every direction (Spec. 1501). It often appears that the alteration has taken a natural course and follows the direction of the twinned lamellæ. Some authors[5] have expressed the opinion, that the fissures take place in the plane by which the lamellæ are joined; but I think that the plane of junction has nothing to do with the alteration of the crystals, for their substance in this place must be as compact as in other places. We often observe from the microscopical examination of other minerals, that the alteration generally proceeds parallel to the direction in which the best cleavage has taken place. The best cleavage of plagioclase is parallel to the brachypinacoid and this also represents the plane of junction. It therefore seems that the alteration proceeds from the fissures, which are the lines that represent this plane.

We recognize very often a greenish fibrous substance in the fissures. This substance is soluble in cold hydrochloric acid and is called "viridite." It represents the "chloritic constituent of greenstones." It seems that this viridite has been infiltrated and has arisen by the decomposition of augite.

The feldspathic substance becomes dull in the course of its decomposition, and then it only shows the twin-lamellation in some unaltered parts, by crossed nicols. Finally no plagioclase can be recognized, and in consequence of this, the microscopical investigation

[1] Classification et caracteres mineralogiques des roches homogenes et heterogenes. Paris, 1827, p. 80.

[2] Traite de mineralogie, Paris, 1822, IV.

[3] Ueber die Bildung der Harzgebirges Abhdlg. d. Kgl. Geo. J. W.

[4] Man. of Geol., '73, p. 79. See later view, ed. of '74, pp. 70, 736, also Man. of Min. & Lith. p. 451, T.C.C.

[5] Dathe. Mikroskopische Unters. ueber Diabase. Zeitschrfs. d. d. Geol. Gesellsch. 1874, p. 5.

of greenstones is sometimes very difficult. The dull substance, which represented formerly the feldspathic constituent shows a granular or fibrous aggregation in polarized light. There is no doubt that plagioclase has also been changed into viridite, like augite, and therefore thin sections of diabases which are totally decomposed show a greenish substance, the origin of which can only be established by long study.

Small prisms and needles are often enclosed in plagioclase (Spec. 912); octahedra of magnetite, and hexagonal folia of hematite also occur. In its fissures, films of hydrated oxide of iron are not unfrequent.

§ **65.** *Orthoclase.* Generally no orthoclase is present in diabase. Wherever this mineral appears, it forms irregular individuals, which are more or less altered. In polarized light they are only of one color in their fresh parts. Distinct crystals are of rare occurrence.

In this place we may also allude to the interesting fact that the glassy variety of orthoclase, called "sanidin," can also be recognized in diabase (Spec. 2072). This sanidin forms transparent, glassy, tabular crystals. Its water-clear substance is crossed by many fissures in all directions, as is to be seen by the aid of the microscope. The individuals which are unaltered contain many vapor cavities. The presence of this mineral has not been established in the diabases of other countries.

§ **66.** *Augite.* This mineral is a chief constituent of diabases, as we have already mentioned. Julien[1] maintained the opinion in his paper, that in the rocks from the Iron Region of Lake Superior, no augite occurs. It is very difficult indeed to distinguish augite from hornblende in these rocks by the unaided eye, but microscopically the characteristic properties of augite as a constituent of this rock are easily recognized in most cases. In § 15 we have already given the method of distinguishing augite from hornblende by the aid of the microscope.

Augite rarely forms well shaped crystals in these diabases, the outlines being generally irregular. Twin crystals are not unfrequent. Only a few other minerals have been found enclosed in augite. However, we sometimes notice the presence of rods of plagioclase (Spec. 996), crystals of magnetite, small prisms of apatite, etc. In Spec. 884 numerous vapor cavities occur.

Many fissures cross the individuals of augite in every direction, but they often show the characteristic angle made by the two prism-faces (86° 7′). The decomposition proceeds from the fissures, so we observe the beginning of it on the outlines of augite. The result of the decomposition is a green fibrous mineral, which later on fills up the whole substance of augite. Many names (such as delessite, diabantachronyn, etc.), have been given to this mineral, which is the "chloritic substance" of many authors. It is not probable that this green substance is always of the same composition, and therefore the name "viridite" may be best applied. Viridite is soluble in hydrochloric acid, and appears in polarized light to be composed of an aggregation of small fibres. It occurs also in cavities and fissures of the rock, and seems to be composed chiefly of silica, protoxide of iron and alumina. The lime of augite is transformed into calcite (Spec. 827), which is now present in the rock in consequence of the decomposition of the former mineral, but we do not doubt that in some circumstances calcite can also be an original constituent of diabases.

Viridite induces sometimes the formation of other minerals, and these are epidote and augite. The epidote is yellowish-green in color, is slightly dichroitic, and forms clinobasic crystals or irregular grains. The individuals occur in the viridite, and it is beyond doubt that they have been formed out of it (Spec. 301?). This succession has already been described by Dathe.[2]

The phenomenon of the transformation of viridite into augite, has not been observed until recently. It is very interesting to have the fact established that this mineral, after

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[1] Mich. Geol. Survey, Vol. II, p. 42. [2] l. c. p. 17.

having been changed into another, has finally returned to its former state. The new-formed augite is represented by delicate crystals, the outlines of which are sharply defined. They are completely fresh and of a green color (see Spec. 1659). Such individuals are only present in viridite and do not seem to occur in any other part of the rock.

§ **67.** Distinct crystals of hornblende are present in some diabases (Specs. 884, 996), and always easily recognized. By a gradual addition of hornblende the diabase changes into diorite, and under these circumstances, such a rock represents an intermediate state between diabase and diorite.

Some diabases contain brown folia of biotite (Specs. 3079, 827), which sometimes have been changed into viridite.

Olivine is rare in occurrence in the diabases of the Iron region. It is present now and then as an accessory constituent (Spec. 1659). True olivinic-diabases were not observed, although they doubtless occur.

§ **68.** Small quartz-grains occur frequently in diabase, but are not generally visible to the naked eye. The grains are irregularly shaped and contain many fluid-enclosures, which sometimes contain a bubble which moves about (Specs. 827, 889, 1616, etc.). Diabase in which quartz is frequent in occurrence, is called quartz-diabase.

§ **69.** Magnetite occurs in many diabases, and generally forms therein sharply defined octahedra, which are sometimes aggregated (Spec. 1659, etc.).

Some blood-red folia of hematite also occur in Specs. 827, 3079.

Titanic-iron is abundant in nearly all diabases, and is much more frequent than magnetite. It is especially present with hexagonal forms, but distinct crystals are rare in occurrence. The individuals are generally rod-like in appearance, and then form delicate aggregations, which represent the hexagonal forms (Specs. 912, 913).

The change of titanic-iron into a grayish-white mineral is a peculiar characteristic sign. This change is seen to start from the contours.

Fissures which cross each other at an angle of 60° are also sometimes to be recognized in the planes of the individuals. From these fissures a change also proceeds. Dr. Gümbel[1] expressed the opinion that this grayish-white mineral might be an original one, and called it "Leucoxen." According to his investigations, it is composed of silicic acid and titanic acid.[2] Törnebohm,[3] in his investigations of the diabases of Greenland, establishes the fact that this white mineral was produced in consequence of the decomposition of titanic iron, but he thinks that it may be titanite, an opinion with which I cannot agree. As regards its structure and appearance, this mineral has no affinity with titanite. Cohen[4] finally maintained the opinion that this mineral might be pure titanic acid.

Pyrite is not unfrequent in some diabases. This mineral is easily recognizable from its metallic luster by reflected light.

§ **70.** We may now mention the presence of a substance in many diabases which gives a good proof as to the eruptive character of these rocks. This substance has been squeezed in between the constituents of the diabase. It represents no true glass, but is amorphous in appearance, and has been devitrified into a granular substance. The development of such a substance by metamorphism is impossible, and it can only be considered as the remains of a liquid mass. Zirkel[5] proved the presence of an inserted substance in the diabases of Scotland, which form layers and dykes between the lower carboniferous sandstone.

In the following §§ the most characteristic varieties of diabase will be described.

[1] Die palæolithischen eruptivgesteine d. Fichtelgebirges, 1874, p. 22.

[2] l. c. p. 35.

[3] Geoliska Foreingens i. Stockholm, Vol. II, p. 545.

[4] Jahresbericht der geograph. Gesellschaft zu Hamburg, Vol. II, p. 225.

[5] Zeitschrift d. deutschen Geol. Ges. 1871, p. 23, Vol. XXIII.

§ **71.** *Coarse diabase.*

Specs. 912, 913. Mich., L'Anse Iron Range, T. 49 N., R. 33 W., Sec. 9, N. W. qr. The individuals of augite are very large, and rather fresh and unaltered, yellowish-green in color, and highly fissured. A little hornblende is also present. Plagioclase forms delicate rod-like crystals, which show a beautiful twin-lamellation in polarized light. They are all fresh, and unaltered. The inserted substance is squeezed in between these constituents, and is therefore wedge-like in appearance. It is amorphous, and always easily recognizable. A little orthoclase is perceptible. The crystals of titanic-iron, which are also unaltered, are aggregated. These aggregations represent the hexagonal forms of the crystallization of this mineral. These specimens are the exact type of diabases.

§ **72.** Specs. 1110, 3079, Washington mine.

Spec. 1110 forms a true "trap dyke," and therefore its eruptive nature is beyond all doubt.

Plagioclase forms long, small rod-like crystals, and is rather fresh and unaltered. In these specimens also a little orthoclase is present. Augite is already a little decomposed, especially on its fissures, and has induced the formation of greenish viridite. An inserted substance, which has not been individualized, is recognizable. Apatite is abundant, and forms small colorless needles of 0.009 millimetre in length, which are widely distributed throughout the whole rock. Biotite in irregular brown folia, which show a strong dichroism, is very frequent. Magnetite forms small octahedra, and a little titanic-iron is also recognizable. Blood-red hexagonal folia, which are not rare in occurrence, belong to hematite.

§ **73.** Spec. 2072. Bed XIX, Wis., T. 33 N., R. 19 E., Sec. 12, 600 N., 250 W.

Augite is of a dark-green color and forms well-shaped crystals. Plagioclase is also present in distinct crystals, which are only slightly altered. The presence of a sanidin-like orthoclase is very remarkable, as we have formerly mentioned (see § 65). Only a few vapor cavities are recognizable in its water-clear substance. Besides titanic-iron we observe also a little magnetite. Apatite is not of unfrequent occurrence.

§ **74.** Spec. 884. Mich., L'Anse Iron Range, T. 49 N., R. 33 W., Sec. 9, S. W. qr.

Augite is very fresh and unaltered, and contains many vapor cavities. Hornblende forms good crystals, which, however, are recognizable by their dichroism and their prismatic cleavage, shown by the fissures which cross each other at an angle of 124° 30.' This specimen is a totally crystalline one, and therefore no inserted substance is perceptible. Plagioclase forms delicate crystals which show a beautiful twin-lamellation in polarized light; sometimes agate-like striation is recognizable. This mineral contains many microlites of apatite. Titanic-iron is abundant in distinct crystals. Delicate films of hydrated oxide of iron occur in the fissures of the rock.

§ **75.** Specs. 1427, 1501. Mich., T. 47 N., R. 45 W., Sec. 18, W. line.

Plagioclase has been a little altered, and therefore on its fissures the substance has become a little dull. In these parts no iron-lamellation is recognizable by polarized light. Augite has also been altered a little on its fissures. Its substance is fibrous and changed into viridite. Titanic iron is frequent, and we also find a little magnetite in sharply defined octahedra. Biotite in brown folia has also been a little altered. The inserted substance is brownish and globular in appearance.

§ **76.** Spec. 1659. Falls of the Sturgeon river, Mich.

This is a very typical specimen. In a thin section we first recognize the crystals of plagioclase. They are 0.35 millimetre in length, and of 0.1 millimetre in breadth. They have not at all been altered, but in their fissures films of hydrated oxide of iron appear. The substance between the larger crystals of plagioclase consists of smaller crystals of augite, plagioclase, magnetite, and an inserted substance, which has not been individualized. Augite is of a yellowish-green color, and is very fresh. Magnetite is abundant, and forms distinct octahedra. Small crystals of olivine are sometimes present.

§ **77.** Spec. 889. Altered diabase. Mich., L'Anse Iron Range.

We find augite nearly totally changed into viridite. The latter substance is greenish and fibrous, and is also present in the fissures of the rock, where it has settled. Plagioclase is dull in appearance, in consequence of its decomposition. Its characteristic twin-lamellation is only recognizable in some parts. A little quartz is present in irregular grains, which contain many fluid enclosures. The bubbles of some are movable. Little individuals of hornblende, which are not unfrequent, have also been partly changed into viridite. In the viridite, crystals and grains of yellowish-green epidote appear, which are the results of new production in viridite. Titanic iron forms distinct crystals, which have been altered on their outlines, into a greenish-gray substance. It owes its greenish color to the viridite, which probably has been mixed with the grayish-white substance.

§ **77.** Spec. 3070. Decomposed diabase.

The whole rock has been nearly totally changed into viridite and its fissures have also been filled with this substance. The plagioclases which have kaolinized represent a dust-like substance, which is greenish in consequence of the presence of viridite. In the viridite, new formed distinct crystals of augite appear, while no trace is perceptible of the original individuals of augite. Besides viridite, calcite is also present in the fissures, and has been formed by the decomposition of the original augite. It is colorless, and often shows a distinct twin-lamellation in polarized light.

§ **78.** Spec. 1616. Quartz diabase. Bed VIII?, Mich., T. 39 N., R. 29 W., Sec. 15, N. W. qr. of. N. W. qr.

This rock specimen is remarkable by the presence of many quartz-grains. In their water-clear substance we only observe a few fluid-enclosures, but numerous colorless needles of apatite. The other constituents of this rock are much decomposed. The substance of augite is recognizable only in some parts, the others have been changed into viridite. Plagioclase is dull in appearance, but the twin lamellation is mostly easily recognizable. A little orthoclase is also present. Titanic-iron is abundant, but has mostly been changed into the well known grayish-white substance.

§ **79.** Spec. 2059. Decomposed diabase. Bed XVI, Mich., T. 39 N., R. 30 W., Sec. 24, 900 N., 850 W.

This whole rock has been totally changed. Neither augite nor plagioclase is recognizable. In consequence of the decomposition, viridite, magnetite and calcite appear. The latter mineral especially has filled the cavities of the rock.

§ **80.** Spec. 821. Decomposed diabase. N. of Northwestern Hotel, Marquette.

Calcite is abundant in the cavities of the rock, and consequently it effervesces with acids. This mineral and viridite are products of decomposition, and besides these magnetite in very small, irregular grains also occurs. The plagioclase has been totally decomposed. In the viridite numerous small blood-red folia of hematite are present. The crystals and irregular granules of titanic-iron have been changed into a grayish-white substance ("leucoxene"), but the remains of the original mineral are quite recognizable.

§ **81.** Spec. 827. Decomposed diabase. S. of Northwestern Hotel, Marquette.

Augite has been changed into viridite. But it is remarkable that crystals of augite as newer products are present in the viridite. Blood-red folia of hematite and small crystals of magnetite also occur therein. Plagioclase is quite distinguishable, its substance is dull, and much altered, and it is in some parts of a greenish color, which is produced by the addition of viridite. Biotite, in brown, irregular folia, shows the beginning of alteration. Titanic-iron has been partly changed into the well known grayish-white substance. Quartz is not unfrequent. It forms small, irregular granules, which contain small fluid enclosures. Small needles and prisms of apatite are distributed throughout the whole rock. The cavities of the rock are mostly filled with calcite; sometimes the interior consists only of this mineral while the exterior consists of greenish viridite.

§ **82.** Spec. 2079. Decomposed diabase. Bed XV?, Mich., T. 40 N., R. 30 W., Sec. 9, 100 N., 2000 W.

In consequence of the decomposition of this rock, the greater part of the augite has been changed into viridite. The feldspar constituent has been kaolinized, and therefore it is represented by a dull substance. Quartz occurs in small grains, and in its fissures some greenish viridite has sometimes formed. An interstitial substance is present, and has also been altered, but it is quite recognizable. Some parts of the rocks are filled with brownish clusters of hydrated oxide of iron. A little calcite is present, which has been produced in consequence of the decomposition of augite. Some crystals of augite occur in the virdite.

§ **83.** Spec. 996. Diabase. Mich., T. 51 N., R. 31 W., Sec. 28, W. of Slate river.

This rock is rather fresh and unaltered. The crystals of augite are of a yellowish-green color, and contain many small rods of plagioclase. All crystals of plagioclase show distinctly the characteristic twin-lamellation in polarized light. A little hornblende is present, as also numerous octahedra, and irregular grains of magnetite. The interstitial substance has been squeezed in between the individuals of plagioclase and augite.

§ 84. Conclusions.

1. The diabases are eruptive rocks, for in the greater number of the varieties an interstitial substance is present, which is amorphous and may be considered as the remains of the original igneous fluid magma.
2. The microfluidal structure, which is recognizable in the thin sections of some specimens, is also proof of the eruptive nature of the diabase.
3. The diabases may be classified into diabase (typical varieties), and quartz-diabase. (The third class of olivine diabase is not present amongst the rocks from the iron region of Lake Superior.) Olivine and quartz do not generally appear together in diabases.
4. In consequence of the decomposition of augite, a greenish fibrous "chlorite-like" mineral appears, called viridite.
5. The presence of calcite is accompanied by the change of augite; it is, however, possible, that calcite may appear as an original constituent. This mineral especially fills up the fissures and cavities of the diabases.
6. Epidote and augite may be formed from the viridite as secondary products.
7. Titanic-iron and magnetite are essential constituents of diabase. They appear together, or singly.
8. The grayish-white substance, which very often surrounds the crystals of titanic-iron, is an altered form of this mineral.
9. The feldspar constituent of diabase is represented by plagioclase (labradorite or oligoclase); a little orthoclase is, however, sometimes present.
10. Diabase often contains hornblende. By a gradual addition of this mineral, transitions from diabase into diorite appear.

§ 85. 14. Diorite.

Diorite is generally not distinguishable from diabase by the unaided eye, and therefore the greater part of the greenstones from the iron region of Lake Superior have been called diorite. However, diorite is less abundant, in all countries, than diabase.

These two rocks generally show the same composition and structure, with the exception that hornblende is a chief constituent of diorite and that augite is a chief constituent of diabase.

In diorite, besides plagioclase and hornblende, titanic-iron, magnetite, quartz, apatite, augite, calcite, biotite, etc., appear.

Hornblende is of a green color, and distinct crystals are generally not recognizable. The characteristic cleavage expressed by the fissures is quite perceptible, and also a strong dichroism when tested by a single nicols prism. We observe the beginning of decomposition in the hornblende in most cases, and virdite the chief secondary product, which shows the same properties as the viridite which has been formed in consequence of the change of augite in the case of diabase. Biotite is often associated with hornblende, and more or less abundant in the different specimens. Quartz is generally more frequent in diorites than in diabase, and a little quartz occurs in most of the specimens.

The individuals of plagioclase show the same characteristics as in diabase. Orthoclase occurs in greater or less quantities, but is, however, only an accessory constituent. The crystals of augite which appear in diorite, show, generally, the beginning of a change into hornblende, and therefore sometimes represent a mineral called "uralite" (Specs. 464, 192).

Apatite is abundant in nearly all the specimens. In sections cut perpendicularly to the main axis, it forms sharply defined hexagons, while in sections parallel to the main axis, it forms long needles and prisms. The abundance of apatite is especially characteristic of hornblendic rocks. Calcite has been formed mostly in consequence of the decomposition of hornblende, but, however, in some cases we can establish an original formation of this mineral.

In the examined specimens of diorite no trace of an interstitial substance could be recognized, nevertheless we may suppose the same formation in diorite as in diabase.

In the following sec;ions the most interesting specimens of diorite will be described.

§ 86. Spec. 464. Mich., T. 47 N., R. 26 W., Sec. 17, S. W. of N. E. qr.

The large individuals of hornblende show distinctly the prismatic cleavage in sections perpendicular to the main axis. The individuals are striated in sections parallel to the main axis. The substance of hornblende is clear, except in those parts which have been altered. Small prisms and needles of apatite and a little magnetite are enclosed therein. The alteration of hornblende takes place on the outlines and in the fissures, and the new formed mineral is the well known viridite. This substance principally fills up the cavities of the rock. Sometimes it seems to be homogeneous in common light, but by crossed nicols it shows itself to be composed of small fibres. In the viridite many sharply defined crystals of augite occur, which have been formed out of this mineral as secondary products. Their substance is very clear and of a yellowish green color. Calcite, which shows distinctly its rhombohedral cleavage, has a water-clear substance, and is milky-blue in appearance by polarized light. This mineral occurs in the fissures and cavities, and has also, probably, been formed by the decomposition of hornblende.

Plagioclase, in rod-like crystals, has also been altered a little, but its characteristic twin-lamellation is quite recognizable by crossed nicols.

Biotite forms irregular brown folia, which are strongly dichroitic and are especially associated with hornblende.

The crystals and irregular individuals of titanic iron have been partly changed into the already mentioned grayish-white substance. A little magnetite is also present.

The occurrence of original augite is very remarkable. This mineral shows the beginning of a change into hornblende, and therefore represents in this state the mineral called uralite. The original forms of crystallization of augite are, however, still recognizable. It is very curious, that in one part hornblende has been changed into viridite, and this mineral into augite, and in the other part the original augite has been changed into hornblende (uralite).

§ **87.** Spec. 3075. Diorite. Light-House Point Quarry, Marquette.

Besides the chief constituents, hornblende and plagioclase, a little quartz is also present, which forms irregular water-clear grains. They contain many fluid-enclosures, in which the bubbles often move about. Whenever hornblende is not represented by distinct crystals, it is quite recognizable and is only a little altered. Plagioclase is also rather fresh, and its twin-lamellation appears always between crossed nicols. Biotite forms brown irregular folia. Titanic-iron is abundant, and occurs in association with a grayish-white substance. Prisms and needles of apatite pierce, especially the individuals of hornblende, in every direction.

This specimen is a very typical one.

§ **88.** Spec. 37. Diorite. Bed IV, Mich., T. 47 N., R. 27 W., Sec. 29, N. W. qr. of S. E. qr.

The crystals of plagioclase have been much altered, and in consequence of this, its substance is dull. The characteristic twin-lamellation is still recognizable only in some parts. Hornblende has been partially changed into viridite, and in the latter substance new-formed crystals of augite appear. Biotite in irregular folia has often grown together with hornblende. Small crystals of original augite are present, which show the beginning of a change into uralite. Apatite is not unfrequent. Titanic-iron has partly been changed into a grayish-white substance. Some individuals of orthoclase are recognizable. This diorite resembles much the "epicliorite" of Gümbel[1] and also a diorite from Danemore in Sweeden, according to a personal communication from Mr. Törnebohm.

§ **89.** Spec. 563. Altered diorite. Mich., T. 47 N., R. 26 W., Sec. 17, N. W. qr. of N. W. qr.

Plagioclase has been very much altered and in its fissures viridite has formed. Hornblende shows the change into viridite, but in some parts its substance is fresh. Titanic-iron is also decomposed and has been changed for the greater part into the well known grayish-white substance. A little original augite is present.

§ **90.** Spec. 2098. Diorite porphyry. Bed XV, Wis., T. 38 N., R. 21 E., Sec. 20, 1800 N, 0 W.

This rock is especially characterized by a groundmass, which consists of the constituents of diorite, and in which large crystals of feldspar are imbedded.

These crystals of feldspar are very much decomposed. Their substance is dull, and partly filled with greenish viridite, which substance has arisen from the change of hornblende. Nevertheless we may consider these individuals of feldspar to be triclinic, for in some places the twin-lamellation is still recognizable in polarized light.

The groundmass consists especially of hornblende, the alteration of which has been mentioned. Plagioclase is less abundant and also altered, like the larger crystals. A little augite, which is to be considered as an original constituent, is present.

§ **91.** Spec. 192. Quartz diorite. Mich., T. 47 N., R. 27 W., Sec. 2, N. W. qr. of S. E. qr.

Besides plagioclase, which has been altered, orthoclase appears. The latter mineral occurs either in single crystals or its individuals are grown together with quartz. As regards appearance and composition, these two minerals resemble very much the so-called "lapis hebraicus."

Titanic-iron has been changed into leucoxene, but its original forms are quite recognizable. Hornblende is much decomposed, and in consequence of its change viridite is present. In the latter mineral secondary crystals of augite occur. Calcite fills up the cavities and fissures of the rock.

[1] Die palæolithischen Eruptivgesteine des Fichtelgebirges, Munchen, 1874, p. 10.

§ **92.** Spec. 1730. Altered diorite. Quarry near Cleveland Dock, Marquette.

Hornblende is predominant in this specimen, but it is much decomposed, and partly changed into viridite. We may consider the presence of magnetite as partly resulting from the change from hornblende. Its appearance points to such a formation. Dr. Dathe [1] has already mentioned the formation of magnetite in consequence of the change from augite. Plagioclase is much altered, and only in some places its twin-lamellation is still recognizable. Apatite is abundant.

§ **93.** Spec. 1726. Diorite. Quarry near Cleveland Dock, Marquette.

This rock is a little altered. Hornblende is represented by large green individuals, which are sometimes composed of an aggregation of small microlites. Hornblende has been partly changed into viridite, and in consequence of this, the latter mineral occurs in the fissures of plagioclase, which has also been a little altered. A little orthoclase is present. Titanic-iron forms fine aggregations, which represent the hexagonal forms in their composition. Small veins of calcite occur, which contain distinct crystals of augite. The secondary origin of these two minerals is beyond all doubt.

§ **94.** Spec. 1713. Decomposed diorite. Quarry near Cleveland Dock, Marquette.

Plagioclase is totally decomposed, only some kaolinized spots point to the former presence of this mineral.

Hornblende has been nearly completely changed into viridite and is only recognizable in some places. We observe the formation of yellowish-crystals of epidote in the viridite. Calcite is present, and has also been formed in consequence of the decomposition of hornblende.

Apatite is abundant and is everywhere wholly unalterd.

§ 95. 15. Gneiss.

Gneisses are schistose rocks, which generally consist of quartz, feldspar and mica. Instead of the latter mineral, often hornblende, chlorite or sericite appear. In consequence of this, we distinguish mica gneiss (common gneiss), hornblende-gneiss, chlorite gneiss and sericite gneiss.

Feldspar is chiefly represented by orthoclase, but in all gneisses a little plagioclase (oligoclase) is present. Quartz always forms irregular grains, which generally are composed of smaller ones, which appear with different colors in polarized light.

Sometimes a groundmass occurs which is composed either of quartz or of feldspar, in association with mica or hornblende. Larger individuals of quartz and feldspar are imbedded in such a groundmass, and are porphyritic in appearance.

The appearance of the constituents of gneiss may vary:

1. Larger individuals of quartz or feldspar are imbedded in a quartzose or feldspathic groundmass, which also contains mica, hornblende, etc. (porphyritic gneisses).
2. Single individuals of quartz, feldspar and mica, or hornblende, compose the rock (typical gneisses).
3. Irregular small individuals are aggregated. In this aggregation occur numerous clusters and single individuals of mica (Spec. 2234).

§ 96. a. *Mica gneiss.*

Spec. 1641. Possibly Laurentian. Mich., T. 39 N., R. 28 W., Sec. 8, Falls of Sturgeon river, Menominee region.

The water-clear, irregularly shaped quartz-grains are filled with rows of fluid enclosures, and also contain numerous long bristle-like microlites. The reddish crystals of orthoclase have been much altered, and in consequence of this, their substance is dull and not transparent. Muscovite occurs in colorless scales and folia; besides this, biotite appears in brown folia, which show a strong dichroism, and are therefore easily distin-

[1] Zeitschrift d. Deutschen Geol. Ges. 1874, p. 29, Vol. XXII.

guishable from those of muscovite. Magnetite is represented by large, sharply defined octahedra of 0.12 millimetre in length and breadth, which are irregularly distributed throughout the whole rock. Small red transparent needles, easily perceptible by strong power, also occur, and they may possibly belong to rutile.

§ 97. Spec. 1656. Possibly Laurentian. Mich., T. 39 N., R. 28 W., Sec. 8.

This rock resembles Spec. 1641. The quartz-grains contain many fluid-enclosures and microlites, and also sharply defined rhombohedra of calcite. The orthoclase is somewhat decomposed, and reddish in appearance. Among the mica constituents muscovite is predominant, but is associated with brownish biotite. They form a felt-like mass. Irregular grains of magnetite occur.

§ 98. Spec. 146. Porphyritic gneiss. Bed V., Mich., T. 47 N., R. 26 W., Sec. 23, S. W. qr. of S. W.

The groundmass represents a compact aggregation of scales of mica and small grains of quartz. Therein occur some larger folia of muscovite and biotite. Octahedra and irregular grains of magnetite are also distributed throughout the groundmass. Magnetite often shows the beginning of a change into hydrated oxide of iron.

The boundaries between the larger individuals of quartz and feldspar, and the groundmass, are sharply defined. The quartz contains many fluid enclosures, irregular folia of muscovite, biotite and magnetite. Hydrated oxide of iron has formed in its fissures. The individuals of feldspar consist of an aggregation of small ones, which are grouped together in different directions. Mica and magetite are inclosed therein. The greater part of these individuals are represented by orthoclase, but sometimes they consist of plagioclase, which shows the characteristic twin-lamellation between crossed nicols.

§ 99. Spec. 2069. Porphyritic gneiss. Bed XV., Mich., T. 39 N., R. 30 W., Sec. 8, N. W. qr.

The rounded quartz grains are filled with numerous fluid-enclosures and small needles of apatite. The feldspar constituent is especially represented by orthoclase, which contains many small prisms and folia of sahlite, which have been imbedded generally parallel to the plane M. In its fissures a greenish chlorite-like mineral occurs. The groundmass is especially filled with scales and folia of muscovite and biotite. Irregular black dots of coal (plumbago) appear.

§ 100. Spec. 2234. Gneiss. Bed XVI., Wis., T. 39 N., R. 18 E., Sec. 19, 825 N., 2000 W.

The greater part of the rock consists of an aggregation of small quartz and feldspar grains, with much brown mica. Single folia are scattered over the whole substance, but generally they are aggregated in large clusters. The presence of original calcite is interesting. This mineral forms irregular grains, showing distinctly the rhombohedral cleavage, and are generally aggregated. These aggregations are irregularly distributed throughout the whole rock, and lie between the individuals of quartz and feldspar. Small needles and crystals of magnetite occasionally appear.

§ 101. Spec. 944. Gneiss. Mich., T. 49 N., R. 33 W., Sec. 16, N. side.

The individuals of feldspar contain a reddish, dust-like substance which seems to be original. They also contain small microlites crossing one another at an angle of 60° and colorless folia of muscovite. As may be seen in polarized light, quartz consists of an aggregation of small grains with but few fluid enclosures. The mica constituent is only represented by muscovite, and it is not abundant.

Spec. 1 resembles this rock, only quartz is more abundant and a little garnet appears.

§ 102. b. *Hornblende-gneiss.*

Hornblende-gneiss consists of hornblende, quartz and feldspar. The latter mineral is gen erally represented by orthoclase, in association with which a little plagioclase occurs.

In some gneisses the feldspar constituent is chiefly plagioclase. The former we may designate as syenite-gneiss, and the latter as diorite-gneiss, for they resemble syenite and diorite in relation to their lithological composition.

§ 103. b. 1. *Syenite-gneiss.*

Spec. 1762. Mich., T. 42 N., R. 28 W., Sec. 32, E. line.
Spec. 2120. Bed XIX, Wis., T. 38 N., R. 20 E., Sec. 8, 200 N., 700 W.
Spec. 2211. Bed XIX?, Wis., T. 39 N., R. 17 E., Sec. 27, 500 N., 1700 W.

We observe in thin sections parallel to the schist plane, that the individuals of horn blende are not placed in this direction, but on the contrary they lie confused together, and therefore sections of hornblende occur which are cut perpendicularly and others which are cut parallel to the main axis. Distinct crystals of hornblende are not unfrequent, and are sometimes pierced by colorless needles of apatite. The individuals of hornblende are mostly aggregated. Biotite appears here and there in brown folia, mostly in association with hornblende.

Orthoclase forms no distinct crystals, but irregular grains — the outlines of which can only be recognized in polarized light. The individuals are always very fresh, and unaltered, and therefore they are sometimes not to be distinguished from those of quartz. Plagioclase is present in greater or less quantities. It shows, by crossed nicols, a beautiful twin-lamellation, according to the freshness of its substance. Besides apatite, generally a little hornblende is enclosed in feldspar.

The general habitus of the quartz characterizes it as an original constituent of the crystalline schists. The water-clear grains consist of an aggregation of smaller ones, as may be seen in polarized light. Small fluid-enclosures occur, also some microlites, and small prisms of hornblende. Magnetite occurs in small irregular, opaque grains, but in small quantities. In Spec. 2120, small colorless grains of sahlite are present.

§ 104. Spec. 2105. Porphyritic hornblende gneiss. Bed XIII, Mich., T. 39 N., R. 30 W., Sec. 14, 1350 N., 1960 W.

The groundmass consists of an aggregation of small irregular grains of orthoclase, which are intermingled with small prisms of hornblende. The latter often form a felt-like mass. Irregular grains of titanic-iron are distributed throughout this groundmass. They are nearly always surrounded by the grayish-white substance, which has arisen in consequence of their decomposition. Wedge-like crystals of titanite sometimes occur. Brown folia of biotite are also present in the groundmass. In the fissures, membranes of hydrated oxide of iron appear.

Larger individuals of quartz and hornblende have been imbedded in the groundmass. Quartz contains many fluid-enclosures; in some of which a cube of halite occurs, and also in some the bubble moves about. Small prisms of hornblende have settled into the fissures and are arranged perpendicularly to them. They are probably of secondary origin. In the fissures of feldspar some prisms of hornblende also occur; but at the same time in its substance original prisms are enclosed. Plagioclase is rare and a little apatite is present.

The presence of aggregations of calcite is remarkable; their mode of occurrence indicates clearly that they are original constituents.

§ 105. b. 2. *Diorite gneiss.*

Spec. 1757. Mich., T. 42 N., R. 29 W., Sec. 26, near E. qr. post.

As was formerly mentioned, hornblende-gneisses in which the feldspar constituent chiefly consists of plagioclase, are called diorite-gneiss. They have no relations with diorite as to their structure and formation.

Plagioclase is mostly fresh and unaltered. It forms irregular grains, which show distinctly the characteristic twin-lamellation in polarized light. There also appear individuals which are twinned according to the Pericline-law, and in consequence of this, we observe two systems of twinned individuals which cross each other at an angle of 86° 40′.

A little orthoclase is present, but its substance is a little dull in consequence of the beginning of alteration.

Quartz forms irregular grains which are composed of an aggregation of smaller ones. Numerous fluid-enclosures appear in its water-clear substance; also, small microlites are not unfrequent.

The green prisms of hornblende show perfectly the prismatic cleavage, and in sections parallel to the main axis they are striated. They often enclose in their substance again, distinct crystals of hornblende. Biotite is present in brown folia, which are strongly dichroitic, and which sometimes are regularly grown together with the hornblende prisms, and then the plane of junction is the prism face.

The individuals of hornblende are sometimes perforated, and probably in connection with this, there appear tongs-shaped fragments, which often have arranged themselves so as to radiate from the quartz-grains. It is also possible they may belong to mica.

Small irregular grains of garnet occur in this gneiss.

§ 106. c. *Chlorite gneiss.*

Spec. 3003. Mich., T. 48 N., R. 23 W., Sec. 30, S. W. qr.

Feldspar has much altered in this specimen; only fresh places are sometimes recognizable by the aid of the microscope. For the greater part it consists of orthoclase. In its substance, by a strong power and in a thin section, numerous colorless scales of a mica-like mineral appear. These scales have undoubtedly been derived from the change from orthoclase. They are not present in the unaltered parts, but occur in the fissures. from which the alteration proceeds. Plagioclase is recognizable in some places by polarized light.

The large water-clear granules of quartz contain many fluid-enclosures, which are distributed through its whole substance. Some colorless microlites also appear. All individuals of quartz consist of aggregations of smaller ones. Membranes of hydrated oxide of iron occur in the fissures.

Chlorite is less abundant than the before-named constituents. If forms small irregular green scales and folia, which are generally aggregated into clusters. Occasional folia occur in the quartz and feldspar.

A little apetite is present in orthoclase, and small individuals of hornblende occasionally appear.

§ 107. d. *Sericite-gneiss.*

Spec. 2271. Bed XVI, Wis. Below Sturgeon Fall, Menominee Region, T. 33 N., R. 21 E., Sec. 27, 1230 N., 850 W.

This rock seems to have been formerly a "gray-wacke," which has been changed now into sericite-gniess.

The chief constituents are quartz, orthoclase and sericite. Quartz occurs in irregular granules, which partly contain many fluid-enclosures. The individuals of feldspar are also irregular, and sometimes rounded. They are much altered, and are dull in appearance. Many folia of sericite occur in a quartzose groundmass, and form irregular aggregations and clusters. On the physical properties of sericite, see § 118. Numerous rhombohedra are present, which for the greater part are now filled with brownish hydrated oxide of iron. It is probable that they consisted formerly of calcite.

Some green folia of chlorite occur and also irregular black dots of coal are recognizable. A dust-like substance is widely spread over the whole rock.

§ 108. 16. Mica-schist.

As we mentioned in § 5, muscovite and biotite constitute the mica-schists. Both varieties can be readily distinguished by the aid of the microscope.

Muscovite is always present in the form of small, colorless, irregular folia, which appear in bright colors in polarized light. In it no dichroism is recognizable. This mica is itself a chief component of some schists (Specs. 2239, 2222, etc.), but it occurs also in schists which are composed essentially of biotite.

The folia of biotite are always recognizable by their brown color, and strong dichroism. They compose the greater part of mica-schists, and they are also abundant in schists which chiefly consist of muscovite.

Quartz is a very important constituent. This mineral generally forms aggregations with which the folia of mica are interwoven. Such aggregations represent a groundmass in most of the schists. The quartz-grains are very small, contain but few fluid-enclosures, and their outlines are only recognizable by crossed nicols. In some mica-schists larger granules of quartz are present, but are not related to those which form the groundmass.

Instead of quartz, calcite or feldspar sometimes forms the groundmass; in such cases these minerals also consist of an aggregation of small, irregular individuals. No mica-schist was observed which consisted of an aggregation of folia of mica alone.

Magnetite is abundant in all specimens. It is present in some parts, in the form of sharply defined octahedra — in others it occurs in irregular grains, which are sometimes aggregated into clusters.

Hornblende in the form of green acicular prisms is not unfrequent, and in some cases this mineral represents a chief constituent.

Green folia of chlorite are often associated with those of mica. Some individuals of feldspar occur occasionally.

The presence of tourmaline and zircon in some specimens is remarkable.

§ 109. a. *Mica schist.*

(In which the mica constituent is represented by muscovite.)

Spec. 2058. Bed XVI, Wis., T. 33 N., R. 20 W., Sec. 15, 1650 N. 0 W.

Spec. 2222. Bed XVIII, Wis., T. 39 N., R. 17 E., Sec. 24, 150 N., 1540 W.

Spec. 2225. Bed XVIII, Wis., T. 39 N., R. 18 E., Sec. 30.

Muscovite forms irregular, colorless folia in sections parallel to the base, which are striated in sections parallel to the main axis. They appear in bright colors in each position by polarized light. Aggregations of irregular quartz grains form the groundmass. Some large individuals contain many fluid-enclosures. In Spec. 2222 irregular grains of calcite are recognizable, and compose the groundmass in association with quartz. Brown folia of biotite are not unfrequent. Magnetite is rare in occurrence.

The abundance of small crystals of zircon is remarkable. This mineral generally forms small reddish-brown prisms, sometimes with a pyramid at the ends. Twin-crystals, where the plane of junction seems to be 2 P. occur. It may be mentioned, that crystals twinned according to this law never were observed in zircon by the naked eye. Many individuals of this mineral have been cramped in development and therefore they show no distinct forms of crystallization. The individuals have mostly formed parallel to the schist-plane and are often aggregated.

§ 110. Spec. 2239, Wis., T. 39 N., R. 18 E., Sec. 22, 400 N., 1350 W.

Spec. 442, Bed V, Mich., T. 47 N., R. 26 W., Sec. 22, S. W. qr. of S. W. qr.

The folia of muscovite have all formed parallel to the schist-plane. The groundmass consists of an aggregation of small quartz-grains. Biotite is abundant, but in general no single folia occur, its brown folia being aggregated in clusters. The individuals of biotite are always larger than those of muscovite. Magnetite is single black grains is disseminated throughout the whole rock. In Spec. 2239 small grains of tourmaline are present.

§ **111.** Spec. 1085. Quartzose mica schist. Bed XIV, Mich., S. W. of the old Washington mine.

Quartz appears in the form of large rounded granules, in the water-clear substance of which are numerous fluid-enclosures, some being provided with a movable bubble. The quartz grains contain many sharply defined, blood-red hexagonal folia of hematite.

We observe muscovite and hematite, parallel to the schist-plane; and cementing the larger grains of quartz. Hematite occurs in rather long grains and folia, which are generally not transparent. Biotite is to be recognized by the brown color of its folia.

§ 112. b. *Mica-schist.*

(The mica constituent being represented by biotite).

b. 1. *Mica-schist (typical varieties.)*

Spec. 227. Mich., T. 47 N., R. 28 W., Sec. 13, S. W. qr. of N. W. qr.
Spec. 2162. Bed XIX, T. 42 N., R. 32 W., Sec. 35, S. W. qr., Paint Portage.
Spec. 2163. Bed XIX, T. 42 N., R. 32 W., Sec. 35, S. W. qr., Paint Portage.

These specimens are chiefly composed of biotite and quartz.

The angular and irregular quartz-grains represent in their aggregation the groundmass of the rock. Minute fluid-enclosures appear in their water-clear substance.

The brown folia of biotite are interwoven with this groundmass, and are often aggregated in clusters. Muscovite is not frequent in occurrence.

Magnetite is irregularly distributed throughout the whole rock, in sharply defined octahedra, or irregular grains.

In Spec. 2162 some green folia of chlorite appear, and also some small prisms of tourmaline.

§ 113. b. 2. *Magnetic mica-schist.*

Spec. 1101. Washington mine.
Spec. 1102. Washington mine.
Spec. 2087. Mich., T. 41 N., R. 30 W., Sec. 6, S. E. cor.

These specimens are similar to the before-named (§ 112), but they are filled with numerous crystals and grains of magnetite. In sections cut perpendicularly to the schist-plane, we observe some bands, which only consist of an aggregation of such individuals of magnetite.

§ 114. b. 3. *Hornblendic mica-schist.*

Spec. 2212. Wis., T. 40 N., R. 17 E., Sec. 35, 1475 N., 900 W.

The small prisms of hornblende are visible to the naked eye, and are porphyritic in appearance.

The groundmass of this schist consists of angular small grains of quartz. The chief constituent is biotite. Its irregular brown folia are imbedded in the groundmass.

The hornblende prisms are distributed through the whole mass in every direction, and lie with regularity parallel to the schist-plane. They are mostly of a bright-green or bluish green color, and show a distinct dichroism. Sharply defined crystals do not occur; its prisms are ragged and uneven, as is the case in nearly all crystalline schists in which hornblende appears as a constituent. Sometimes the prisms have broken into several pieces. The individuals of hornblende are intermingled with those of biotite, but the latter are more abundant. The former are striated in sections parallel to the main axis. In sections perpendicular to the main axis, the characteristic angle of

124° 30′ made by the two prism faces is quite recognizable. The orthopinacoid $\infty P \infty$ appears in combination with the prism. Small needles of apatite appear, but are not frequent. A little magnetite is also present, and some calcite.

§ 115. b. 4. *Chloritic mica-schist.*

Spec. 2254. Mich., T. 39 N., R. 29 W., Sec. 16, 1700 N., 30 W.

The greater part of the groundmass is represented by an aggregation of small quartz-grains, but carbonate of lime also takes a share in it. The larger grains of calcite here also show instances of a distinct twin-lamellation.

Brown folia of biotite are intermingled with green folia of chlorite without regularity, but the former mineral predominates.

The forms of aggregation of magnetite in this schist are remarkable. Its octahedra have grown together in one direction, and perpendicularly to these, similar octahedra are aggregated. In this manner tree-like aggregations are formed, which appearance generally characterizes the magnetite of such rocks as basalt, diabase, etc. Besides these, grains of magnetite appear in this rock, aggregated in irregular clusters.

§ 116. b. 5. *Feldspathic mica-schist.*

Spec. 2090. Bed XIX, Wis., T. 40 N., R. 19 E., Sec. 18, 750 N., 1,000 W.

In all the before mentioned specimens, aggregations of quartz chiefly formed the groundmass. It is feldspar which composes a groundmass in this schist. Its small individuals show already the beginning of decomposition, and in consequence of this fact, they are easily to be recognized. The feldspar is especially represented by orthoclase, but a little plagioclase also occurs. A little calcite is also present in irregular grains, but quartz is rare. Biotite forms small brown folia which have formed parallel to the schist plane. Magnetite is abundant, and some larger crystals of orthoclase occur, which are sometimes twinned according to the Carlsbad law.

§ 117. b. 6. *Calcareous mica-schist.*

Spec. 2255. Mich., T. 39 N., R. 29 W., Sec. 16, 1690 N., 30 W.

We may properly mention also in this class Specs. 2212 and 2254, but the lithological characters of these schists are expressed by other constituents.

The larger individuals of calcite show a distinct twin-lamellation, which is not the case with the smaller ones. Such rocks represent the transition from mica-schist into limestone (compare § 37).

Biotite is the chief constituent, and besides this some folia of green chlorite occur. A little muscovite appears in the form of colorless folia. Quartz with some fluid-enclosures is not unfrequent, and magnetite is present in black irregular grains.

Spec. 1100 from Washington mine is a calcareous mica-schist.

§ 118. 17. Sericite-schist.

Spec. 2071. Bed XIV, Mich., T. 39 N., R. 30 W., Sec. 8, N. W. qr.

Spec. 2077 from a test-pit near the center of south line of Sec. 25, T. 40, R. 31, Mich.

List[1] named in 1850, the hitherto so-called chlorite or talc-schists from Taunus on the Rhine, "sericite-schist." It is composed of a scaly mineral, with a silky luster — mica-like or damourite-like in structure. Color, yellowish-white or leek-green. Streak, dirty-white. Before the blow-pipe, thin scales are opened, and they are fusible in strong heat to a grayish-white enamel. With fluxes sericite gives the reaction of iron. Sp. Gr. 2.8; hardness 1. A chemical analysis of sericite from "Nerothal near Weisbaden" gave:

[1] Jahrbuch d. ver. f. Naturkunde. Herzglh. Nassau 1850, p. 126, and 1852, p. 123.

SiO^2 49.00, Al^2O^3 23.65, FeO 8.07, MgO 0.94, CaO 0.63, NaO 1.75, KO 9.11, HO 3.41, TiO^2 1.39, Si F 1.60.

Sericite belongs, with regard to its composition, to potash-mica, and Naumann [1] mentions this mineral in that place. Dana [2] places sericite with the hydrous silicates, especially with damourite.

It is beyond all doubt that sericite is a distinct mineral with regard to its microscopical structure. It represents principally an essential constituent of sericite-schists and gneisses.

Sericite appears in the form of scaly folia with a fibrous structure. By this structure it is quite distinguishable from mica, but it is a little similar to the structure of talc. The scales are generally not isolated from the rock-substance, but are mostly aggregated. These aggregations represent sometimes a felt-like mass. The dichroism of sericite is very feeble, and often not to be recognized.

Sericite does not form any crystals as constituents of sericite-schist. I have only once observed rhombic folia of this mineral in an augite schist from Rauenthal in Taunus, the prism angle of which was about 125°. This is very nearly that of muscovite.

Quartz is a chief constituent of sericite-schist. It forms partly a groundmass with which the silky scales are interwoven, and partly appears in the form of water-clear granules, the outlines of which are generally rounded. The scales of sericite accumulate on the outlines of quartz.

These larger quartz-grains are filled with numerous fluid-enclosures, which are arranged in rows, but they are absent from others. This fact agrees with the observation made by Sorby [3] in the quartz of some mica-schists. This author from this fact formed the probably correct opinion that the origin of these quartz grains was different.

We often find numerous scales and folia of sericite in the form of rows enclosed in quartz-grains, which at the first moment induces the belief that they were enclosed simultaneously with the crystallization of quartz. This is by no means the case, for between crossed nicols we observe that quartz appears with a one colored figure. The quartz grains are crossed by small veins of quartz of secondary origin and these form an aggregation of smaller grains, as may be seen by polarized light, and with these aggregations the folia of sericite are interwoven. Sericite only occurs in secondary quartz and therefore it is also of secondary origin.

The groundmass of sericite-schist consists of an aggregation of very small quartz-grains in which the minute scales and folia of sericite appear. It is remarkable that the sericite is always inseparably united with quartz. Sericite never occurs isolated in these schists, hence the amount of silica is always higher in the analysis than it probably should be. Regarding these facts, the chemical composition of sericite is very similar to that of muscovite.

The scales and folia of sericite are generally irregularly distributed through the quartzose groundmass, but sometimes they show an aggregation in the form of zones, by which parts rich in sericite alternate with others which contain but little. In some specimens the folia of sericite finally surround the grains of quartz in the form of radiated aggregations

The abundance of well-shaped rhombohedra, having the form of calcite, is remarkable. They consisted probably of carbonate of lime, but now no trace of this mineral is perceptible. The original mineral has been dissolved out, leaving the cavities, which are often filled with hydrated oxide of iron. The latter substance occurs also in the fissures of the rock.

Tourmaline is not unfrequent in occurrence. It forms small prisms of a bluish-gray

[1] Elemente d. Mineralogie Leipzig, 1874, p. 483.
[2] A system of Mineralogy, 5th ed. p. 487.
[3] Quart. Journal of the Geol. Soc., 1863, p. 401.

color, which are strongly dichromatic when tested by a single nicols prism. These small individuals are sometimes broken up into several pieces (see § 26).

The structure of sericite-schists differs from that of the other so-called "crystalline-schists," as already mentioned. We are enabled to determine the origin of these rocks by microscopical investigations. The result of such study indicates beyond all doubt that the sericite-schists were originally fragmental rocks, and were brought into this crystalline state by metamorphism. We need not go into further details on this point, but give only the principal facts which prove the original fragmental state.

a. The occurrence of rounded grains of quartz, which have the form of pebbles.

b. The granules of quartz are filled with numerous rows of fluid enclosures, which break off suddenly on the outlines, which is not the case with the quartz of granite, gneisses, etc. In these and other crystalline rocks, the rows of the fluid enclosures ramify into the most irregularly shaped quartz grains.

c. There are grains of quartz which contain numerous fluid enclosures, and others that contain almost none.[1] Probably these grains originally came from different rocks.

d. The grains of quartz are often surrounded by radiating folia and scales of sericite, as is the case in real fragmental rocks, such as sandstones and clay slates. This has been proved several times by Dr. Zirkel.[2]

e. Broken prisms of tourmaline are often found. The pieces which belong to each other are generally observed close together.

f. A dull, dirty dust is present in all sericite-schists, which probably is the remains of the fragmental substance.

g. Rhombohedra occur, such as are sometimes present in fragmental rocks, which are entirely wanting in crystalline ones. They very likely represent former crystals of calcite. After the lixiviation of the latter mineral, the crystal spaces are filled partly or entirely with hydrated oxide of iron.

The above named facts show that at the formation of these rocks, mechanical forces were at work, as proved by the presence of rounded quartz-grains, and broken crystals of tourmaline, quite similar to the state in which these minerals are found in real fragmental rocks, for instance, in sandstones and clay slates. On further investigation we are able to prove that sericite is of secondary origin. This mineral is present only in the groundmass; and folia of it also occur in the fissures of the grains of quartz, or in small quartz-veins which cross the original quartz-grains.

The occurrence of the rhombohedel pseudomorphs in the sericite-schists is of the same significance. It seems that the process has been such, that a change in the cement of the original rock has taken place, with the formation of a crystalline substance (quartz-groundmass and sericite). Through this metamorphism the rhombohedra of calcite have been preserved without being damaged. In the second change the lixviation has taken place by fluids, which contained carbonic acid. This is the reason of the preservation of the crystal shapes. These rhombohedral cavities would serve now as a place for the accumulation of the hydrated oxide of iron, which has entered by fissures. In consequence of this, fissures are still found inside the rocks, with brown films and amorphous masses of hydrated oxide of iron.

We can finish these examinations with a last look at the occurrence of sericite-schists in other countries and a glance as to the age of these schists.

The sericite-schists, after having been observed in Taunus, were found by Lipold[3] in the Salzburger Alps. Törnebohm[4] proved the occurrence of sericite in the "halle-

[1] Sorby in Quarterly Journal of the Geol. Soc., 1853, p. 401.

[2] Pogg. Ann. C., XLIV, p. 319

[3] Jahrb. d. geol. Reichsanstalt, 1851, pp. 201, 350.

[4] Neues Tahrb. f. Mineralogie, 1874, p. 141.

flinta" of Sweden. In many parts of the Alps, in the Fichtelgebirge and in the Hartz mountains, rocks of this description are present.

The antiquity of the sericite rocks was proved in nearly all places, and it is remarkable that these interesting rocks have been also observed in the iron region of Lake Superior.

Spec. 2071 has been described by Dr. H. Credner,[1] in his paper on the rocks of the upper peninsula of Michigan, as talc-schist. Many sericite-schists are called by this name, for they agree slightly with regard to their physical properties with talc-schist. Tourmaline is especially abundant in Spec. 2077.

§ 119. 18. Amphibolite.

The group of amphibolite comprises all rocks which belong to the "crystalline-schists" which chiefly consist of a hornblendic mineral. The most abundant are actinolite and the common hornblende (amphibole).

§ 120. a. *Actinolite-schist.*

A. 1. Spec. 2198. Wis., T. 40 N., R. 17 E., Sec. 34, 1735 N., 950 W.
Spec. 2238. Wis., T. 39 N., R. 18 E., Sec. 28, 1330 N., 1050 W.

These two specimens represent typical actinolite-schists. Actinolite forms colorless prisms, the ends of which are ragged and uneven in sections parallel to the main axis. Sections cut parallel to the base are not frequent, but show perfectly the angle of 124° 30′ made by the two prism faces.

The prisms have mostly formed parallel to the schist-plane, but in this plane they lie confusedly together in all directions, and the prisms are often cracked and broken. The crystals are fissured parallel to the main axis, but fissures also appear, which cross the individuals in every direction. An alteration proceeds from the latter.

But few minerals appear enclosed in actinolite. Some small brown folia can be seen belonging to an unknown mineral, identical with those which occur in diallage. The abundance of zircon is remarkable, which mineral forms prisms of 0.1–0.2 millimetre in length. These small prisms are sometimes aggregated in clusters. The individuals are brownish-yellow in color.

In Spec. 2198 some crystals of greenish hornblende occur, which can be easily distinguished from those of the colorless actinolite.

The groundmass in which the individuals of actinolite are imbedded, consists generally of an aggregation of small quartz-grains and a pale-green, foliaceous, chlorite-like mineral. The broken individuals of actinolite have been cemented by the same substance.

§ 121. a. 2. *Magnetic actinolite schist.*

Spec. 221. Mich., T. 47 N., R. 37 W., Sec. 13, N. E. qr. of S. W. qr.

A compact rock, the constituents of which are only recognizable by the aid of the microscope.

It consists of an aggregation of colorless small individuals of actinolite, in association with which magnetite occurs. A groundmass is not present, and with the exception of magnetite this rock represents a pure actinolite-schist. The small prisms lie confusedly together, and therefore in a thin section we observe sections of these minerals cut parallel and perpendicularly to the main axis. The prismatic cleavage in the latter is always quite recognizable. Magnetite is frequent in occurrence. It forms single, small, opaque octahedra, or its individuals are aggregated in clusters. In consequence of the beginning of decomposition, some crystals are surrounded by brownish hydrated oxide of iron.

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[1] Zeitschrift d. deutsch. geol. Ges. 1869, p. 529.

§ 122. a. 3. *Magnetic actinolite schist.*

Spec. 308. Mich., T. 47 N., R. 27 W., Sec. 13, N. E. qr. of S. W. qr.
Spec. 1116. Mich., N. E. of Champion Mine.
Spec. 1155. Mich., T. 48 N., R. 30 W., Sec. 25.
Spec. 2241. Bed XV, Wis., T. 39 N., R. 18 E., Sec. 28, 1500 N., 1050 W.

These specimens are very similar to Spec. 221 (Sec. 121); but actinolite forms here only small, colorless needles in aggregations, which lie parallel to the schist-plane. They are intermingled with small grains of magnetite, which compose alternating bands within the rock. Magnetite has been changed into hydrated oxide of iron in some places. Julien[1] has designated Specs. 1116 and 1155 as "magnetic anthophyllite schist," but as we formerly mentioned, this constituent must be considered to be actinolite.

§ 123. a. 4. *Magnetic actinolite schist.*

Spec. 177. Sharply defined colorless prisms of actinolite have formed in a felt-like groundmass of small needles of actinolite. The yellowish-brown color of this groundmass proceeds probably from hydrated oxide of iron. The crystals of actinolite contain much magnetite; sometimes their outlines consist of this mineral and sometimes, even, the crystals consist partly of magnetite. Magnetite is also abundant in the groundmass where it occurs in large, sharply defined octahedra.

§ 124. b. *Hornblende rock and schist.*

These rocks are composed of green individuals of hornblende, in association with which occur quartz, feldspar, calcite, magnetite, titanic iron, apatite, etc.

Although we may generally consider the schistose structure of the hornblende-schists as having its origin in the arrangement of the hornblende prisms which lie parallel to their main axis, it is not, however, always the case. In consequence of this, we often observe in thin sections parallel to the schist-plane, sections which are cut perpendicularly to the main axis of the prisms.

The microscopical structure of hornblende-schists generally agrees with that of mica-schists. A groundmass is usually present, which consists either of an aggregation of small grains of quartz, or of feldspar or calcite. Besides these, hornblende-schists appear which are composed only of hornblende-prisms and in which no groundmass is recognizable.

The hornblende-rocks are only to be distinguished from hornblende-schists by their massive, non-schistose structure. With regard to their composition, and the structure of their constituents, they are wholly similar to hornblende-schists.

Apatite is not very frequent; its appearance, however, like that of titanite, is characteristic of hornblende rock. Magnetite and titanic-iron are abundant.

The hornblende-rocks and schists which are only composed of individuals of hornblende or in which the groundmass represents an aggregation of quartz-grains, are called simply "hornblende-schists or rocks," and these will be described in §§ 125-130.

§ 125. b. 1. *Hornblende-schist and rock.*

Sec. 1752. Hornblende-schist. Mich., T. 42 N., R. 29 W., Sec. 22, near center of S. W. qr.

All prisms of hornblende lie parallel to the schist-plane. The ends of the prisms are ragged and uneven, as in the case in nearly all hornblende schists. The striæ are parallel to the main axis. The individuals of hornblende are aggregated, and have taken place in a quartz groundmass. Fine crystals of plagioclase as an accessory mineral

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[1] Mich. Geol. Survey, 1873, Vol. II, p. 92.

appear, which show perfectly the characteristic twin-lamellation in polarized light; also a little orthoclase, apatite, and irregular opaque grains of magnetite.

§ **126.** Spec. 2167. Hornblende rock. Bed XVIII, Wis., T. 40 N., R. 18 E., Sec. 9, 1040 N., 470 W.

Thin sections contain instances of crystals cut parallel to the main axis, and also others which are cut perpendicularly to it. The yellowish-green or bluish-green colored individuals of hornblende, which are sometimes twinned, lie confusedly together, and sometimes a prism is crossed by another. Brown folia of biotite are widely spread through the whole rock. The groundmass is composed of an aggregation of quartz grains, which contain minute fluid-enclosures, small needles and prisms of hornblende and scales of biotite. Some crystals of orthoclase appear. Yellowish wedgelike crystals of titanite are not unfrequent. Irregular opaque grains of titanic-iron are present, which sometimes show the beginning of a change into the well known white substance. Apatite is not frequent in occurrence.

§ **127.** Spec. 745. Hornblende-rock.[1] Boulder from south shore of Lake Michigamme. (Source unknown.)

This rock is almost entirely composed of large prisms of hornblende. In sections perpendicular to the main axis, we observe the prism with its characteristic angle of 124° 30′, the orthopinacoid and the brachypinacoid. The prismatic cleavage is perfectly recognizable in these sections. A little quartz is present in which small needles of hornblende occur. Small grains and crystals of orthoclase appear, in which the beginning of alteration may be recognized. Titanic-iron is not unfrequent.

§ **128.** Spec. 1636. Hornblende-schist. Falls of the Sturgeon river, Michigan, T. 39 N., R. 28 W., Sec. 8, N. E. qr. of S. E. qr.

The green prisms of hornblende are associated with brown folia of biotite. The abundance of titanic-iron is remarkable. The change of this mineral into white substance called "leucoxen" by Gümbel, is quite recognizable. Its individuals have been surrounded by this latter substance, and sometimes the decomposition has taken place in such a manner, that no trace of the original mineral is perceptible, but, however, the original forms of crystallization are perfectly shown. In our investigations of the diabase (§ 69), we proved that the opinion of Dr. Gümbel, who mentions this white substance as an original one, cannot be correct, and also in this case, the change of titanic-iron is a fact which is beyond all doubt. Colorless grains of sahlite occur in this specimen. They are often aggregated in clusters. A little titanite is also present.

§ **129.** Spec. 2261. Hornblende-schist. Wis., T. 38 N., R. 21 E., Sec. 32, 900 N., 2000 W.

A very typical specimen. The green prisms of hornblende lie mixed together. Sections parallel to the main axis, and others which have been cut perpendicularly to it, occur. Quartz forms the groundmass. Opaque irregular grains of magnetite are abundant.

§ **130.** Spec. 2124. Hornblende-schist. Bed XIX, Wis., T. 38 N., R. 20 E., Sec. 15, 1000 N. 1970 W.

This rock resembles Spec. 1752. Delicate green prisms of hornblende are abundant, which are imbedded in a quartzose groundmass. Aggregations of sahlite and single hexagonal folia of hematite occur. Irregular grains of magnetite are distributed throughout the whole section.

§ **131.** b. 2. *Feldspathic hornblende schist and rock.*

As we formerly mentioned, there are amphibolites which contain a groundmass composed of grains of feldspar or calcite, besides those which consist of an aggregation of single hornblende prisms, or which contain a quartzose groundmass. The greater part of hornblende schists and rocks from the iron region of Lake Superior are feldspathic.

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[1] Mich. Geol. Survey, 1873, Vol. II, p. 164.

It is sometimes very hard to prove the feldspathic nature of the individuals of the groundmass mineral, for they show therein generally the same appearance as is characteristic of the quartz as a constituent of the crystalline schists. In consequence of this, irregular grains of feldspar are aggregated and form the groundmass. The single grains can only be distinguished from each other in polarized light, by which they appear with different colors. By common light the single individuals are not distinguishable. They are mostly represented by orthoclase, but sometimes also plagioclase occurs. The colors which appear by crossed nicols cannot be always a test by which to distinguish feldspar from quartz, especially if the feldspar is fresh and unaltered. It is interesting to find that many grains of orthoclase are twinned according to the Carlsbad-law, and in consequence of this, such a mineral cannot be quartz. If the beginning of alteration is recognizable, it is beyond all doubt, that the mineral is feldspar.

Larger individuals of feldspar are present in some places, and then such rocks often resemble syenite, especially if they are not schistose. By the gradual reception of quartz, a feldspathic hornblende-schist will finally represent a hornblende-gneiss. In the following sections we shall prove that the feldspathic hornblende-rocks cannot be identified with syenite.

§ **132.** Spec. 1761. Hornblende-schist, Mich., T. 42 N., R. 28 W., Sec. 32, E. line.
This specimen represents a very typical feldspathic hornblende-schist. The groundmass consists of an aggregation of irregular grains of orthoclase, with which those of plagioclase have been intermingled. The green hornblende-prisms are generally present in sections parallel to the main axis. Some aggregations of magnetite occur.

§ **133.** Spec. 527. Hornblende-schist. Mich., T. 47 N., R. 27 W., Sec. 15, N. W. qr. of N. E. qr.
The crystals of hornblende have formed themselves parallel to the schist-plane, and occur in a feldspathic groundmass. Some irregular grains of quartz are present, the fluid-enclosures of which sometimes contain a bubble that moves about. A little biotite appears and also small needles of apatite. Titanic-iron is generally surrounded by the white substance.

§ **134.** Spec. 3071. Micaceous hornblende-schist.[1] 20th mile post M. & O. R. R.
The prisms of hornblende and the numerous brown folia of biotite form a felt-like aggregation, which has been imbedded in the groundmass. The latter consists wholly of an aggregation of irregular individuals of orthoclase.

The greenish hornblende has altered and shows the beginning of a change into viridite, in which substance some grains of epidote occur. A little calcite has settled in the fissures of the rock and has been formed in consequence of the decomposition of hornblende.

§ **135.** Spec. 3029. Micaceous hornblende schist.[2] Republic mine.
Besides hornblende, biotite is abundant. These constituents together or separately form aggregations, which have taken place in the feldspathic groundmass. The occurrence of calcite therein is remarkable. In this case, this mineral is an original constituent. The small grains are aggregated in clusters, which are intermingled with small folia of biotite. These clusters lie also in the groundmass, and are doubtless of original formation. Apatite shows sharply defined hexagons in sections parallel to the base, and is also present in the form of long prisms, which represent sections parallel to the main axis. A little quartz is recognizable.

§ **136.** Spec. 2182. Micaceous hornblende schist. Bed XVII. Mich., T. 41 N., R. 31 W., Sec. 17, 760 N., 1375 W., on Brulè river.
The groundmass consists of an aggregation of small individuals of feldspar, but also larger crystals are present. They consist partly of orthoclase, the individuals of which

[1] Mich. Geol. Survey, Vol. II, p. 210.

[2] Mich. Geol. Survey, Vol. II, p. 205.

are sometimes twinned according to the Carlsbad-law, in which the plane of junction is parallel to the clino-pinacoid, and which are characterized by a line dividing a crystal into two parts, which, by crossed nicols, show different colors. The feldspar constituent is partly represented by plagioclase.

The greenish-hornblende appears mostly in the form of microlites, which are aggregated. Larger prisms are rare in occurrence. Brown mica is abundant, but its folia are small and narrow.

Long needles and prisms of apatite pierce the rock in every direction. Small, yellow and wedge-like crystals of titanite occur.

Titanic-iron in association with the white substance is present.

§ **137.** Spec. 3076. Hornblende-schist. Light-house Point Quarry, Marquette.

Hornblende is present in irregular green folia, which are striated. Biotite is, however, not rare in occurrence. Numerous sharply-defined hexagonal folia of hematite appear, being blood-red in color. Calcite is abundant, and its individuals often show a distinct twin-lamellation. Titanic-iron forms very small grains, but each is surrounded by the known white substance. Minute folia and scales of muscovite appear.

The groundmass consists of an aggregation of individuals of feldspar.

§ **138.** Spec. 325. Hornblende-schist. Mich., T. 47 N., R. 27 W., Sec. 18, N. W. qr. of N. W. qr.

The groundmass consists chiefly of an aggregation of small individuals of orthoclase, but also minute grains of plagioclase occur. The small prisms of hornblende are of bluish-green and of yellowish-green color. Numerous small and narrow folia of biotite appear. A little calcite is present and also some crystals of titanite.

§ **139.** Spec. 1614. Hornblende-schist. Mich., T. 39 N., R. 29 W., Sec. 15, N. W. qr. of N. W. qr.

The individuals of hornblende represent large folia or plates, in a thin section, which show also characteristic properties of this mineral. The occurrence of original calcite is remarkable, and very interesting in its appearance. It forms sharply defined rhombohedra, which sometimes are aggregated, and partly reach into the prisms of the hornblende. The outlines of the latter mineral are marked in this case by the rhombohedra. A little quartz is present, containing colorless needles of apatite, which sometimes have broken into several pieces. Titanic-iron is present in irregular individuals. The groundmass consists of feldspar.

§ **140.** Spec. 1528. Hornblende-schist.[1] Mich., W. branch of Ontonagon river, T. 46 N., R. 41 W., Sec. 13.

The hornblende-prisms are of a pale green color, and bear some resemblance to actinolite. The individuals are sometimes cracked and shaken. Magnetite is frequent in occurrence, but it shows the beginning of a change into hydrated oxide of iron, and therefore it is surrounded on its outlines by this latter brownish mineral. The groundmass consists of an aggregation of irregular grains of orthoclase.

§ **141.** Spec. 2051. Hornblende-schist. Wis., T. 38 N., R. 20 E., Sec. 23, 1450 N., 800 W.

The hornblende appears in the form of small microlites, and by this also the larger individuals represent an aggregation of such microlites. All are of a light-green color. Neither magnetite nor titanic-iron is present. The groundmass consists of an aggregation of small individuals of orthoclase and plagioclase, the former mineral predominating. Fine aggregations of colorless grains of sahlite occur, which appear with bright colors in polarized light.

§ **142.** Spec. 2122. Altered hornblende-schist. Wis., T. 38 N., R. 20 E., Sec. 8, 2000 N., 900 W.

The green prisms show the beginning of decomposition, and a change to viridite

[1] Mich. Geol. Survey, Vol. II, p. 171.

has taken place. Small individuals of yellowish-green epidote occur, which have been newly formed in the viridite. Titanic-iron has been also changed into the grayish-white substance. Orthoclase composes the groundmass. The single individuals are dull in appearance, in consequence of the beginning of alteration. Minute irregular grains of quartz occur.

§ **143.** Spec. 1099. Hornblende schist.[1] Edwards mine.

The hornblende is typical in appearance. Its section perpendicular to the main axis is characterized by many fissures, which show the prismatic angle of 124° 30′. Its forms of crystallization are also perfectly recognizable in this plane.

The longitudinal sections show a striation parallel to the main axis. The groundmass is feldspathic. Many small needles and prisms occur, which are especially present in the individuals of hornblende. Calcite appears in the fissures of the rock. Titanic-iron is frequent in occurrence.

§ **144.** Spec. 3022. Hornblende rock.[2] Republic mine.

A coarse-grained rock in which hornblende is the chief constituent. Aggregations of orthoclase and a little plagioclase represent the groundmass. Alteration has already begun in the minerals composing the groundmass. Biotite in brown folia is abundant. A little quartz in irregular water-clear grains appears. Small bluish-gray prisms of tourmaline, which are strongly dichroitic, occur, but are not abundant. Hexagonal prisms and needles of colorless apatite pierce especially the individuals of hornblende. Magnetite and titanic-iron are present.

§ **145.** Spec. 1103. Feldspathic hornblende-rock.[3] Washington mine.

The aggregations of hornblende-prisms lie in a feldspathic groundmass. The single individuals are yellowish-green and bluish-green in appearance. The feldspar, in irregular grains, is mostly represented by orthoclase and composes the groundmass. They show a mosaic-like aggregation in polarized light. Larger grains of orthoclase also appear, which are sometimes twinned according to the Carlsbad-law. They contain small prisms of hornblende, grains of magnetite and brown folia of biotite. The latter mineral is widely spread through the whole rock. This rock, which is characterized by a massive structure, cannot be considered as a diorite, for the feldspar-constituent is especially represented by orthoclase. Nevertheless we cannot consider it to be a syenite, for this rock principally consists of hornblende, and further contains a groundmass, which is composed of a mosaic-like aggregation of small individuals of orthoclase. The massive and eruptive rocks never have this appearance.

These hornblende rocks represent, with regard to structure and the general character of their constituents, distinct members of the group of "crystalline schists," with the single exception that a schistose structure is entirely wanting.

§ **146.** Spec. 1087. Feldspathic hornblende-schist. (Hornblende-gneiss, Julien.[1]) Old Washington Mine.

This specimen is very rich in feldspar. Irregular grains of orthoclase and plagioclase form the groundmass, but larger ones also occur in it. The green hornblende prisms are very fresh and unaltered. Numerous folia of biotite occur. Magnetite is abundant. Distinct individuals of quartz are not present, and therefore this rock cannot be a gneiss, as Julien calls it. However, it is possible that in other hand-specimens quartz may occur as an essential constituent.

§ **147.** Spec. 2089. Hornblende-schist. Bed XIX, T. 40 N., R. 19 E., Sec. 18, 750 N., 1000 W.

The hornblende occurs mostly in the form of long, narrow prisms, which have all formed parallel to the schist-plane, and therefore no cross-sections of their individuals

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[1] Mich. Geol. Survey, Vol. II, p. 168.
[2] Mich. Geol. Survey, Vol. II, p. 204.
[3] Mich. Geol. Survey, Vol. II, 1873, p. 156.

occur. Muscovite and biotite are both present, but the latter is much more frequent in the form of large irregular brown folia. Small wedge-like crystals of titanite occasionally occur. Crystals and grains of titanic-iron are mostly surrounded by the grayish-white substance. The fissures of the rock are filled with calcite. Aggregations of small individuals of orthoclase form the groundmass.

§ 148. b. 3. *Calcareous hornblende-schist.*

The third group of amphibolites is one in which carbonate of lime represents a chief constituent. This mineral also forms a groundmass in these rocks, as is the case in "calcareous mica-schists." The small irregular grains of calcite are aggregated, and the other constituents are imbedded in this substance. Sometimes the individuals show a distinct twin-lamellation and the rhombohedral cleavage is also quite perceptible. The non-twinned grains of calcite appear of a milky-blue color by crossed nicols. Of the original formation of these individuals of calcite there is no doubt, since the other constituents have formed in it.

§ 149. Spec. 2135. Hornblende-schist. Wis., T. 39 N., R. 19 E., Sec. 11, 390 N., 620 W.

Small and delicate green prisms of hornblende are mostly aggregated and lie in the calcareous groundmass. Small single prisms of hornblende also appear, enclosed in calcite. Biotite in brown folia is frequent in occurrence.

§ 150. Spec. 2061. Hornblende-schist. Bed XIV, Mich., T. 39 N., R. 30 W., Sec. 15, 1140 N., 225 W.

Hornblende is present in very small prisms or in yellowish-green folia. The latter resemble the biotite a little, but their optical properties establish their hornblendic nature. Minute irregular grains of quartz appear. The other part of the rock is represented by an aggregation of irregular grains of calcite.

§ 151. Spec. 817. Hornblende-schist.[2] N. of Northwestern Hotel, Marquette.

This specimen is an aggregation of very small prisms of hornblende which are imbedded in a calcareous groundmass. Minute grains of quartz occur and magnetite is distributed throughout the whole rock, in which the beginning of a change into hydrated oxide of iron can be observed.

§ 152. Spec. 113. Hornblende-schist. Mich., T. 47 N., R. 27 W., Sec. 15, N. W. qr. of S. E. qr.

Besides hornblende small folia of biotite occur. Opaque grains of titanic-iron are not unfrequent, and are generally a little altered. Some colorless individuals of sahlite appear, which show a cleavage by which the pyroxenic minerals are characterized. Aggregations of calcite represent the groundmass.

§ 153. 19. Augite-schist.

(Micaceous augite-schist.)

Spec. 1170. Champion mine. It was formerly believed that augite could only occur especially in basic rocks — not in association with quartz, and not present in crystalline schists. Some time ago this mineral was observed as a constituent of some crystalline schists in Silesia and in Taunus.

The groundmass of this rock is represented by an aggregation of water-clear quartz grains, which contain only minute fluid enclosures.

Augite (sahlite) forms irregular individuals of a pale green color, which have all formed parallel to the schist plane, and, therefore, no sections cut perpendicularly to the main axis occur in the slice. Sometimes the individuals are twinned, and in consequence, the two parts of augite appear with different colors by polarized light.

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1 Mich. Geol. Survey Vol. II, 1873, p. 136.

2 Mich. Geol. Survey, Vol. II, 1873, p. 175.

Biotite is abundant. It forms irregular folia, which show a strong dichroism. The folia are mostly aggregated in clusters, but single ones also are distributed throughout the rock.

Some colorless folia and scales of muscovite are present. Magnetite occurs in sharply defined octahedra, and in irregular grains.

§ 154. 20. Chlorite schist.

Chlorite schist consists of an aggregation of folia of chlorite, but even in typical specimens it is associated with other minerals.

Chlorite generally appears in the form of pale, green colored folia or scales. Its dichroism is feeble and sometimes not easily recognizable. In polarized light, the folia appear partly in bright colors, partly in darkness, when lying parallel to the base.

The irregular shaped folia have mostly formed themselves parallel to the schist-plane, but others lie in other directions.

A great number of different minerals have a share in the composition of chlorite schists. If they are present in considerable quantity, they represent a chief constituent of these schists.

Quartz may first be mentioned. This mineral generally constitutes the groundmass in the form of the well-known aggregations. Besides this mode of occurrence, it appears also in larger grains. Feldspar, as well in the form of orthoclase, as plagioclase, is sometimes not unfrequent. By a gradual increase of this constituent at length a chlorite-gneiss would appear. Biotite is abundant, its presence being proven in nearly all specimens. Magnetite is present in the form of sharply-defined octahedra or in irregular grains. Titanic-iron, zircon, tourmaline, actinolite, etc., appear now and then. In § 155, the typical varieties of chlorite-schist will be described.

§ 155. a. *Chlorite-schist.*

Spec. 1250. Norway Portage, Michigamme river.
Spec. 2082. Bed XVIII. Mich., T. 41 N., R. 30 W., Sec. 30, 1250 N., 1750 W.
Spec. 2094. Bed XVIII. Mich., T. 41 N., R. 31 W., Sec. 23, S. W. qr. of N. E. qr.
Spec. 2097. Bed XVIII. Mich., T. 41 N., R. 30 W., Sec. 30, lot 3.
Spec. 2132. Bed XVII. Wis., T. 39 N., R. 19 E., Sec. 7, 1800 N., 1950 W.
Spec. 3055. Barnum mine.

Chlorite schist generally shows, in a thin section, a woven mass of green folia of chlorite. The size is variable — sometimes the folia are also visible to the naked eye, and then they show a bluish-gray color under the microscrope, but sometimes they are very small, and then appear in the form of minute, nearly colorless, scales.

Compact clusters of aggregated green folia sometimes occur in the loose structure of the other folia of chlorite (Spec. 2094). Quartz is abundant in the form of aggregations of irregular angular grains. They contain minute fluid-enclosures, which are not, however, abundant.

The chlorite-schist of Norway Portage is especially rich in quartz.[1]

Magnetite occurs in all specimens, and generally appears in the form of sharply defined octahedra, which may be separated from the rock when powdered by means of a magnet. It is sometimes aggregated.

Biotite occurs in simple folia, and is easy to recognize by its brown color and its strong dichroism (Specs. 2132, 2097).

The appearance of small prisms of tourmaline which cannot be seen by the naked

[1] Julien has provisionally called this rock, "Micaceous siliceous schist" (Mich. Geol. Survey Vol. II, p. 108), but it consists of chlorite, quartz and magnetite, and therefore it is a true chlorite-schist. Spec. 3055, of Barnum mine, has been called by the same author, "Gray feldspathic argillite," but it is also a typical chlorite-schist.

eye is remarkable. Zirkel[1] proved the presence of colorless prisms of a mineral which resembled tourmaline very much in appearance, in a chlorite-schist from Einsiedel in Bohemia. The prisms of tourmaline are bluish-gray in color and strongly dichroitic. They are mostly broken into several pieces, generally parallel to the base.

Zircon in reddish-brown small prisms is abundant in Spec. 2094. (See § 25.)

§ 156. b. *Quartzose chlorite-schist.*

Spec. 137. Mich., T. 47 N., R. 26 W., Sec. 33, N. E. qr. of N. E. qr.

A groundmass is present which is composed of an aggregation of small grains of quartz. Besides these, larger individuals of this mineral occur. They contain many fluid-enclosures, which sometimes show a movable bubble, and also numerous small needles and prisms of apatite occur in the pellucid quartz.

Chlorite occurs in the form of clusters of its green folia, as well as in single folia in the fissures of quartz.

Numerous small prisms of zircon are recognizable. A little calcite appears in sharply defined rhombohedra, or in irregular grains, which seldom show a distinct twin-lamellation by polarized light.

§ 157. Spec. 906. Mich., L'Anse, T. 50 N., R. 33 W., Sec. 18, N. of W. qr. post.

The quartzose grains contain some few fluid-enclosures, and besides these some microlites occur. The folia of chlorite are mostly aggregated in clusters, but also single ones appear in the groundmass and in the larger grains of quartz. Magnetite is present in irregular grains. A little feldspar (orthoclase) occurs in the form of round individuals, which are dull in appearance in consequence of the beginning of alteration. Minute scales of chlorite appear in their fissures.

§ 158. c. *Feldspathic chlorite-schist.*

Spec. 932. Mich., T. 50 N., R. 32 W., Sec. 13, near center.

This specimen is chiefly of chlorite and quartz. Magnetite occurs in distinct octahedra.

The appearance of feldspar is interesting, the presence of which had already been established by Julien.[2] This mineral does not form here sharply defined crystals, but is present in round and angular grains. These individuals are enclosed by lenticular masses of the folia of chlorite, giving rise to the conjecture that the feldspar may have existed before the formation of the chlorite. Feldspar is represented as well by orthoclase as by plagioclase. The twin-lamellation of the latter mineral can be particularly well recognized by crossed nicols.

§ 159. d. *Micaceous chlorite-schist.*

Spec. 729. Mich., Spurr Mountain Iron Range, T. 48 N., R. 31 W., Sec. 23.

This rock is remarkable especially from the presence of the beautiful pseudomorphs of chlorite after garnet. Pumpelly[3] has made exact microscopical investigations on this subject.

No quartz is recognizable, and therefore this specimen presents in a thin section only a woven mass of green folia of chlorite.

Biotite occurs in the form of numerous brown folia, which are strongly dichroitic and, on an average, 0.4 millimetre in length and 0.1 millimetre in breadth. The folia are laminated in sections parallel to the main axis. Muscovite is not unfrequent. It forms colorless folia of the same size as those of biotite, and appears in bright colors by

[1] Mikroskop. Beschaffenheit, etc., p. 474, 1873.
[2] Mich. Geol. Survey, Vol. II, p. 104.
[3] American Journal of Science and Arts, 1875, July, Vol. X.

polarized light. Many grains and plates occur, probably partly magnetite and partly titanic-iron.

§ **160.** Spec. 2091. Bed XVIII, Wis., T. 40 N., R. 19 E., Sec. 18, 900 N., 100 W.

Besides chlorite and quartz, biotite is abundant. Its brown folia are widely spread over the whole rock and easy to recognize by its characteristic properties. Magnetite is present in numerous irregular grains. We also observed a dust-like non-crystallized substance in all parts of the thin section.

§ **161.** Spec. 2078. Bed XII, Wis., T. 39 N., R. 19 E., Sec. 11, 200 N., 760 W.

This specimen represents chiefly an aggregation of green folia of chlorite in which numerous brown folia of biotite have formed. Irregular grains of calcite appear here and there. A grayish, dust-like, non-crystallized substance is also present, as is the case in Spec. 2091.

§ **162.** Spec. 537. Mich., T. 47 N., R. 27 W., Sec. 11, S. W. qr. of S. W. qr.

Spec. 931. Mich., T. 47 N., R. 27 W., Sec. 15, S. W. of N. W.

These specimens represent chiefly a compact woven mass of green folia of chlorite.

Brown folia of biotite are abundant, sometimes in nearly the same quantity as chlorite. Some colorless prisms of apatite occur. The quartz in minute grains contains a few fluid enclosures.

Feldspar (especially orthoclase) appears, and its substance is filled with minute scales of chlorite. It is very little altered. We may finally mention the presence of roundish grains of garnet and of sahlite. In Spec. 931 small folia of muscovite are recognizable.

§ **163.** e. *Actinolitic chlorite schist.*

Spec. 2227. Upper falls, Pine river, Wis., T. 39 N., R. 18 E., Sec. 30.

The groundmass consists of an aggregation of small grains of quartz. Numerous colorless prisms of actinolite occur in association with the green folia of chlorite. It is, however, quite easily recognized by its characteristic properties, as we have shown in § 12. Brown folia of biotite appear now and then. The black, opaque grains, which are irregularly distributed throughout the whole rock, are magnetite.

§ 164. 21. Talc-schist.

Spec. 1081.[1] Old Washington mine.

Spec. 3074.[2] Grace Furnace, Marquette.

Talc-schist consists of scaly and laminated aggregations of talc. The structure of these schists is always very fine and scaly. The single folia of talc are colorless and mostly fringed.

Spec. 3074 from Grace Furnace resembles much a talc-schist from Schwarzenbach, in the "Fichtelgebirge," Bavaria. It consists chiefly of white folia and scales of talc, which are irregularly aggregated and represent a felt-like mass. Minute grains of quartz occasionally appear. Small grains of magnetite occur, each surrounded by brown, hydrated oxide of iron, occasioned by the oxidation of the magnetite. Besides these minerals, hexagonal folia of hematite, bluish-gray prisms of tourmaline and small crystals of zircon are present.

In Spec. 1081 aggregations of angular grains of quartz form the groundmass, with which the folia and scales of talc are interwoven. Magnetite appears in numerous sharply defined octahedra with which a yellow, transparent, unknown mineral, is sometimes associated. This mineral also occurs in single prisms; it suggests zircon but has not the properties of that mineral. Green folia of chlorite are sometimes present.

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[1] Altered biotite schist (Julien).

[2] Talcose argillite (Julien). See talc in the two preceding chapters. T. B. B.

§ 165. 22. Eklogite.

Spec. 1091. S. E. of Old Washington mine.[1]

Spec. 3027. Washington mine.[2]

A great number of different rocks have been called "eklogite." According to the investigations of R. v. Drasche,[3] this rock consists either of garnet and omphacite, a variety of augite, or of a hornblendic mineral nearly as related to smaragdite as to the common hornblende.

Besides garnet, it is composed of a hornblendic or an augitic mineral.

Eklogite is not very widely distributed, but it occurs in association with Archæan rocks.

We may now mention the occurrence of eklogite from the iron-region of Lake Superior.

Spec. 3027. Washington mine.

Garnet is plainly visible to the naked eye in a thin section cut perpendicularly to the schist-plane. This mineral forms, microscopically observed, irregular grains or distinct crystals in regular hexagonal or rectangular sections. The individuals are highly fissured, and contain numerous needles and prisms of actinolite. They are of a very pale-red color.

The hornblendic constituent is represented by actinolite, which is of a pale-green color, or colorless in appearance. The prisms of actinolite are fissured parallel to the main axis, and their ends are ragged and uneven. The needles and prisms are partly ranged parallel to each other, and partly lie confused. The numerous irregular black grains, which are widely spread through the whole rock, are magnetite.

Spec. 1091. S. E. of old Washington mine.

The same constituents are present in this specimen as in the before mentioned ones. The prisms of actinolite are larger and more distinctly recognizable. Some folia of brown biotite occur. The grains of garnet are also larger, but always irregularly formed. The garnet holds crystals of magnetite and small needles of actinolite in great numbers. Large sharply defined octahedra of magnetite are richly dispersed throughout the whole rock.

Julien (l. c.) has called these rocks "brown anthophyillite-schist." As I have mentioned before (§ 12), this constituent belongs to the monoclinic system, and is a hornblendic one according to its physical properties.

It may seem strange that these rocks have not been called "garnetiferous actinolite-schist or rock," but in consequence of their transition into true garnet rock,[4] as is also the case with eklogites of Saxony, I preferred the name "eklogite." A rock which has as constituents, actinolite and garnet, has quite as just a claim to be called eklogite, as one of which the constituents are hornblende and garnet, or smaragdite and garnet. The cases are perfectly parallel, as these rocks are also intercalated between the Archæan schists.

§ 166. B. Fragmental-rocks.

This class of rock comprises all those which have been formed mechanically out of the materials of older rocks. The fragmental-rocks, therefore, are made up of sand, pebbles, clay, etc., which are deposited especially as a sediment. These rocks are not of frequent occurrence in the Archæan formation, but, however, they occur as well in the lower as in the upper part of the series.

By their structure and composition we can distinguish clay-slates, sandstone, and chert-breccia amongst the fragmental-rocks of the iron region of Lake Superior.

[1] Mich. Geol. Survey, Vol. II, p. 91.

[2] Mich. Geol. Survey, Vol. II, p. 205.

[3] Tschermak. Mineralog. Mittheilungen, 1871, Vol. II, p. 58.

[4] There has been no true garnet rock in quantity observed in the iron bearing series. T. B. B.

§ 167. 23. Clay-slate.

Clay-slate consists principally of argillite, but it is also rich in other substances, and crystalline elements, as will appear below. According to the nature of accidental constituents, we are able to distinguish: Clay-slate (typical varieties), carbonaceous clay-slate, novaculite and micareous clay-slate (phyllite). The latter sometimes shows a transition into mica-schist.

§ 168. a. *Clay-slate.*

Spec. 983. Mich., T. 50 N., R. 32 W., Sec. 13, near center.
Spec. 998. Slate river, Mich., T. 51 N., R. 31 W., Sec. 21.
Spec. 807. Sec. 11, T. 47 N., R. 26, Michigan.
Spec. 814. Chocolate flux quarry, near Marquette.
Spec. 2067. Bed VI, Mich., T. 40 N., R. 30 W., Sec. 32, 420 N., 400 W.
Spec. 2147. Bed XVIII, Wis., T. 40 N., R. 18 E., Sec. 14, 1375 N., 750 W.
Spec. 2237. Bed XVI, Wis., T. 39 N., R. 18 E., Sec. 28, 1325 N., 1050 W.

Before the microscope was adopted in lithological investigations, the geologists maintained the opinion that clay-slates only contained those substances which were formed from destroyed and decomposed constituents of rocks, with the exception of some minerals which were visible to the naked eye.

The exhaustive work of Dr. Zirkel[1] was destined to give us fresh light on this matter. His investigations proved that clay-slate unquestionably contains crystalline elements, especially in his examinations of Devonian and Silurian specimens,[2] all coming from quite different localities; he found them all filled with thin yellowish-brown needles. These needles seldom reach a breadth of more than 0.003 millimetre, and sometimes a length of 0.03 millimetre. They are generally straight, but curved ones, however, do occur. Two, three or more needles sometimes meet, forming a fork-like or star-like aggregation. In another case, quite thin ones cluster at the ends of a thicker one in the form of a zigzag. These crystals are nearly all placed parallel to the original slate-plane. In the direction of their longitudinal axis, they are, however, distributed confusedly in different portions. Sometimes they lie singly, at others they aggregate in thick clusters.

The mineralogical nature of these crystals cannot be determined on account of their minuteness. They are supposed to bear a little resemblance to hornblende. It is remarkable, that in all of the numerously examined Silurian and Devonian clay-slates these yellowish-brown needles were wanting.

Dr. Zirkel recognized as a further crystalline element in the clay-slates, pale-yellow folia of a mica, or talc-like mineral, which correspond with those which are recognized as constituents of "phyllite" (micaceous clay-slate). This mineral is especially found in those places where the before-named crystals are numerous. In many clay-slates grains of pyrite appear, and around these crystalline folia of mica have often clustered. In other varieties of clay-slate, small transparent grains of a reddish-brown color occur, which are supposed to be oxide of iron. They are too small to admit of an examination of their optical character. Other black irregularly shaped substances seem to be coal dots. The carbonate of lime, which is recognized by its effervescence, when treated with hydrochloric acid appears distinctly in the clay-slate as microscopical scales of calcite.

Till now we could only observe with the aid of the microscope proper fragmental elements, which help to form the clay-slate. Firstly, irregular and fragmental folia and scales of a talc or mica-like mineral, consisting of delicate lamellæ, which are bent a little. Secondly, there occur irregular particles of quartz, and then fragments of feldspar partly decomposed, which are very seldom recognizable.

[1] For a continuation of Dr. Wichmann's investigations of these clay slates, see Journal Geological Soc., London, Feb., 1879. T. B. B.

[2] Pogg. Ann. CXLIV, 1871, p. 39, and Mikrosk. Besch., 1873, p. 490.

In the clay-slate silica shows a peculiar appearance. Colorless places in the thin sections are sometimes observed, which are mostly of an egg-like shape. In polarized light they appear in bright colors. They often contain numerous fluid-enclosures, which are arranged in rows, and which are doubtless quartz. This form of quartz has nothing to do with the before-mentioned fragmental grains. Followed, their outlines run into the surrounding substance of the rock.

A colorless substance, which is especially rich in crystalline elements, is found amongst the constitutents of clay-slates. Like cement, it penetrates everything. It is of a real homogeneous and amorphous constitution, and is recognized by polarized light to be perfectly isotropic. This material represents probably an opaline substance, or it may, perhaps, be a porocline amorphous silicate.

Besides these classical investigations of Dr. Zirkel, those of Dr. Auger are also remarkable. He not only confirmed the results of the labors of the before named investigator, but recognized in tourmaline [1] a new crystalline constituent of some clay-slates. He observed this mineral in the form of a bluish-gray, or of pale-green prisms, the ends of which, in most cases, manifested different forms — one end being pointed by an acute angle, the other being generally blunted by a right angle plane. On an average they are 0.5 millimetre in length and of 0.1 millimetre in breadth. Now and then such a prism is broken into two or more pieces, which are placed near to one another, and lie parallel to the main axis. This is a proof that these pieces belong together and had formerly composed one crystal. The basic cleavage is distinctly recognizable and may possibly have favored the breaking of the prisms before the solidification of the rock. With regard to its optical properties, this mineral refracts the light doubly, and is strongly dichroitic. These facts can only be true of tourmaline.

We may mention finally the investigations of Dr. G. R. Credner[2] on the crystalline constituents of clay and clay slate, but which, however, are not of great importance. He recognized the presence of the same crystalline constituents which had been found in the Silurian and Devonian clay-slates, in the younger clay slates from the carboniferous period to the tertiary, but in a proportion decreasing with the age of the rocks.

§ **169.** The question of the formation of the aforementioned crystals (clay-slate-needles) is of great importance in view of the origin of clay-slate. Dr. Zirkel has expressed the opinion that these needles were formed during the deposition of the clay-slate as mud, and before the solidification of the rock. He says:[3]

"After the recognition of these facts, there arises the question, whether the microscopical half-crystalline state of the clay-slate is a more or less original one, whether the rock has obtained this structure in the beginning (be it immediately during its deposition as mud, or at least before its solidification), or whether, on the other hand, this half-crystalline condition has been developed in the slate long afterwards, during the following geological periods, by additional and secondary metamorphic processes of any kind, as is theoretically the case for the microscopically wholly crystalline schists. Every accurate examination of the thin sections, every scrupulous observation of the number, position and distribution of the crystalline elements (which can scarcely have afterwards grown in the solid rock), has thus far always ended with the conviction, that the first of these alternatives is just as probable as the latter is improbable."

Although in these words a distinct opinion has been expressed, Dr. G. R. Credner adopted the view that these crystalline elements are the results of a "chemical precipitation of the ocean."

Delesse,[4] in speaking of the investigations of Dr. Zirkel, says:

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[1] Tschermak. Mineralog. Mittheilungen, 1875, p. 162.
[2] Zeitschrift f. d. Gesammten Naturw., 1875, p. 507.
[3] Mikroskop. Beschaffenheit, p. 493.
[4] Revue de Geologie dans les Annees, 1873-74. Paris, 1876, p. 203.

"It appears that the crystalline structure that is observed in the slates is not to be looked upon as an original substance, for to admit that it goes up to the deposition of the slate would be to go back to the theory of Werner; it is, however, possible that the crystalline structure of the schist has developed itself at the epoch of its consolidation, and is the result of the compression that it has undergone; in one word, of its metamorphism."

§ **170.** After having given the results of the microscopical investigations of clay-slates of the Devonian and Silurian ages, it must be interesting to examine those of the Huronian period. In no specimen could the needles, which are characteristic of the Silurian and Devonian clay-slates, be found; but a mineral was found, however, easily recognizable and present in great quantities in the thin sections. This is tourmaline, as already proved by Dr. Auger (l. c. p. 163) in some German specimens, though only in small quantities.

Tourmaline represents, sometimes, a chief constituent in the clay-slates of the iron region of Lake Superior. It appears in the form of small prisms of 0.015 to 0.03 millimetre in length, and 0.003 to 0 025 millimetre in breadth (Spec. 2067). On the ends of the prisms, rhombohedra often appear in combination and sometimes also as the base. Crystals even occur there, which show a distinct hemimorphism, which is an especial characteristic of this mineral. The prisms are of a bluish-gray color, the larger ones often darker colored, but all showing a very strong dichroism. Completely formed individuals are not frequent; they have been mostly broken into several pieces. Generally the fragments which belong to each other are found close together, so that this circumstance enables us to conceive what the entire crystal would be. Sometimes the fragments are linked in the form of a chain. In Spec. 2067, I could recognize an individual which had been broken into eight pieces, which had all been cemented again by the clay-slate substance.

The question now arises as to the origin of these crystals of tourmaline. We can assume four possibilities for their formation:

1. They may be the remains of the original rock, from the destruction of which clay-slate has been formed.
2. They may be the result of precipitation from the ocean.
3. They may be the result of a metamorphism.
4. They may have been formed during the deposition of clay-slate, as mud.

1. If tourmaline had been a constituent of the original rock, the decomposition of which has induced the formation of clay-slate, it must have been destroyed in the same manner as was the case with quartz. But the prisms of tourmaline possess so sharply defined outlines, that we cannot possibly consider it as a constituent of the original rock. In clay-slates, quartz is only to be found in the form of small fragments; feldspar is very indistinctly recognizable. In consequence of these facts, we may safely entertain the opinion, that such a theory on the origin of tourmaline cannot be maintained.

2. If we could consider these prisms of tourmaline as precipitated from the ocean, we should agree with the theory which Dr. G. R. Credner has given in his paper on the crystalline elements in clay-slates and clays. But such an explanation cannot be considered as sufficient. Taken in the abstract, it is incredible that a mineral, composed of so many different elements as tourmaline is, could be formed in the ocean. We have no proof that the ocean is capable of inducing the precipitation of crystals of any mineral, and until such a proof be given we can never accept such a theory, except as to those which are soluble in water.

3. If we consider the presence of tourmaline as the result of a metamorphism which had taken place in the rock, we should agree with the opinion expressed by Delesse. We have never doubted that the formation of minerals as a result of metamorphism is possible; but in this case such an opinion is not acceptable. As we have formerly

mentioned, the prisms of tourmaline are generally broken into several pieces. These fragments belong to one crystal, and in our opinion we can recompose such a crystal. If a metamorphism had taken place at the time of the formation of these individuals, the rock must have already been solid; and if, later, the crystals were broken by mechanical processes, the substance which cemented the single fragments must have been a crystalline one. But the substance which cements these fragments consists of amorphous clay, and therefore the crystals cannot have been produced by metamorphism.

4. Having shown, as I believe, the impossibility of the three before mentioned hypotheses, I have only to express my agreement with the opinion that the formation of tourmaline took place in the clay-slate whilst in its state of mud. Dr. Zirkel has expressed this opinion in relation to the development of the "clay-slate needles" of Devonian and Silurian clay slates. We can accept this theory in every respect as to the formation of tourmaline in the Huronian clay-slates from the iron region of Lake Superior.

The opinion that metamorphism can take place in clay-slate, is by no means to be disregarded. I consider all crystalline schists to be the results of a metamorphism, and from this arises the opinion that three different stages had existed before a rock arrived at its present state: 1st. The deposition on the bed of the ocean. 2d. The formation of crystalline elements during its state as mud. 3d. The metamorphism by which the rock enters into a crystalline state. The latter takes place by gradual transitions. These transitions may be seen by careful observation in that of micaceous clay-slate (phyllite) into mica-schist. The same crystalline elements, such as tourmaline, hematite, etc., are present in most crystalline schists.

Other crystalline elements appear in all clay-slates. We can now especially mention the occurrence of hematite in clay. Its simple folia are blood-red in color, and sometimes represents sharply defined hexagons (Spec. 161). The scales and folia are generally rounded, and often widely spread over the whole rock (Spec. 814, from the Chocolate Marble quarry).

Small colorless folia and scales of mica are more or less abundant in the different specimens. They are very irregular and often fringed. Sometimes they are aggregated in clusters, or form star-like aggregations. Some folia are often very similar to chlorite (Spec. 2237).

Small cubes of pyrite occur now and then. Carbonate of lime is present in some specimens in the form of minute colorless scales. Spec. 983 is crossed by many small veins of calcite, which are naturally of secondary origin.

The appearance of crystalline quartz is remarkable, and by this peculiarity it is readily distinguishable from the fragmental quartz grains. In some parts fine aggregations of grains appear in polarized light. They show the same appearance as is characteristic of the quartz in the crystalline schists, where it forms the groundmass. I consider this state as the beginning of a change into a crystalline rock, and the more a clay-slate is of a crystalline nature, the more it shows the presence of such aggregations. This condition is comparable with the act of crystallization of a hyaline substance. There is as just a claim to establish the act of crystallization out of a porodine state. The presence of amorphous silicic acid, or of an amorphous silicate, has already been shown by Dr. Zirkel, and the same substance is present in the Huronian clay-slates. It is very possible that this porodine substance has entered into a crystalline state, and in consequence of this, the before mentioned aggregations of quartz appear.

In Spec. 814 many small rod-like colorless crystals appear, which lie parallel to the slate planes.

Distinct fragmental elements are sometimes recognizable. In Spec. 807 there appear fragmental grains of quartz, and also some which resemble feldspar very much. In Spec. 2147 fragmental grains of quartz are also present, etc.

Minute and irregular black dots of coal occur in more or less quantities in all specimens. If these dots represent a chief constituent, such a rock is called "carbonaceous clay slate."

Brownish amorphous clusters of hydrated oxide of iron are irregularly distributed. Spec. 2237 is especially filled with such clusters.

§ 172. We may finally mention the occurrence of "phyllite" (micaceous clay-slate). These rocks represent an intermediate state between clay-slate and mica-schist. Only two specimens could be examined.

Spec. 692. Boulder, Ann Arbor, Mich. (Origin unknown.)

Spec. 1526. Mich., T. 46 N., R. 41 W., Sec. 13, W. branch of Ontonagon R.

These rocks also contain prisms of tourmaline. Small folia and scales of hematite, and folia of mica are especially abundant. Aggregations of quartz are frequent, but, however, a clay-slate substance is recognizable. Spec. 692 contains, microscopically observed, staurolite of a yellow-color. Rounded grains of quartz appear in the substance of the latter mineral, and this occurrence of quartz is an especial character of staurolite.[1]

§ 173. b. *Carbonaceas clay-slate.*

Spec. 1163. S. C. Smith mine, Michigan.

Spec. 2134. Bed XIII, Wis., T. 39 N., R. 19 E., Sec. 11, 250 N., 730 W.

Spec. 2169. Bed XVIII, Wis., T. 40 N., R. 18 E., Sec. 9, 800 N., 450 W.

Spec. 3064. L'Anse Iron range, Mich., T. 49 N., R. 33 W., Sec. 9.

In a thin section, a greater part of the rock appears to consist of carbonaceous matter. Between the irregular black dots the clay-slate substance is recognizable. The coal either forms compact clusters, or is distributed in irregular small dots. Sometimes they are placed parallel to the schist-plane (Spec. 2134). The clay-slate substance seems generally to be perfectly isotropic, but by polarized light some crystalline irregular grains of quartz appear (Specs. 2134, 2169). Some folia of a mica-like mineral occur. Sometimes irregular grains of a yellowish-green color are present (Spec. 2134), which very much resemble epidote.

The presence of carbonaceous clay-slates among the Huronian rocks, seems to indicate the presence of much organic life at the period of their formation.[2]

§ 174. c. *Novaculite.*

Spec. 3013. Morgan Furnace Quarry, Marquette, Mich.

The clay-slates which are rich in quartz, and in consequence are very hard, are called novaculite. A clay-slate substance is also recognizable in a thin section of this rock, and it is filled with a dust-like material and a little hydrated oxide of iron, but the whole rock shows a very crystalline structure and composition. The well known aggregations of irregular quartz grains are distinctly recognizable by polarized light. We observe many small, colorless scales of a foliaceous mineral, which is probably talc. They all run parallel to the schist plane. Prisms of tourmaline, generally broken into several pieces, occur here and there. This mineral also appears in the form of fine microlites. Hematite, in the form of small blood-red folia, is irregularly distributed throughout the whole rock.

The presence of garnet is remarkable. This mineral occurs in small, irregular grains, which are quite distinguishable. By polarized light they can be recognized as perfectly isotropic bodies. Dr. Zirkel established the fact of the presence of numerous grains of garnet, which showed the composition of "spessartine" in a "whetstone" from Recht in the Ardennen.

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[1] Zirkel, Mikroskop. Beschaffenheit, p. 201.

[2] T. B. Brooks in American Journal of Science and Arts, Vol. XI, March, 1875.

§ 175. 24. Sandstone.

Sandstones represent an important division among the fragmental rocks. They consist chiefly of fragments of quartz, which have been cemented by different substances. Many sandstones when examined by the naked eye are like quartzite, but their fragmental character can be shown distinctly by the aid of the microscope. In quartzite, an interstitial substance can never be present. The greater part of the examined specimens have been called "quartzite."

The cement which joins the fragments of quartz together, is sometimes varied in its nature. It may be represented by carbonate of lime, by hydrated oxide of iron, or by a silicate of protoxide of iron, etc.

176. a. *The cement consists of carbonate of lime.*

Spec. 1621. South of Lake Hanbury, Menominee region.
Spec. 2257. Mich., T. 39 N., R. 29 W., Sec. 16, 1575 N., 30 W.
Spec. 2258. Mich., T. 39 N., R. 29 W., Sec. 16, 1540 N., 30 W.

These specimens are all from the same bed.

The quartz-grains are perceptible by a glance through the microscope. Their angular and rounded forms point to the fragmental origin of their individuals. These fragments of quartz are partly filled with numerous rows of fluid-enclosures, and partly contain delicate black needles.

The cement which joins the fragments together, consists for the greater part of carbonate of lime, which in most of them has the appearance of distinctly recognizable calcite. There are also present sharply defined rhombohedra, which surround the grains of quartz as irregular individuals, and which in many cases are twinned. Finally carbonate of lime forms small regular grains, which compose the greater part of the cement.

The scales and rhombohedra of calcite show in polarized light the characteristic pale-blue color, while the lamellæ of the twinned individuals sometimes show different bright colors. Spec. 2258 is rich in twinned individuals.

In the before mentioned chalky cement, numerous small black particles, irregularly distributed, are to be observed. They are mostly aggregated in small clusters, but also occur singly. This mineral is not soluble in hydrochloric acid, and therefore cannot be magnetite. If small pieces of the rock are melted by the aid of the blow-pipe these black particles disappear, and they are therefore probably carbonaceous.

These sandstones are sometimes crossed by small veins of quartz. They consist of aggregations of small grains, and sometimes also contain scales of calcite and minute coal dots.

§ 177. b. *The cement consists of hydrated oxide of iron.*

Spec. 2259. Mich., T. 39 N., R. 29 W., Sec. 16, 1300 N., 30 W.

This specimen is richer in quartz than the before mentioned; the cement being in a less quantity.

The fragments of quartz here contained consist of rounded and angular grains. They are partly filled with numerous small fluid enclosures, often dust-like in appearance under low power, and partly contain numerous small bristle-like microlites.

The cement which joins the fragments of quartz, seems to consist chiefly, in this case, of hydrated oxide of iron. It represents a dirty-brown, amorphous substance, in which numerous small black coal dots are imbedded.

This rock falls to pieces, when boiled in hydrochloric acid, and forms a sand consisting of grains of quartz, whilst the hydrated oxide of iron dissolves in the acid.

This sandstone is sometimes also crossed by small veins of quartz, which show under the microscope the same appearance as those mentioned in § 176.

It appears as if metamorphic action had taken place in this rock. Probably the cement consisted formerly of carbonate of lime, for we still recognize sharply defined rhombohedra, which now consist of hydrated oxide of iron. There can be no doubt, that these rhombohedra formerly represented crystals of calcite.

§ **178.** c. *The cement consists of a silicate of protoxide of iron.*

Spec. 1447. Mich., T. 47 N., R. 46 W., Sec. 12, S. half.

The chief constituent of this rock is quartz, which appears in the form of angular grains, partly filled with numerous fluid enclosures, microlites, etc.

Besides this, feldspar occurs, also present in the form of irregular grains. It is remarkable that the individuals of this mineral are very fresh and unaltered. Orthoclase appears with bright colors in polarized light, and plagioclase shows its beautiful and characteristic twin-lamellation.

Some grains of magnetite are recognizable.

The cement which joins the before mentioned constituents of this rock together is homogeneous in appearance. It is of a green color, and perfectly isotropic, as may be seen in polarized light. In consequence of the greenish color and of its homogeneous nature, I consider it to be a silicate of protoxide of iron. On finishing the microscopical examination of this rock, I had no material left from which to determine its chemical composition. Throughout the cement, black, irregular dots of coal are irregularly distributed. Some minute scales of carbonate of lime occasionally appear.

§ **179.** d. *The cement consists of an opaline substance or an amorphous silicate.*

Spec. 242. Mich., T. 47 N., R. 26 W., Sec. 3, S. W. qr. of N. E. qr.

The angular and rounded grains of quartz contain numerous fluid-enclosures. Some individuals of orthoclase are present, which are sometimes twinned according to the Carlsbad-law.

The cement is colorless in its substance and amorphous. It is uncertain whether it consists of an opaline substance or represents an amorphous silicate.

Numerous folia and scales of a mica-like or chloritic mineral are imbedded in this cement. Irregular clusters of hydrated oxide of iron occur. Small, black particles are distributed through the whole rock, which are carbonaceous.

§ 180. 25. Chert-breccia.

(Hornstone Breccia.)

Spec. 1487. Sunday Lake outlet, Mich., T. 47 N., R. 45 W., Sec. 18, W. side.

Chert is always composed of a crystalline aggregation of small quartz-grains, as may be seen in polarized light.

This rock consists of irregular, angular fragments of greenish-gray chert. They appear colorless in a thin section, but, microscopically observed, the fragments are furnished with many enclosures. Sharply defined rhombohedra are especially present in great numbers. These crystals possess a rough surface, and belong probably to calcite. They often contain a dust-like substance. The individuals are sometimes aggregated in clusters, which then represent star-like aggregations. The outlines of the fragments of hornstone are also surrounded by calcite, and the ends of these reach into the before named fragments.

Fluid enclosures are abundant in some grains. Small, nearly colorless needles and scales occur everywhere, and green folia of chlorite are not unfrequent.

The substance which cements the fragments of chert seems also to be a siliceous one. It becomes transparent in some parts of a thin section only, and here we recognize it as consisting of quartz, which is filled with numerous particles, and irregular grains of calcite. Besides this a dust-like substance is present, in consequence of which the cement is not pellucid. Some irregular folia of chlorite occur, and also a black opaque substance.

APPENDIX A.

Letters and Notes of Dr. T. Sterry Hunt *on the iron-bearing and associated rocks of the Marquette region, and comparisons with the Archæan of Canada and of the Eastern United States.*[1]

Extracts of a letter to Prof. Alex. Winchell, dated Montreal, Nov. 26, 1869, with regard to certain Huronian greenstone rocks from Northern Michigan, sent the author for examination: "My own observations on the Huronian of Canada date back fifteen or twenty years, and were made on specimens collected by Mr. Murray in his surveys. I have, however, since studied with much care the similar rocks formed in the Laurentian [Norian, then included as Upper Laurentian] and the (so-called) altered Paleozoic areas of Eastern Canada and elsewhere. In no case does the impossibility of giving distinct names to mixed crystalline rocks present itself more forcibly than with the present class. They are, for the most part, mixtures of an anorthic feldspar with an amphibolitic mineral, generally pyroxene or hornblende, but by the disappearance of the feldspar, passing into pyroxenite or amphibolite; while, on the other hand, the feldspar sometimes constitutes ninety-five per cent. of the mass, and we have something near to a normal anorthosite rock. Again, the feldspar ranges from anorthite to oligoclase, and even to albite, while the amphibolic element may be either pyroxene or hornblende, or in some cases a mixture of the two. In many instances this exhibits a sort of degeneration, indicated by a less degree of hardness, and passes into more or less hydrated and aluminous mixtures, related to chlorite or delessite in composition, and this, in some cases, while still retaining the form of hornblende or diallage. Add to this the great variations in texture, from coarse, apparently granitoid mixtures, to fine impalpable aggregates like some greenstones, whose constituent minerals can only be determined by ultimate analysis. Fortunately, these various rocks so pass into each other that their minute definition is of no great consequence. For these mixed, partly feldspathic rocks, we have but three or four definite names, dolerite and diabase for pyroxenic, and diorite for hornblendic felsites (anortholites)." To this follow descriptions of various specimens, designated as diorites of various characters, chloritic schists, and chloritic diorites, sometimes amygdaloidal. Reference is also made in the letter to the Geology of Canada, published in 1863. Chapter XX. See pages 602–612.

The general results of these examinations and of those of subsequent collections, are set forth in a subsequent letter of Dr. Hunt to Major Brooks, dated Montreal, Feb. 22, 1871, which is subjoined.

Montreal, *Feb. 22, 1871.*

My Dear Sir: — Various circumstances have combined to make me delay so long any reply to your letters of Nov. 29 and Dec. 6. I find you are waiting my conclusions, some of which are very interesting and important. You remark about the *mica-schists* as being supposed by me wanting in the Huronian of Canada, and you send me Nos. 1215, 1154, 1152, 1153. Now I have for some time past recognized a *mica-schist series* which I supposed to overlie the Huronian, in fact the *White Mountain series*, provisionally named by me Terranovan [and since called Montalban]. See Am. Jour. July, 1870.

[1] They should have appeared in my Mich. Geol. Report, Vol. I, 1873. The specimens referred to by Dr. Hunt are in my collection now deposited in the Amer. Museum of Natural History, New York. — T. B. B.

I was therefore delighted to find in the specimens just named well-characterized White Mountain mica-schists, holding garnets and well defined crystals of staurolite [1153]; while the peculiarly knotted mica-schist is not less characteristic.[1] These rocks are abundantly spread to the north of Lake Superior, as last years collections show me; but although I have not there been able to fix their relation to the Huronian diorites, talcose schists, iron ores, etc., I conclude, from the facts seen near Portland in Maine, and those described by Rogers in Penn., that they are overlying rocks and in some cases at least unconformably so. You say that "they are the youngest rocks in the region belonging to the Huronian."[2] I suspect that they belong to the same series. I distinguish three crystalline gneissic series: I. Laurentian (not to speak for the present of the Labrador), II. Huronian, III. Terranovan [Montalban]; these being respectively in the United States, the rocks of the Adirondacks, the Green Mountains and the White Mountains. I hope you will be able to decide whether there is any want of conformity between II and III in your region.[3] I should mention that in Hastings Co., Ontario, the three series all are represented, and that there is apparently a stratigraphical break between each.

The collections sent last year from Smith [since called Republic] Mt. and vicinity, are also members of what I regard as the III series, and quite unlike the Huronian type II. I have laid out before me 580, 584, 585, 586, 588, 590, 593, 597, 599, 601, 603, 604, 605, 606, 608, 615, 616, 620, 621, 626, 627, 628, 629, 634, 635, 636, 638,[4] all of which I conceive belong to III. The dark mica-schists 580, 593, 590 (with garnets), 606, do., the mixed hornblende (actinolite), with mica and garnet, 620, and the peculiar mica-schists, 635, 636, 638, are noticeable. Many of these rocks are very quartzose, as 599, 604. Feldspar is occasionally developed, giving a gneiss, which is seen in 619, and better in 628, in which the white cleavable orthoclase is developed so as to form a porphyritic gneiss. I find also a small specimen, 1174, which has the characters of the series III, and I shall be pleased to hear something of its stratigraphical relations,[5] as well as that of the numbers 580 to 638. It will be most important to know their relations to the ordinany Huronian type of rocks, II, and to learn whether, like 1215, 1151–1154, they belong to the summit of your series of crystalline schists.

As regards series II, which was in 1862 declared by Macfarlane to be the same with the Green Mt. group, I have for some time been of that opinion, and have briefly expressed it in a paper on the rocks of E. Mass., read last October to the Bost. Nat. Hist. Soc. (not yet published), which compares the dioritic, chloritic and hornblendic rocks of the two series. Their copper, nickel and iron ores are characters in common. My opportunities for studying the Huronian had been very imperfect, as Mr. Murray's collections were so, and were made many years ago, and since remain, with few exceptions, packed away. It was not therefore till I saw the Huronian rocks displayed along the coast of New Brunswick, that I realized how much they were like the Green Mt. rocks, all of the types of which may be found on the Bay of Fundy from Eastport

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[1] Just as this manuscript was leaving my hands, I was enabled, through the kindness of Prof. C. H. Hitchcock, to examine hastily his suite of New Hampshire rocks in the Amer. Mus. of Nat. Hist., N. Y. Certain Paleozoic crystalline rocks embraced by him under the name *Coös group*, seemed to both of us to have more lithological resemblance to my mica-schists (bed XIX) than to the older Montalban rocks. The presence of the two collections of N. H. and Mich. rocks in the same building enable the comparison to be very satisfactorily made. — T. B. B.

[2] In the Menominee and probably Marquette regions, a younger, heavy and apparently conformable granitic bed has been made out, which gives off dykes into the underlying schists.— T. B. B.

[3] They are unquestionably conformable over a wide area. — T. B. B.

[4] All these specimens are Huronian except, perhaps, Nos. 606, 616, 628, and belong to the middle and lower divisions, and are mostly banded ferruginous schists, greenstones, mica schists and quartzites. — T. B. B.

[5] From bed X, Middle Huronian.— T. B. B.

to the head of the bay. The same rocks are equally well seen in Hastings Co., 40 miles from L. Ontario.

Your Michigan slates, 1046, 1051, and 1081, 1176, 1164, greenish, unctuous, talc-like in feeling, are just like those which are with our iron ores in the Green Mountain chain. Again, the diorite rocks, 504, 508, 69, the latter with epidote and calcite in the same, are very typical varieties; 508 is a very magnesian diorite, as I found by a partial analysis, and the film in the joints of the rock owes its fine, rich green to chromium, which seems to be a common accompaniment of the magnesian rocks of this group. I should expect the serpentine of Presqu' isle to be chromiferous.[1] The diorites along the shore of the Bay of Fundy are associated with chromiferous serpentines; 1214 is a greenish micaceous schist with garnets, and 295 an obscure rock of the same kind; 1097 is a scaly chlorite with garnets. It is, however, difficult, if not impossible, to define separately the various types of these rocks, and one can do little more than name, as lithologists have generally done, the few well marked and characteristic forms, leaving the great mass in a sort of chaos. The general character of the great groups among the crystalline rocks are, however, well defined. Among your rocks is an argillite with the limestone, a reddish, unctuous rock, which I recognize as not unfrequent in the same position with us in Canada, and also in Rhode Island.

There are four other argillites, 1201, 238, 264, 358, all showing a distinct cleavage, independent of the bedding. I should like to know their history and their geological place.[2] As regards the placing of the subordinate divisions of this series II, I think we are not yet in possession of facts enough to subdivide the series. I hope your report will give us much information on the subject. I forgot to mention the plumbaginous schists, 644 and another, very soft and bluish, 1163. We have such in our Green mountains, but I do not feel sure of their place. Plumbaginous mica-schists also occur in III, in New Hampshire.[3]

You ask about several specimens, viz.: 1110, which seems a fine-grained compact dolerite; 416, a distinctly granular diorite; 417, a fine-grained green diorite, looks more like a bedded rock than a dyke; 418, coarsely crystalline diorite; 419, like 417.[4]

I have thus, I think, touched on the principal points of interest in your collection, of which the two great facts are the close resemblance, and I believe the identity, of the great *iron-bearing dioritic-talcose*[5] *series*, with Green Mt. series II, and the equally close resemblance of the rocks, 1215, 1151 to 1154, with the White Mt. series III, which I conceive to belong to a higher horizon (see on this point a note to my paper on granitic rocks, 2d part, Amer. Jour. Sci. for March). I really hope that I have not delayed too long to be of use to you; I fear so when I read your note of Feb. 11.

A word about *felsites*. I have a large specimen of conglomerate, with native copper in the paste, from the Albany and Boston Mining Co.'s property, brought me by Macfarlane, who has briefly described it in the Geol. Rep., Canada, 1866, p. 156. The porphyry boulders and pebbles of which he there speaks, are fine examples of the felsite of which I wrote you, better named *eurite* or petrosilex, and passing into quartziferous porphyry. See my paper in Amer. Jour. Sci., Feb., 1871, p. 84, § 5, for a notice of these rocks. Now, what is the source of these boulders? I suspect it will be found to be in the lower part of the Huronian system, for it has the typical character of the Huronian eurites, as seen all along the E. coast of New England, from Rhode Island to New-

[1] It is not certain that this is of Huronian age. Serpentine is rare in this series, and is apparently an altered greenstone. — T. B. B.

[2] Middle and Lower Huronian, associated with quartzites or limestones. — T. B. B.

[3] Carbonaceous slates, sometimes graphitic, are very abundant in the lower part of the Upper Huronian, in the Menominee region. — T. B. B.

[4] These specimens are all from well-defined dykes, which are rare in the Huronian. — T. B. B.

[5] Dr. Hunt, I suppose, includes here the unctuous-feeling schists which are now being called hydro-micaceous. — T. B. B.

foundland, and also north of Lake Ontario. Do you know any such rock *in situ?* [1] and have you perhaps deemed it eruptive? Many thanks for the note about the iron ore, as as to the origin of the hydrous ore by hydration of hematite. I do not feel disposed to admit it, for we have no proof that hematite ever becomes hydrated, but clear proof that hydrous and anhydrous oxides may be successively deposited. Thus we have hydrous, anhydrous and half-hydrated oxides often associated, and in such ways as to show that they represent different stages in the process of deposition. Small variation in temperature may affect the change (Dana's Min., 5th ed., p. 168.)

Hoping soon to hear from you and to learn that these notes are in time, I remain, with best regards to Prof. Winchell and yourself,

Very faithfully yours,

To Major T. B. Brooks. T. Sterry Hunt.

Philadelphia, Penn., *May 20, 1878.*

Dear Major Brooks: * * * The announcements made in my letter to you identifying the formations XIX and XX (the micaceous schists, with hornblendic and staurolitic schists and the white feldspathic gneisses) with the Montalban, which I at that time (1871) ventured to declare to belong to a newer and distinct series from the Huronian, were, as you know, an anticipation of some years of the published conclusions of yours that they are the *youngest Huronian rocks*, a strong confirmation of the great value of the distinctions, which in my letter to you of Feb. 22, 1871, were presented *for the first time.* All my subsequent work in Pennsylvania (Proc. Amer. Assoc., 1876) and in North Carolina, as well as Fontane's work in Virginia, have confirmed this.

I count this a great point gained in American stratigraphy — the recognition of the *newer gneissic series* above the Huronian, to which I have given the name of *Montalban.* (The *Terranovan* suggested in 1870, was made up of *Montalban* and Taconian, as I have since shown.) Another point: In 1873, after I had discussed the matter with you in Marquette in August, 1872, I became satisfied that, in opposition to your view, the copper rocks were unconformable to the Huronian, and in February, 1873, called them a distinct group, the *Keweenaw group* (Trans. Amer. Inst. Min., Eng., Vol. I, pp. 339, 341). It was in March, 1875, two years later, that you announced the same conclusion and called them *Keweenawian*, to which I replied by recalling my previous statement and suggesting the more euphonious *Keweenian* (see Harper's Annual Record, 1876, XCV). Keweena and *Keweenawon* were written by early voyagers, and the syllable *aw* is the broad *a* of the Canadians; so *Keweena* gives, I think, Keweenian.[2] * *

Very truly yours,

T. Sterry Hunt.

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[1] Prof. Irving describes heavy beds of Huronian quartz-porphyries, associated with quartzites, in central Wisconsin. A porphyrite occurs at the Peminee falls, south of the Menominee region, belonging probably to the upper Huronian, and it is exceedingly probable that the porphyries described in Owen's report, on the Minnesota shore of Lake Superior, are of Huronian age. I think it may be confidently asserted that no porphyry occurs in the Marquette and Bad R. Huronian, which join the copper series south of L. Superior. Is it not probable that the material of the porphyries and conglomerates of the Keeweenaw series, came from the N. W.?— T. B. B.

[2] My paper, Am. Jour. Sci., March, 1875, was written in Dresden, where I had not access to the literature pertaining to these rocks, and was not then aware that Dr. Hunt had suggested the name which I applied to the copper-bearing series, which from my own personal observations I believed I had proved to be non-conformably interposed between the Huronian and Silurian of the Lake Superior basin. — T. B. B.

APPENDIX B.

SKETCH OF THE LAURENTIAN ROCKS OF MICHIGAN.

The following, prepared four years since, chiefly for the information of explorers and mineral prospectors, would not appear here save that there still seems to be a great lack of information regarding this important system south of Lake Superior. It is a promising field for the stratigrapher and lithologist.

Mica gneiss. This very abundant rock throughout the Laurentian area, contains usually as essential ingredients: grayish white and reddish orthoclase feldspar, grayish white to smoky quartz, and usually dark, but sometimes silvery, colored mica; chlorite is often present, pyrites very common, and epidote rare.

In texture it varies from fine-grained through a coarse variety, in which there is less mica, to a granitic-gneiss, often porphyritic, with large crystals of feldspar, where the only indication of bedding is a general parallelism in the rectangular facets of the feldspar crystals. This variety is very abundant southeast of Michigamme lake.[1]

Frequently the mica, which is seldom abundant, is replaced by, or seems to pass into, chlorite, forming a well characterized and very abundant chloritic gneiss, which often contains garnets.[2] By the disappearance of the feldspar and quartz, a chloritic schist is produced, which in the Lake Gogebic region (if its age was properly made out) is very abundant.

In the same manner, but rarely, a talcy gneiss related to protogine is produced.

Hornblendic gneiss. Almost equally abundant is the hornblendic variety, in which a greenish black, sparkling hornblende, wholly or in part, replaces the mica. It is often fine-grained and schistose, and not unfrequently banded. This rock seems characterized by the tendency of its hornblende to become altered into a chloritic mineral, sometimes without losing its form. By this process it is believed that many of the numerous beds of chloritic gneiss have their origin.

An interesting banded epidotic variety occurs near Lake Gogebic, and has been fully described by Mr. Julien.[3]

Hornblende schist. By the prevalence of hornblende in hornblendic-gneiss, originates a true hornblende schist. In certain fine-grained varieties which occur south of Felch Mt., the hornblende has much the appearance of black mica. A variety containing chlorite occurs northwest of Michigamme lake.

The rock is rare in the Gogebic district, and most abundant in the Menominee region, where an interesting variety, in which the hornblende was distributed in long, parallel, black prisms, with white quartz and little feldspar, is abundant in the north part of T. 41, R. 29, Mich. These prisms are often fine and needle-like, lying parallel with the schistose planes. A slaty structure is sometimes approached and the rock is often banded. It usually contains but little quartz or feldspar. However, a variety in which the feldspar considerably preponderates — a hornblende-feldspar rock — has been observed.

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[1] If we suppose the mica to disappear from a fine grained variety of gneiss, a granulite rock would result, and if in this variety the quartz greatly predominates, a quartzite would be produced. This is believed to be the case in the few instances in which thin beds of these or related rocks occur, hence they will not be considered as distinct kinds.

[2] A schist believed to be Laurentian, with highly contorted laminæ and rich in small rose-colored garnets, was observed on the southeast side of the Republic Mountain in the Marquette region.

[3] Mich. Geol. Report, 1873, Vol. II, p. 137 [1351].

The schist is occasionally very fine-grained, and again a coarse and almost massive syenite or hornblende rock; the latter variety containing, in some instances, magnetite. Specks of iron pyrites are not infrequent.

The fact that hornblende schist is often one of the most conspicuous, although not most abundant, rocks in the Laurentian, is owing to the strong contrast of color its dark strata presents when bedded in the light-colored gneiss and granite.

Chloritic gneiss. The tendency of the hornblendic variety to pass through alteration of the amphibole into this perhaps most abundant and wide-spread variety of gneiss, has been noticed. The greenish-black or brown, soft, foliaceous mineral, characteristic of this rock, has often such an intermediate character between chlorite and mica as renders its determination difficult. Epidote is more common in this variety than in either of the others, and in it minute veins of calcite are sometimes found.

Chloritic gneiss in several varieties, white-banded, reddish, partially decomposed, is very abundant near the head of Lake Gogebic, south and southeast of L'Anse, at the mouth of Dead river, and in the Menominee region.

A variety of chloritic gneiss, containing an appreciable amount of sericite or talc, occurs on Sec, 16, T. 49 N., R. 33 W., Michigan, and many varieties have the unctuous feeling which suggests the possibility of small quantities of this mineral.

Granite. This abundant rock has already been mentioned as that extreme massive variety of gneiss in which all interior evidence of bedding is obliterated by metamorphic action. I assume it to be an altered sedimentary rock — as it apparently must be from its structural relations with the other beds, the granite dykes and certain great irregular red masses, not being included. It is usually a coarse aggregate of orthoclase feldspar, of a light gray to flesh-red color, and darker on fresh fracture, with a less amount of grayish-white quartz, and still less mica. The latter mineral is often entirely absent when a variety of pegmatite and coarse graphic granite, common south of the Marquette region, is produced.

The decided feldspathic varieties suggest the abundant anorthosite rock of Canada, except in the variety of the feldspar.

Among the varieties a red massive granite,[1] which may possibly produce building material, occurs in several places in the Menominee region. A fine-grained, white variety, holding but little mica, which has the appearance of altered hornblende, is less common. One of the most interesting varieties is that in which large crystals of feldspar, arranged with the axes rudely parallel, give the rock the character of a porphyritic granite gneiss, forming the transition varieties between the two kinds of structure.

Seggregations of foliaceous chlorite occur in certain granites of the Menominee region, and a well characterized chloritic granite, which we may suppose to have been derived from syenite by the alteration of hornblende, passes into chloritic gneiss.

Hornblendic granite (syenite?). A gneiss in which the mica is replaced wholly, or to a great extent, by hornblende, has been described. If we suppose this to take on the granitoid character, as do the other varieties of gneiss, a syenitic rock would be the result.

This rock has only been observed at a few points in the Marquette region, where an interesting variety contained but little black hornblende.

Dr. Credner (in Zeitschrift der Deutschen Geologischen Gesellschaft, XXI Band, 1869) has well expressed the transitions and alterations of the characteristic Laurentian rocks thus: "The uniformity of this rock series of mica, hornblende and chloritic gneisses, repeating itself in every one of the many gneiss-granite districts, which by the prevalence of the minerals which produce the schistose structure passes into mica, hornblende and chloritic schist on the one hand, and by the disappearance of the parallel structure, the same gneisses graduate into granite, syenite and chloritic granite on the other hand."

[1] Prof. Pumpelly believes this is eruptive.

The superposition of the various rock beds of the Laurentian over any considerable area is usually obscure, owing to the numerous and complicated folds, and the prevailing general uniformity in the lithological character of the rocks.

Their order may, however, be in part made out in localities like the north part of T. 41, R. 29, Mich., where there is a prevailing east-west strike, and where tolerably well characterized dark-colored hornblendic strata are associated with light-colored masses of granite, and several varieties of gneisses.[1] The absence of the easily to be recognized beds of limestone which characterize the Laurentian series of Canada, renders the stratigrapher's task, there difficult, here far more so.

Cutting the Laurentian rocks in all directions are dyke-like masses of granite and greenstone. The granite dykes are often narrow, sometimes irregular in direction, and generally coarser-grained and more micaceous than that of the granitic masses penetrated. They sometimes cut the greenstone dykes, indicating less age. In a few instances, and only in the Menominee regions, have small granite dykes yet been seen to penetrate Huronian rocks, and well defined greenstone (dolerite) dykes are nearly as rare in this system.

The greenstone dykes of Laurentian age are far thicker, more regular and persistent than those of granite, and vary in composition from a black-green, fine-grained, heavy, crystalline rock, resembling some of the Huronian bedded diorites, to a variety resembling hornblendic rock. Near the Republic mountain are several dykes of this class running northeast and southwest, and others nearly north and south. In other places in the Marquette region, an east and west system has been observed. Foster and Whitney's Report on Lake Superior, Part II, page 38, notes cutting the granite of one of the Huron islands, six powerful parallel straight dykes of greenstone within a distance of forty rods, one of which was ninety feet in thickness. In one instance a dyke-like mass of hornblendic rock showed a schistose structure parallel with its walls.

May not the erosion of these dykes, and the overflows which possibly accompanied them, have afforded much of the material forming the greenstones and related schists of the Huronian? May not considerable magnetite have come from the same source?

In some instances, more recent fissures (veins) have been observed cutting these dykes, but no lode promising to bear valuable ores has yet been developed in our Laurentian.

Dr. H. Credner, in the paper above named, p. 516, describes as Laurentian certain limestones and dolomitic marbles, conglomerates, calcareous chloritic schists, and spotted arenaceous chloritic schists, as well as a talc gneiss (protogine), which appear to me to belong to the Huronian series, both on stratigraphical and lithological grounds; hence are not embraced in this sketch.

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[1] Pumpelly and Credner studied this locality, the results being given in Credner's paper already mentioned.

PART VIII.

THE

GEOLOGY

OF

THE MENOMINEE IRON REGION

(ECONOMIC RESOURCES, LITHOLOGY, AND WESTERLY EXTENSION.)

BY CHARLES E. WRIGHT.

PROF. T. C. CHAMBERLIN,

State Geologist.

SIR: — Herewith I submit to you my report and map of the Menominee region.

The first field work in this district, under the auspices of the Wisconsin Geological Survey, was done by Major T. B. Brooks and myself, as assistant, in 1874. In 1876, this work, as you well know, was continued, with considerable reluctance, by myself, but owing to an unfortunate sunstroke, received on the Pine river, I was only enabled to give one month's field work to this region, which work consisted of a reconnoissance of the Brulè and Pine rivers; also a trip by assistant, F. H. Brotherton, Esq., south from the Upper Quinnesec falls to the Peshtigo river.

In 1877, I devoted another month's field work in examining the country westerly from the north and south centre line of range 17 of towns 39, 40 and 41, Wisconsin.

Chapter I of the following report contains a full description of the Menominee iron mines and explorations, with several analyses of the ores. In Chapter II are described the specimens collected by Major T. B. Brooks and myself from this district, in 1874. In Chapter III will be found the geological results of the two months' field work already alluded to.

To my field assistants, Messrs. F. H. and W. F. Brotherton, must I express my sincere thanks for the faithful manner in which they performed their work; to my friend, Major T. B. Brooks, for many valuable suggestions; to Messrs. Mathews and Longyear and to the Chicago and Northwestern Railway Company, for important topographical notes; to J. J. Hagerman, Esq., for analyses of iron ores; and to many others without whose assistance this report would have been far more incomplete than it now is.

Very respectfully yours,

CHARLES E. WRIGHT.

MARQUETTE, MICH., *September 12, 1879.*

THE MENOMINEE IRON REGION.

CHAPTER I.

MENOMINEE IRON RANGE.

ECONOMIC.

This district now embraces the northern portion of Marathon county, of this state, and in Michigan the country immediately north of the Menominee river. If the rapid progress which has been made within the past year continues, the present limits of this new iron district will very soon reach far up the Brulè river.

It is more than probable that the valuable iron ore beds of this range, now so extensively and profitably wrought on the Michigan side of the Menominee river, extend westward into Wisconsin. We will, therefore, consider first in detail the recent developments on the north side of the river, that we may better realize the value and importance of the undeveloped iron ore deposits of the Menominee range located within Wisconsin.

The existence of iron ore in the Menominee district on either side of the river has been known for more than thirty years, and extensive explorations have been prosecuted at intervals since 1867. During the winter of 1873 and '74 the first shipment of iron ore from the range, about fifty tons, was made from the Quinnesec mine and taken to the Menominee furnace, where it was smelted with very satisfactory results, but it was not until 1877 that a branch railroad, from the Chicago and Northwestern Railway, enabled this and other mines to ship regularly to market; to-day, however, this railway company with their usual promptness are doing all that can reasonably be expected of them to promote the interests of this new mining district.

The most easterly of the Menominee range mines are the Emmett and Breen. Explorations were made at this point as early as 1870, which gave promise of good ore in paying quantities. The first shipments of ore were made from the Breen mine in 1877, amounting in that year to 5,812 gross tons, the Emmett not shipping any ore until the next season. These mines adjoin each other, and are located on the north side of a swamp and along the south side of a low ridge or plateau. The general trend or strike of the formation is about east and west and the dip is 60° to the south; the ore stratum, therefore, dips under the swamp.

The ore of the Emmett mine consists of two varieties, the one a soft specular blue ore[1] and the other a brown hematite. Analyses of these ores made by myself afforded the following results:

	No. 1.	No. 2.	No. 3.
Oxide of iron	93.850	81.570	83.860
Alumina	.720	......	......
Lime	.870	3.150	2.700
Magnesia	......	1.800	1.600
Manganese	.600	......	......
Sulphur	.090	.056	.020
Phosphoric acid	.110	.295	.100
Silica	1.400	5.550	6.760
Carb. acid, water, etc	2.360	7.579	4.960
Metallic iron	65.700	60.330	58.700
Phosphorus	.047	.129	.044

Nos. 1 and 3 are respectively the soft specular ores of the Emmett and Breen mines, and No. 2 the soft brown ore from the Emmett mine.

A singular feature in connection with the two kinds of ore at the Emmett mine, is that the blue ore overlies the brown ore, and is therefore, apparently, more exposed to the swamp water than the brown ore, though the brown ore contains more phosphorus and is a completely hydrated peroxide. The two ores are in direct contact. The brown ore, at one point in the mine, had a thickness, measured at right angles to its bedding, of 50 feet, and the blue ore of 20 feet.

These soft specular blue ores of the Menominee range are very deceptive in their appearances to one not familiar with them. They are light compared with the hard specular ores, and many of them, after a short exposure, become coated with a thin grayish film; exactly what this is I never have determined. It is no doubt a soluble mineral substance contained in the hydroscopic water, which is deposited by evaporation at the surface. At first I supposed it to be carbonate of lime, but it does not effervesce with acid. It is probably some soluble silicate.

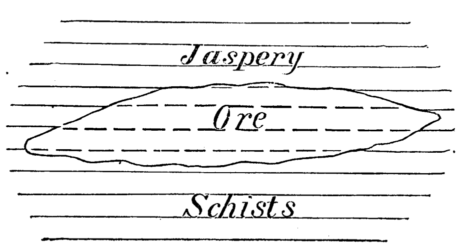
[1] This ore is really a soft specular variety, as it consists of an aggregation of minute crystals or particles of specular ore, and in this respect differs from the so-called soft hematites, which are chiefly an amorphous mass of red and yellow oxides of iron.

The Breen mine also presents some interesting points. One in mind occurred in the opening of one of the pits. After removing some three feet of earth there was exposed a vein of soft specular blue ore, twenty feet or more in width. It was plainly bedded and had a slaty structure. Its strike of nearly east and west, and dip of 60° to the south, exactly coincided with that of the formation as exposed in the other openings; but after mining down only a few feet, they unexpectedly came upon horizontally bedded sandstone. The ends of the slaty ore were angular and well joined to the sandstone below. For a moment it appeared almost unaccountable, for here was an older rock, apparently in place, overlying a younger one, without a chance of explaining it by an overturned dip.

A large piece of slaty ore, near by, imbedded in the sandstone, having a reverse dip to this larger mass, furnished, to my mind, the probable key to the phenomenon. It would seem that during the deposition of the sandstone these ferruginous schists and other members of this series, dipping to the south, formed an abrupt cliff with the waters of the Silurian sea beating against which, in time, undermined a portion of the face, thereby causing a slide and breaking off of the projecting masses. In this manner, some of the sliding portions, with their lower ends buried in the sands, would appear undisturbed.

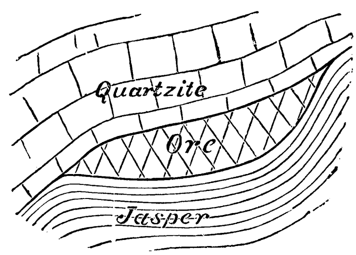
During the past winter and spring considerable excitement was gotten up over the reported discovery of gold and silver, associated with the iron ore of the Emmett mine. Several assays were made, some, it is said, with fair results. Gold seekers and adventurers flocked in from different parts of the country. The officers of the Emmett mine, at that time, ordered their agents in Cleveland to discontinue the sales of their ore; but after a brief period the iron rod again resumed its sway and the golden sceptre was laid aside.

On the same range, six miles to the west of Waucedah, is the Vulcan mine. The mining operations here are more extensive than at the Breen or Emmett mines. The old workings are located near the west quarter post of Sec. 10, T. 39, R. 29, Mich., and are on the south edge of a broad ridge which admits of good drainage. The ore occurs in lenticular shaped, pocket-like masses, something after the manner shown in the annexed cut. It will be noticed that this



slaty-structured ore passes into the lean ferruginous schists without any break in the stratification.

In this respect the ore deposits of the Menominee range on the Michigan side of the river differ from the hard ore belts of the Marquette range. In this latter district it is very common to find the ore in lens-shaped masses; but the hanging wall of quartzite, and the foot wall of jasper, approach each other and pinch out the ore. See annexed cut.



These lenses overlap each other and are separated usually by chloritic rock. One lens may be magnetic ore and the other specular ore. I have a hand specimen with one-half of it specular and the other portion of it magnetic.

To return to the Vulcan mine, we find the old workings to consist of a large open pit 300 feet long and 80 feet wide by 70 feet deep. The formation has a strike of N. 75° W., and dips 60° to the south. Underlying and overlying the ore are jaspery and ferruginous slaty schists, and again, underlying these schists are the siliceous marbles and quartzite (No. V).

The ore is the soft specular variety and varies in its structure and texture. It is of a good quality, as will be seen from the following analyses:

	No. 1.	No. 2.
Metallic iron	60.130	62.290
Silica	12.910	5.840
Alumina	.310	......
Lime	.090	1.310
Magnesia	.030	......
Phosphorus	.027	.022
Water	6.450	......

No. 1 is a complete analysis made by Dr. J. B. Britton, and No. 2 is a partial analysis made by myself in 1878.

The present prospect for ore in this old pit is not very bright, in fact, in the bottom of the mine, in some places, it is almost entirely wedged out. Whether another lens of ore will be found to either side or further down, is, in my opinion, a very important matter to those interested in the future of the Menominee range. Already we hear vague doubts expressed as to the permanency of these ore deposits, and scarcely a day passes but some one asks the question, "What do you think about these deposits going down?" That these ferruginous schists are as continuous and persistent in depth as any other member of the Huronian series, I think admits of no reasonable doubt. My impression now is, that these ore deposits are of a secondary nature: that is, they were originally the same as the jaspery specular schists in which they occur, and have been brought to their present condition by the dissolving out of the silica from the lean schists. This theory, though an old one, I think, will best account for all of the observed facts connected with the iron mines of this range.

A few hundred feet to the west of the old workings, and on higher ground, are those of the New Vulcan. We find here a very fine surface show of soft specular blue ore. The "stripping" was light and the ledge has been uncovered for several hundred feet in length. Considerable preparatory work has been done, side tracks and two important rock cuts have been made to reach the ore at convenient points. A double incline is already completed to transport the ore down to the ore pockets alongside the railroad track of the old Vulcan; in fact, everything is nearly ready to ship, and no doubt the New Vulcan will make a fair shipping record this season. The Vulcan mine is operated by the Menominee Mining Co.

Only a short distance to the west is another new opening known as the

Curry Iron Mine. It was discovered and opened this season, and is now shipping daily about 150 tons of fine soft specular ore. A little more than a mile to the northwest of the Curry, are the Saginaw, Norway and Cyclops mines, all of which promise well.

The Saginaw is located on the S. W. qr. of Sec. 4, T. 39, R. 29, Mich. The formation at the Saginaw mine has a strike of about N. 75° W., and a dip of 70° to the south on the north side of the property. Immediately to the north of the ore bed, less than one hundred feet, are large outcrops of siliceous marble; south of this, within five hundred feet, numerous drill holes have been put down, which, after passing through from twenty to eighty feet of earth, have met with the siliceous marble. In view of the supposition that the marble underlies the ore bearing belt, we have here what appears to be a narrow synclinal. If this theory be correct, and I am inclined to believe it is, there should be another iron range not far to the south of here, with a southerly dip. Exactly what relation the Saginaw bears to the Curry and Vulcan mines, I am unable to state; but my impression is, in the absence of any facts either pro or con, that these latter mines are on the same belt as the supposed belt south of Saginaw. No ore has yet been shipped from the Saginaw mine, though the mine is about ready to begin mining on an extensive scale.

The Norway adjoins the Saginaw on the west. This mine was opened in August, 1878, and after that date it shipped for that year 7,276 gross tons of ore. It is worked by the Menominee Mining Co. On the east side of the property the formation is very much disturbed and some of the beds are even brecciated. Owing to this irregularity of structure, the results of mining during the early part of this season were not as satisfactory as they otherwise would have been. The ore was somewhat mixed and the assorting was not an easy task. Subsequent explorations from this point, northwesterly for say 1200 feet, have developed some very promising deposits of soft specular blue ore, which will compare well in quality and quantity with the best of the other mines of this range. In going westward, the ground gradually rises, and at the west end the elevation above the railroad track on the east side is about seventy-five feet.

The formation in some of the openings is apparently nearly horizontally bedded; in others it dips at a low angle to the southwest.

Along on the north side of the mine working, from 50 to 200 feet are ledges of silicious marble and calcareous, reddish quartzites. Horizontally bedded sandstone is frequently found capping the ore. The ore in the easterly pits varies greatly in color and texture. Some of it is of the soft, specular, blue variety; another portion is a hard, steely, specular ore, and we also have the hard and soft hematites. Analyses made of the ore, late in 1878, afforded me the following results:

Oxide of iron	85.200	90.710
Alumina	2.300	......
Lime	4.100	......
Magnesia	.620	......
Sulphur	.022	......
Phosphoric acid	.040	.037
Silica	7.500	7.420
Metallic iron	59.640	63.500
Phosphorus	.018	.017

From the Norway we proceed southwesterly about 1000 feet and come to the Cyclops mine, which is also operated by the Menominee Mining Co. This mine was opened last September and shipped that season (1878) 6,058 tons of ore. The ore is a superior quality of the soft, specular variety.

The following analysis was made by myself from an average sample sent me last November by Mr. J. J. Hagerman, the president of the Menominee Mining Co.:

Oxide of iron	95.90
Oxide of manganese	trace.
Oxide of lime	.36
Oxide of magnesia	.30
Alumina	.62
Sulphur	.01
Phosphoric acid	.04
Silica	1.30
Undetermined	1.47
	100.00

The formation, as far as developed, is quite regular; it dips about 55° to the southeasterly. The workings are known as Nos. 1 and 2 shafts, which are about 250 feet apart. No. 1, the southeasterly one, is sunk two levels of 35 feet each. The first level is really two open pits. From the first level a drift connects with No. 2 shaft, intersecting it at 75 feet below the surface. The ground from No. 2 to No. 1 is descending. The vein of ore is heavily capped in places by sandstone. It is interesting to note, in the northeast end face of No. 1, that the ore has worked into the joints of the sandstone, and near the junction may be seen fragments of ore and ferruginous schists imbedded in the sandstone. The ore next to the sandstone is quite soft and friable. Another feature in connection with these soft, specular, blue ores is, that we rarely find any of it changed to the hydrated peroxide of iron, which I think must be due to their crystalline state. The "stripping" in No. 2 was so deep that underground mining had to be resorted to at the start.

At the bottom of the shaft to the southwest a chamber about 50 feet long and 30 feet high has been mined out, while to the northeast not quite as much has been done. The vein varies from 15 to 30 feet in thickness. The progress of this shaft will no doubt be watched with considerable interest by the other mines of the range. The company are putting in large quantities of heavy timber to support the roof. Still, I do not think there is any too much. Where I should anticipate trouble would be below the second level, but then if the foot and hanging walls are good, even if the ore will not stand in pillars, the roof can be supported by timber. How practicable this may be, will, of course, depend on the cost. From what I have seen of these soft, specular, blue ores, I should hardly expect them to stand well in pillars without the pillars are well protected from the atmosphere; for these ores, as a rule, very soon crumble in pieces on exposure. On the other hand, however, I shall be greatly surprised if some economical method is not devised to win these ores by underground mining, in spite of all the present apparent drawbacks.

Quinnesec Village, located at the present terminus of the Menominee River Railroad, is the most important town on the Menominee range. It has a pleasant site and its elevation is 550 feet above Lake Michigan.

We find here several dry goods, grocery and drug stores; well kept hotels, a church, school house, a few fine residences and a full complement of saloons.

The ground to the north side of the village is gradually ascending, and within a few hundred feet, in that direction, we enter a narrow valley, which breaks through the range at this point. On the west side of the valley the ground is sharply ascending, and in less than one thousand feet we attain an eminence of over 200 feet above the village. This elevation commands a fine view and gives one a fair idea of the general lay or topography of the country round about. The deep roaring of the Quinnesec falls can be distinctly heard and the valley of the Menominee river may be plainly traced.

This broad ridge, which we have just ascended, is composed chiefly of lean ferruginous schists, and in these schists occur the ore deposits of the Quinnesec Mine. This mine possesses some advantages over the other mines of this range. Its elevation affords splendid drainage, a desideratum which is appreciated more and more each year by the older iron mines of the Lake Superior district.

The ore of the Quinnesec is rather more compact than that found in the other Menominee range mines, still like them it soon disintegrates on exposure.

The formation in the mine has an east and west strike and the dip is 70° to the north. Considerable prospecting was done here in 1872, '73 and '74; a shaft was sunk some seventy feet deep; also several test pits were dug across the formation, which proved the existence of excellent ore in paying quantities. South of the ore belt, on which they are now working, along the south slope of the ridge, are a series of continuous test-pits and shallow trenches, cross-cutting the ferruginous schists for several hundred feet. Examining these, we find the dip of the formation as we go south from the mine workings to become steeper, then vertical, and finally there occurs a southerly dip. To the extreme south edge of these explorations, near the base of the ridge, is a large shaft. The southerly dip is quite marked. Here and there may be seen on the north side of the shaft, heavy jointing planes pitching at a low angle to the west. Returning to the valley, just to the north of the village, we have to the east side of the valley, in the trend of the ferruginous schist to the west, a narrow range of siliceous marble. On the north and south sides of the marble are magnetic attractions. In view of these and other facts already noted, and knowing too that the marble forms the foot wall of the ferruginous schists, it seems to me that there must have been an uplift here, the marble range being parallel to the axis of the uplift, or, in other words, we have an anticlinal pitching to the west. This hypothesis explains best to my mind, all of the facts which have come under my observation.

From the foregoing, we would expect to find the southerly rim of the anticlinal corresponding to the ore belt in the Quinnesec mine not far to the south.

It must not be inferred, however, from this, that a continuous belt of good ore will be found within this southerly range, for such is not the case in the northerly belt upon which they are now mining; still, I do believe that good ore will be discovered not far to the south of the Quinnesec range, having a southerly dip.

Turning our attention now to the Quinnesec mine workings, we find first, an open cut driven west, horizontally, into the east end slope of the ridge, along the ore deposit, for 350 feet, where the ore passes into jaspery slates, with the exception of a narrow run of ore, for a short distance, on the hanging wall side. On this level are located the engine house, ore pockets, etc. The shafts are irregularly numbered. No. 2 is the most easterly one, and No 1 is directly west of it about 170 feet. They are both on the foot wall side of the ore deposit. No. 3 is about 160 feet westerly from No. 2, and is on the hanging wall side; it is also about 200 feet east from the westerly limit of this level. All three shafts are sunk to the third level, 120 feet down on the dip of the formation. To the east side of No. 3 is a crossing of rock some 50 feet wide.

Going down No. 3 shaft to the tunnel level, 48 feet below No. 1 level, we find in a drift driven west from the shaft, 50 feet of lean ore, and then enter an open pit 120 feet long by 30 feet wide at its east end. To the east of the shaft, a drift is driven under the crossing of rock already noted, and we enter another open pit which extends eastward a little beyond No. 1 shaft.

On the third level, the crossing of rock appears to have "cut out." To the west of No. 3 shaft we have on this lower level, in a drift driven along the hanging wall side, a "run" of 70 feet of good ore; west of this the drift is continued for 90 feet more, but it is in mixed ore. How it may prove to either side of this is, a question that can only be settled by actual explorations. To the east of No. 3, more work has been done. A pillar of ore 25 feet thick has been left to protect the shaft, then comes a chamber 30 feet long by 20 feet wide, with ore still on the foot and hanging wall sides. Continuing eastward on this level, we pass through a drift 45 feet long, driven on the foot wall side of the deposit, and enter another chamber 40 feet long by 35 feet wide. Along the north side of this chamber we have rock; but on the south side it is still ore. Between this chamber and No. 1 shaft, has been left a 25 foot pillar, and on the east side of the shaft is a 15 foot pillar. East again from this point is another large chamber 30 feet wide with, as yet, no true foot or hanging wall to the ore deposit. This chamber connects with No. 2 shaft by a drift.

The ore of this mine consists chiefly of the soft specular blue variety. It is quite slaty, and easily mined. Its quality adapts it to the manufacture of Bessemer steel, as may be seen by the following analyses:

	No. 1.	No. 2.	No. 3.
Oxide of iron	93.87	93.28	89.07
Alumina	.83	1.29	2.21
Lime	.60	.48	.....
Manganese	.15	.03	.....
Phosphoric acid	.07	.08	.024
Sulphur	.02	.04	....
Silica	2.10	4.86	5.40
Metallic iron	65.70	65.300	62.35
Phosphorus	.03	.034	.01

No. 1 is an average which I made of ore collected by myself from the mine in 1873. No. 2 is an analysis made by Dr. J. B. Britton, in 1877. No. 3 is an average of four analyses made by the Lucy Furnace Company, from samples collected by themselves at their works.

The Quinnesec closes the list of the shipping mines of the Menominee range.

Proceeding again on our westward journey, the next mine explorations we meet are near the center of the south half of Sec. 32, T. 40, R. 30, Mich., or two and a half miles west of the Quinnesec mine. The ore is a soft brownish red colored variety, which afforded me on partial analysis, as follows:

Peroxide of iron	91.85
Lime	5.80
Magnesia	.97
Silica	.50
Sulphur	.07
Phosphoric acid	.11
Metallic iron	64.300
Phosphorus	.047

Near the center of the northwest quarter of this section is the Vermillion mine, and west of these again less than one-half a mile are the Walpole explorations. An analysis of the Vermillion mine ore, made by myself from samples brought me in 1873 by Captain Welcome Hyde, afforded the following result:

Peroxide of iron	89.34
Alumina	.44
Lime	1.22
Magnesia	.74
Silica	4.80
Phosphoric acid	.025
Water	3.400
	99.965
Metallic iron	62.538
Phosphorus	.011

This ore is very deceptive; it is very light and resembles common red chalk; in fact, it would make an excellent article for this purpose. I have shown the ore to some of our best iron experts, and rarely ever has one of them estimated the percentage of metallic iron more than thirty per centum; in other words, they did not consider it ore in the commercial sense of the word, but rather a ferruginous clay.

The most reliable field test for the percentage of metallic iron of these Menominee ores, is to judge from the color of the streak powder when scratched with a knife. Northwesterly from here in the N. W. qr. of the S. E. qr. of Sec. 25, T. 40, R. 31, Mich., are some recent explorations which promise well. The ore is the bright, soft specular blue variety, resembling that of the Quinnesec. In quality it is as good as any I have yet analyzed from the Menominee mines, as may be seen from the following analysis:

Peroxide of iron	94.000
Alumina	1.520
Silica	2.730
Phosphoric acid	.026
Undetermined	1.724
	100.000
Metallic iron	65.800
Phosphorus	.012

The strike of the formation in the explorations of this mine is about east and west and the dip is nearly vertical. The vein is about 30 feet thick, but it is split up very much with lenses of rock running parallel with the vein. The widest place of clean ore I saw there, July 7, 1879, was ten feet; still, considering the superior quality of the ore, it is a good "showing," and will warrant the expenditure of considerable capital "to prove it up." As this is the most westerly of the Menominee range explorations, on the Michigan side of the river, it is therefore the nearest to Wisconsin of any of those of the Menominee range that we have thus far considered, and for this reason should possess much interest to the people of this state.

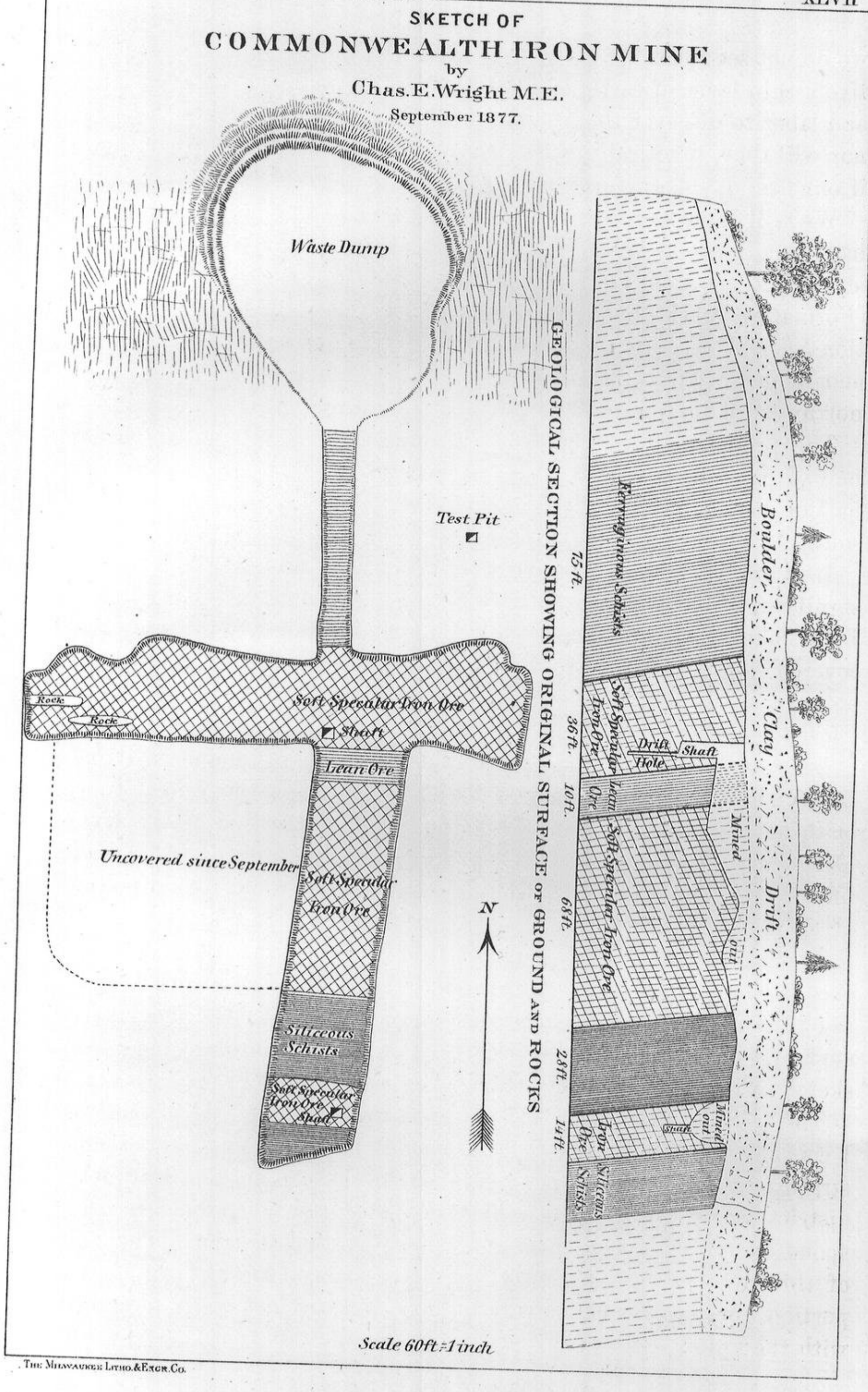
From the explorations in Sec. 25, on the strike of the formation, it is only two miles westerly to the Menominee river, and furthermore, where the general trend would intersect the river, we find, on the Wisconsin side, some strong magnetic attractions. Considering what we have seen to the east of the river, it seems to me that this attractive field in Wisconsin, cannot long remain untouched, but that on the other hand, we shall soon see the explorer delving away in search of iron ore, and shall be greatly surprised if he is not well repaid for his honest labor.

Some three or four years ago, there lay a very large boulder of lean iron ore directly, over the line of these magnetic attractions, which was discovered by some explorers, who, thinking it was a solid ledge, completely undermined it before they were satisfied of its true character. I remember having seen, in 1875, a similar boulder some ten miles west southwest of here — wonder if this boulder will be disturbed in the same manner by some future explorer?

On the Michigan side of the river again, near Lake Antoine, are parties exploring for iron ore, it is said with very satisfactory results.

All of the ores of the Menominee range which we have thus far examined, with only a single exception, are strictly first class. Many of them contain quite a percentage of lime, magnesia and alumina, all desirable elements as impurities, since they, with the silica, are the essential ingredients of blast furnace cinder, and when not contained in the ore, it is necessary to add them in order to reduce the ores to pig iron. The sulphur in the majority of these ores is hardly worth considering, while the phosphorus is remarkably low. Taken as a whole, the adaptability of these ores to the manufacture of Bessemer steel — the ores now most eagerly sought for — cannot be surpassed; as a practical proof of this, the mines of the Menominee range could sell this season double the amount of ore they will be able to mine.

With all these fair prestiges and bright prospects, we cross the river again into Wisconsin, to continue our westward journey, fully satisfied that the same formations which are now economically yielding such rich returns to the east of us, must pass into this state. We may not find the ores outcropping on every hillside; still, even if



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we do not see them, we know they are safely covered with a comparatively thin layer of earth, and all that is needed is a little patience and labor to discover them. They will not burn up where they are, nor will they, practically, waste away; so we need not feel discouraged if our first day's work is not rewarded with an iron mine.

We will leave now this attractive field, in which no exploitations have been made as yet on the Wisconsin side of the river, and proceed at once to the Commonwealth mine, which, geologically, is higher (Formation XIII) than the mines we have been describing (Formation VI.) This mine is located near the center of section 34, town 40, and range 18, Wisconsin, and is in a direct line thirteen miles west-northwest of the present terminus of the railroad at Quinnesec.

The property of this company embraces Secs. 32, 33, 34, the S. half of Sec. 31, and the S. E. qr. of Sec. 28, T. 40, R. 18; also the N. half of Sec. 4, and the N. W. qr. of Sec. 5, of the town immediately south.

Iron ore was known to exist here, by Indians, and "Lake Komon," signifying iron, it is said, in their language, was the original name of Loon lake.[1] About twenty years ago, Col. Charles Whittlesey discovered iron ore on the above property, and from his minutes it was entered, with some other lands, in 1867, by Mr. H. B. Tuttle, of Cleveland, Ohio.

In 1875, our geological party traced out a line of magnetic attractions in sections 31 and 32, and found considerable float ore for two or three miles east of this. Near the center of section 34, we saw a loose ledge of ore exposed under the turned up roots of an old tree, but it was left to Mr. H. D. Fisher, in 1876, under the direction of Mr. H. A. Tuttle, then president of the Commonwealth Iron Co., to first unearth the solid ledge of iron ore, and thus prove its existence beyond all question. Subsequent explorations and work preparatory to actual mining have developed on section 34 the largest surface "show," by far, yet discovered on the Menominee range. See sketch and geological cross section of mine on opposite page.

The ferruginous schists and slates on the foot-wall side of the ore, I consider as the equivalent of the banded jaspers occupying the same stratigraphical position with reference to the ore, in the Marquette district, while the siliceous schists or slates overlying the ore correspond to the "hanging wall quartzites" of that district. The ores of this mine are a soft, steely, specular variety; some of the harder portion present a rich velvety texture, and are not easily scratched with the knife.

---

[1] Lake Eliza of Brooks' report.

The first analysis which I made of this ore was of an average sample, taken in June, 1877, by myself, at every six inches across the 36-foot vein, which afforded as follows:

Peroxide of iron	90.26
Silica	3.24
Phosphoric acid	.53
Sulphur	.02
Metallic iron	63.182
Phosphorus	.234

Average samples taken from a shaft sunk 22 feet into the ledge on the south side of the 36-foot vein (see sketch), afforded me on analysis as follows:

	No. 1.	No. 2.
Metallic iron	62.20	62.00
Silica	3.24	3.44
Phosphorus	.19	.27

No. 1 was an average collected by Major T. B. Brooks, in Sept., 1877, and No. 2 is an average taken a few days later by myself.

Another sample from a nine foot drill-hole put down in the bottom of this shaft, gave:

Metallic iron	63.50
Silica	2.03
Phosphorus	.32

Overlying this 36-foot vein, will be noticed a 10-foot vein of lean ore. Taking an average sample of this, it afforded me on analysis as follows:

Metallic iron	48.10
Silica	10.60
Phosphorus	.15

Other average samples afforded me, on partial analysis, respectively as follows:

	No. 1.	No. 2.	No. 3.
Metallic iron	63.70	56.10	57.50
Silica	5.04	4.94	5.57
Phosphorus	.17	.23	.21

No. 1 was taken by myself just south of the 10-feet vein of lean ore; No. 2 also by myself, as an average of the 68-foot vein (see sketch), and No. 3 was collected by Major Brooks as an average of the 68-foot vein.

The above analyses, as a whole, are certainly very good, especially when we consider that the average ores of the 36 and 68 foot veins were taken across the entire bed, without discriminating between the lean streaks of ore or even narrow runs of rock, and the ore itself, which in the course of mining would be assorted. The shipping ore will probably average from 64 to 65 per centum of metallic iron.

It will be noticed that we have in these analyses quite a range in the percentages of phosphorus, from fifteen to thirty-two one-hundredths of one per centum, and even in the shaft we note one .19, and the other .27, while the iron and silica are nearly the same.

These facts prove conclusively that the phosphorus is very unevenly distributed. This, to a certain extent, may be accounted for, in that the soft, somewhat broken nature of the ore allows the surface water and even the spring water from below, carrying frequently a trace of phosphoric acid in solution, to percolate through the ore bed. The iron oxide, having a strong affinity for the phosphoric acid, would in part deprive the water of it, and thus would result an ore more or less highly charged with phosphorus, depending, as we can readily see, on its physical structure and the permeability of the iron oxide to the water. This theory, I know, is questioned; but my experience as an analytical chemist to the iron mines of Lake Superior, for several years past, including now those of the Menominee range, has demonstrated pretty clearly to my own mind that it is the correct explanation. I know that some of my Menominee range mining friends may doubt this theory, and will probably say, "Our soft specular blue ores are, as a rule, very porous, and absorb water readily; how is it then that they contain so little phosphorus?" At first glance, this may appear unanswerable, but on second thought, it is perfectly consistent with the above hypothesis. The highly crystalline particles of these soft specular ores are impervious to water, and therefore the crystallized iron oxide is not affected by the phosphorus contained in the water. These crystalline particles appear, under a strong Coddington lens, like small scales of micaceous specular iron ore. This will also explain another feature, which we have already noted; that is, the almost entire absence of any small pockets or bunches of hydrated peroxide of iron, or ochreous iron ore, among the soft specular blue ores.

With regard to the ores of the Commonwealth, we find them, on careful examination, to consist of extremely minute grains of iron oxide, which are scarcely distinguishable with the most powerful Coddington lens. No doubt that they were originally crystallized, but now they appear to be a dense amorphous mass of microscopic grains, a very favorable condition for the phosphoric acid to attack and unite with the iron oxide. The most natural conclusion we now arrive at is, that the Commonweath and other ores of this class will decrease in phosphorus as we go down into the solid ledge where they are harder and more compact, and thereby are less exposed to the seeping in of water holding phosphoric acid in solution. To show that this is not a mere hypothetical deduction, I will mention a few facts which have come under my own observation, in connection with our Lake Superior iron mines. The Champion mine, in 1872, averaged about .120 per cent. in phosphorus, but now, 300 feet from the surface, the percentage of phosphorus averages only .035 per cent.

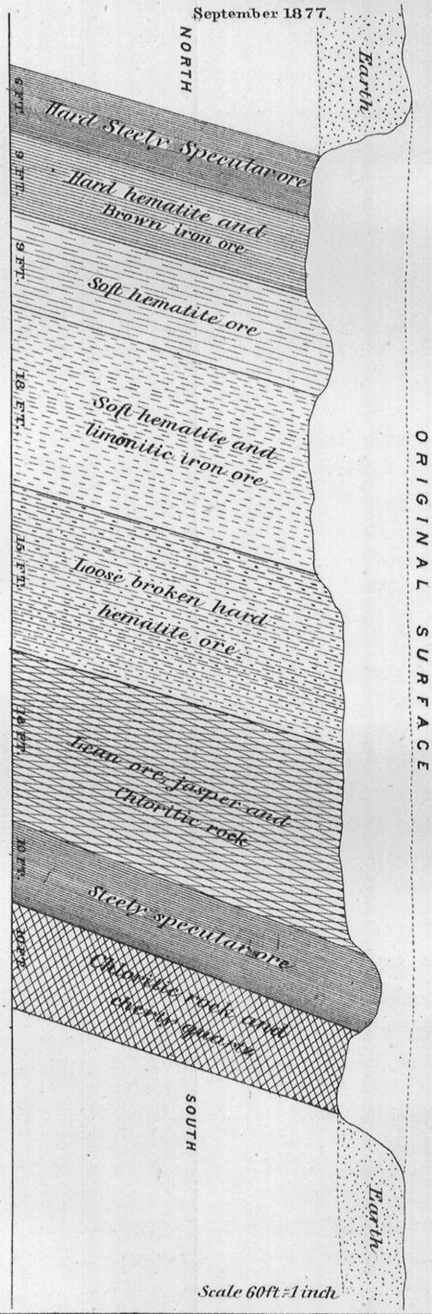
This decrease has been quite uniform from the surface down. The Lake Superior mine has decreased from .120 per cent. to .065 per cent. on the 240 foot level. In the Ishpeming group of mines, of which some are too high in phosphorus for Bessemer steel purposes, I have found that the diamond drill, penetrating these same beds, at depths varying from 300 to 800 feet, has brought up cores of iron ore, which, on analysis, gave low results in phosphorus, some as low even as .013 per cent. Again, in the Winthrop soft hematite mine, where the ore a year ago was rendered quite wet from water-seeping, gave in some analyses as high as .410 per cent. of phosphorus, but now, since they have mined beyond this wet place, the phosphorus has been in some analyses as low as .015 per cent., and the average for this season, thus far, is only .044 per cent.

I could give many other examples in support of this theory, but these, I think, are sufficient to show that, as a rule, the iron ores of our Huronian region are frequently contaminated by water, holding phosphoric acid in solution, and when thus affected, they will decrease in phosphorus as we get down into the solid ledge.

Glancing again at our sketch of the Commonwealth, we find the aggregate thickness of the three strata of ore to be 118 feet, with every indication of its extending to the east and west of here. Whether it will average this great thickness for any considerable distance, can only be demonstrated by actual exploration. My opinion is, however, that the bed has been uncovered at one of its strongest points and that it may lessen in width in the direction of its strike or dip; but even if it should decrease, say one-half its present thickness, it will still be the largest iron mine yet developed on the Menominee range. Its location is exceedingly favorable, as it is on the summit of a high, broad ridge, timbered with splendid hardwood, and the soil for farming purposes is most excellent. A preliminary railroad survey to this property has shown that the gradients against the ore will be light, and that the roadbed will not be an expensive one to build.

West of these workings about two and one half miles, in the southwest quarter of section 32, this company has sunk several test-pits,

SKETCH OF
COMMONWEALTH IRON MINE
by
Chas. E. Wright M.E.
September 1877.



EAGLE MINE, 1877. FACING EAST.

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also a shaft seventy feet deep, which is on a narrow bed of granular specular ore carrying a little magnetite. In sinking the shaft, the stratum of ore widened from two feet to ten feet and then contracted; below this it widened, but very soon narrowed again. No doubt but that ore will yet be found here in paying quantities.

The following analyses are some that I have made of these ores:

	No. 1.	No. 2.	No. 3.
Metallic iron	61.55	64.10	65.07
Silica	7.53	2.31	2.10
Phosphorus	.10	.12	.18

The mine explorations are very conveniently located on the east end slope of a high ridge. The next mine that demands our attention is known as the Eagle. It is located in the N. E. qr. of the S. E. qr. of Sec. 20, T. 40, R. 18, Wis.

Ore was first discovered here by H. D. Fisher, Esq., in 1873. Considerable test pitting and cross trenching has been done immediately about this place. The iron ores and associated rocks are plainly bedded, but much contorted, especially in the eastern portion of the exploration. The strike of the formation averages about N. 80° W., and the prevailing dip is high to the north.

An open trench about 100 feet long, dug in a north and south line, exposes well the character of the ore and rocks within its limits. East and north of this trench a short distance, some test pits have been recently sunk. The first pit is nearly due east of the north end of the long trench and has iron ore in the bottom of it. North of this pit at 25 and 50 feet respectively, are two other test pits, also with ore in the bottom, with a fair indication of ore lying between in the covered spaces.

Beginning now on the south end of our trench (see cross section), we have first ten feet of chloritic rock, cherty quartz and thin seams of steely, specular ore; then comes ten feet of steely, specular ore, somewhat banded with cherty quartz. An average of this bed afforded me on partial analysis:

Metallic iron	49.00
Silica	20.30
Phosphorus	.14

Overlying this, we have eighteen feet of lean ore, jasper and chloritic rock, portions of which are partially decomposed. Now follows fifteen feet of loose, shelly, hard hematite. It is somewhat contorted and broken up, and can be easily picked out without blasting.

An average of this bed, collected by myself, gave:

Metallic iron	53.03
Silica	11.60

Overlying this again, is eighteen feet of plainly stratified, soft hematite and limonitic iron ore, which afforded on partial analysis:

Metallic iron	57.00
Silica	3.80
Phosphorus	.40

Next in order on our cross section comes nine feet of soft hematite ore, which afforded:

Metallic iron	58.10
Silica	3.04

In these two beds we have an aggregate thickness of 27 feet of good hematite, well adapted to foundry purposes.

Next follows nine feet of hard hematite and brown iron ore, and then comes a fine steely, specular ore, very similar in appearance to the most southerly ore shown on our cross section. How far northward they may continue, without any interstratified beds of rock, we only can conjecture, since the trench terminates on this bed of ore, after uncovering six feet of it. An average analysis across this six feet afforded:

Metallic iron	58.10
Silica	4.00
Phosphorus	.39

An analysis of hard hematite ore taken from the test pits, afforded as follows:

Oxide of iron	89.79
Alumina	3.11
Lime	.95
Magnesia	.77
Phosphoric acid	.51
Sulphur	.03
Silica	3.82
	98.97
Metallic iron	62.80
Phosphorus	.22

West of the Eagle mine, about two miles, in section 25, town 40, and range 17, are several test pits which, I understand, have developed a fair showing of ore. This, I believe, comprises all the explorations of the Menominee range of any note, in Wisconsin.

We will now consider briefly the

BELTS OF MAGNETIC ATTRACTIONS

which our delicate needles have detected. The importance of these, from a scientific or economic standpoint, cannot well be overestimated. In the former instance, they indicate to us the strike of the underlying covered rocks, thereby enabling us often to connect widely separated outcrops, and in the latter instance they reveal the position of magnetic ore, or rock, carrying magnetite.

I regret to add, that as a general rule, applied to the Huronian rocks, the attraction is more frequently due to the latter cause than to the merchantable ore. I am inclined to believe, however, from the relation these lines of attraction bear to the associated rocks, that they very often emanate from an iron ore belt. We will consider, however, only the more prominent of these magnetic belts.

Traversing Secs. 8, 5 and 6 of T. 39, R. 17, Wis., and Secs. 36, 35 and 27 of T. 40, R. 16, in a northwesterly direction, is one of the strongest and most persistent magnetic belts we found on the Menominee range, in Wisconsin. We crossed it several times, and when we did so, our compass needles, in every instance, apprised us of the fact.

Only once did we attempt to trace out the attraction, and in so doing we experienced no difficulty. This was in Secs. 36, 35 and 27 of T. 40, R. 17. I regret now that we did not do more of this kind of work, but at that time I had not worked out our field notes and not knowing, to a certainty, the general trend of the magnetic belts and associated rocks, could not, therefore, have done it as advantageously as now.

No exploring or test pitting has been done along this belt; but I doubt not but that workable deposits of good iron ore will be found within it. Northeast of this belt about one mile, is another parallel magnetic belt. It is not as strong or well defined as the first one.

Northeast again in Secs. 36, 35, 25, 26, 27, 28 and 21 of T. 40, R. 17, Wis., are several magnetic belts. See map, plate No. XXX, for location. This I consider a promising locality for good iron ore, and I shall be greatly surprised if valuable iron ore deposits are not soon discovered here.

The attractions in the south half of Sec. 25, belong in all probability to the Commonwealth range.

North again, in Secs. 9 and 10, T. 40, R. 17, are magnetic belts, and at the southeast corner of Sec. 13, of this town, we have a loose ledge of plumbaginous and ferruginous schists. This we will, for the present, designate as the Eagle mine range. Still north again, on the

Michigan side of the Brulè river and along the north side of the chloritic slates, has been reported to me from reliable sources, deposits of iron ore located in the southeast quarter of Sec. 25, T. 42, R. 33, Mich., also in southwest quarter of Sec. 31 and near the center of Sec. 6, T. 42 and 43 of R. 32, Mich. These unquestionably are all on the same belt, and it appears to me that the easterly extension of this range passes along on the north side of the river in Secs. 18 and 17 of T. 41, R. 31, Mich.

A line of magnetic attractions traverses the north half of these two sections in an east and west direction. I did not see any outcrops in the zone of these attractions, but saw instead several pieces of specular quartz schist, which leads me to believe that within this "Brulè range" is a fair show for good iron ore.

We can present now only two locations on the Menominee range in Wisconsin, the Commonwealth and Eagle mines, where iron ore has been developed in paying quantity, but even with this small beginning we have, I think, sufficient evidence in the belts of magnetic attractions to warrant the assertion that the Menominee range in Wisconsin will very soon become one of the leading iron mining districts of this country.

For the manufacture of charcoal pig iron, it offers many superior advantages over any locality I know of, which cannot fail to be quickly recognized as soon as the railroad extension reaches this district. The timber in the vicinity of these iron ranges is chiefly hard wood, and the land, when the forests are cleared away, will yield abundant harvests. Charcoal pig iron could be made here with the present price of labor and material, at a cost not to exceed $14 per gross ton, which would afford a handsome profit.

Another mineral which occurs in this district, associated with the iron formation, is the plumbaginous schist. This substance is very soft and friable, and, owing to this, it is seldom found outcropping. This property is due to the graphite it contains, and hence the richer it is in this mineral, the less likely are we to find it at or near the surface. These facts lead me to the conclusion that very rich and valuable deposits of it will eventually be discovered here. See, also, lithological descriptions, Nos. 149 to 151, page 716.

Mr. H. A. Tuttle, of the Commonwealth Iron Co., who has examined it for economic purposes, writes me, in a recent letter, as follows: "In answer to your inquiries, would state that we find the plumbaginous schist all along on the south side of our iron range, in Secs. 32, 33 and 34. We dug into it on the side hill some fifteen feet, and in that width did not get across it. It is very uniform as to quality; analyses of it gave forty per cent. of carbon. There have been no experiments made of it, except those I made for paint, for which purpose it answers well. It is hardly pure enough for pencils, but possibly might do for foundry facings and other coarse work."

The following analyses of Menominee iron ores was kindly furnished me by Mr. J. J. Hagerman, President of the Menominee Mining Company. The analyses were made during 1878 and 1879:

NAME OF MINE.	Insol. Reds.	Al.	Lime.	Iron.	Phos.	Chemist.
Quinnesec.......	4.349	2.203	....	64.633	0.007	Lucy Furnace Co.
Quinnesec.......	4.349	2.341	....	64.377	0.003	Lucy Furnace Co.
Quinnesec.......	5.283	2.684	....	62.222	0.012	Lucy Furnace Co.
Quinnesec.......	7.613	1.193	....	62.667	0.016	Lucy Furnace Co.
Quinnesec.......	2.980	*	....	67.050	0.017	Cambria Iron Co.
Quinnesec.......	4.750	0.380	1.050	66.190	trace.	C. E. Wright.
Quinnesec.......	*	*	*	66.410	0.017	C. E. Wright.
Vulcan	5.427	2.494	....	63.327	trace.	Lucy Furnace Co.
Vulcan	13.958	2.300	....	57.640	0.009	Lucy Furnace Co.
Vulcan	8.408	1.664	....	61.850	0.017	Lucy Furnace Co.
Vulcan	9.726	0.965	....	61.560	0.018	Lucy Furnace Co.
Vulcan	8.900	*	....	63.160	0.017	Cambria Iron Co.
Vulcan	1.400	*	0.720	†66.570	*	C. E. Wright.
Vulcan	*	*	....	†64.200	0.013	C. E. Wright.
Cyclops.........	4.964	1.386	....	65.486	0.012	Lucy Furnace Co.
Cyclops.........	11.488	1.508	....	60.171	0.015	Lucy Furnace Co.
Cyclops.........	8.464	1.514	....	61.215	0.014	Lucy Furnace Co.
Cyclops.........	8.839	1.438	....	60.393	0.024	Lucy Furnace Co.
Cyclops.........	3.600	0.950	....	64.470	0.019	C. E. Wright.
Norway	12.831	0.712	....	59.777	0.008	Lucy Furnace Co.
Norway	12.377	1.021	....	59.760	0.008	Lucy Furnace Co.
Norway	15.148	1.892	....	57.085	0.009	Lucy Furnace Co.
Norway	*	*	....	61.470	*	C. E. Wright.
Norway	*	*	....	60.640	*	C. E. Wright.
Norway	4.500	*	....	59.200	*	C. E. Wright.
Norway	9.700	*	....	60.780	*	C. E. Wright.

* Not determined. † New bed, just opened.

TABLE OF TIMBER ESTIMATES.

FRACTIONAL PARTS OF SECTION.	Section.	Town.		Range.		State.	Cordage per acre.	Proportion of hardwood.	Proportion of swamp or lake.	REMARKS.
....	15	40	N.	17	E.	Wis.	......	......	......	
....	16	40	N.	17	E.	Wis.	......	......	......	Mostly good pine.
....	17	40	N.	17	E.	Wis.	......	......	......	
S. E. qr.......	18	40	N.	17	E.	Wis.	40	3/4	1/5	
E. hf. N. E. qr.	18	40	N.	17	E.	Wis.	40	3/4	1/10	
E. hf. E. hf...	19	40	N.	17	E.	Wis.	40	3/4	......	
W. hf	19	40	N.	17	E.	Wis.	45	1/4	1/3	
....	20	40	N.	17	E.	Wis.	40	3/4	1/10	Some white pine
S. hf..........	21	40	N.	17	E.	Wis.	45	3/5	......	
N. hf.	21	40	N.	17	E.	Wis.	35	1/2	1/8	Some white pine
S. hf..........	22	40	N.	17	E.	Wis.	35	1/4	1/10	
E. hf. N.W. qr.	27	40	N.	17	E.	Wis.	45	2/3	......	Some white pine
E. hf..........	28	40	N.	17	E.	Wis.	40	1/2	1/3	Some white pine
W. hf.	28	40	N.	17	E.	Wis.	45	3/5	......	
E. hf..........	29	40	N.	17	E.	Wis.	40	1/2	......	
W. hf.........	29	40	N.	17	E.	Wis.	45	3/5	......	
E. hf..........	30	40	N.	17	E.	Wis.	40	1/2	1/10	
W. hf.........	30	40	N.	17	E.	Wis.	40	1/2	1/3	
N. E. qr......	31	40	N.	17	E.	Wis.	40	1/2	1/8	
S. E. qr.......	31	40	N.	17	E.	Wis.	50	3/4	......	
S. W. qr......	31	40	N.	17	E.	Wis.	50	4/5	......	
N. W. qr.....	31	40	N.	17	E.	Wis.	45	2/3	......	
....	32	40	N.	17	E.	Wis.	40	1/2	......	
....	33	40	N.	17	E.	Wis.	40	2/3	......	
W. hf.........	3	39	N.	17	E.	Wis.	55	4/5	......	Good farm land.
....	4	39	N.	17	E.	Wis.	50	1/2	......	
....	5	39	N.	17	E.	Wis.	45	2/3	1/5	
N. E. qr.......	6	39	N.	17	E.	Wis.	45	2/3	1/2	
S. E. qr.......	6	39	N.	17	E.	Wis.	40	1/4	1/2	
W. hf.........	6	39	N.	17	E.	Wis.	40	1/4	3/4	
N. E. qr.......	7	39	N.	17	E.	Wis.	40	1/4	1/2	
W. hf.........	7	39	N.	17	E.	Wis.	50	4/5	1/8	
E. hf..........	8	39	N.	17	E.	Wis.	50	3/4	1/10	
....	9	39	N.	17	E.	Wis.	40	1/2	1/5	
W. hf.........	19	40	N.	16	E.	Wis.	50	2/3	......	Con. white pine
E. hf..........	19	40	N.	16	E.	Wis.	50	......	......	Mostly wh. pine
N. hf. N. hf...	20	40	N.	16	E.	Wis.	50	......	......	Splendid wh. p.
S. hf. N. hf....	20	40	N.	16	E.	Wis.	50	4/5	......	
S. hf..........	20	40	N.	16	E.	Wis.	50	4/5	......	
N. hf.	21	40	N.	16	W.	Wis.	50	4/5	1/6	
S. hf..........	21	40	N.	16	W.	Wis.	50	1/2	1/6	
....	22	40	N.	16	W.	Wis.	50	4/5	......	Good farm land
N. W. qr......	23	40	N.	16	W.	Wis.	50	4/5	1/6	
N. E. qr......	23	40	N.	16	W.	Wis.	45	3/5	1/10	
S. hf..........	23	40	N.	16	W.	Wis.	50	2/3	1/10	
....	24	40	N.	16	W.	Wis.	40	3/5	1/10	
....	25	40	N.	16	W.	Wis.	45	3/5	2/5	
N. E. qr.	26	40	N.	16	W.	Wis.	45	1/2	1/10	
S. E. qr.......	26	40	N.	16	W.	Wis.	45	3/4	......	
S. W. qr.	26	40	N.	16	W.	Wis.	45	2/3	......	
N. W. qr......	26	40	N.	16	W.	Wis.	45	3/5	1/2	
N. hf. N. hf...	27	40	N.	16	W.	Wis.	50	3/4	......	
S. hf. N. hf...	27	40	N.	16	W.	Wis.	40	1/2	2/3	
S. hf..........	27	40	N.	16	W.	Wis.	40	1/2	1/2	
....	28	40	N.	16	W.	Wis.	50	3/4	1/20	
....	29	40	N.	16	W.	Wis.	50	3/4	......	
....	30	40	N.	16	W.	Wis.	50	3/4	1/10	Good p. in N hf

TABLE OF TIMBER ESTIMATES—(continued).

Fractional parts of section.	Section.	Town.		Range.		State.	Cordage per acre.	Proportion of hardwood.	Proportion of swamp or lake.	Remarks.
W. hf.........	31	40	N.	16	W.	Wis.	40	$\frac{3}{5}$	$\frac{1}{6}$	
E. hf..........	31	40	N.	16	W.	Wis.	45	$\frac{3}{5}$	$\frac{1}{10}$	
N. W. qr......	32	40	N.	16	W.	Wis.	45	$\frac{1}{2}$	$\frac{1}{10}$	
N. E. qr.	32	40	N.	16	W.	Wis.	35	$\frac{1}{2}$	$\frac{3}{4}$	
S. hf..........	32	40	N.	16	W.	Wis.	45	$\frac{3}{4}$	$\frac{1}{10}$	
....	33	40	N.	16	W.	Wis.	45	$\frac{1}{2}$	$\frac{1}{2}$	
....	34	40	N.	16	W.	Wis.	45	$\frac{1}{2}$	$\frac{1}{2}$	
N. W. qr......	35	40	N.	16	W.	Wis.	50	$\frac{1}{5}$	$\frac{1}{10}$	
N. E. qr.......	35	40	N.	16	W.	Wis.	50	$\frac{3}{4}$	$\frac{1}{2}$	
S. hf..........	35	40	N.	16	W.	Wis.	50	$\frac{3}{4}$	$\frac{1}{4}$	
N. W. qr......	36	40	N.	16	W.	Wis.	50	$\frac{4}{5}$	$\frac{1}{10}$	
N. E. qr.......	36	40	N.	16	W.	Wis.	50	$\frac{1}{2}$	$\frac{1}{5}$	
S. hf..........	36	40	N.	16	W.	Wis.	50	$\frac{3}{4}$	$\frac{1}{10}$	
W. hf.........	1	39	N.	16	W.	Wis.	50	$\frac{3}{4}$	$\frac{1}{8}$	
E. hf.	1	39	N.	16	W.	Wis.	40	$\frac{3}{4}$	$\frac{1}{3}$	
....	3	39	N.	16	W.	Wis.	50	$\frac{3}{4}$	......	Good farm land
....	4	39	N.	16	W.	Wis.	40	$\frac{3}{5}$	$\frac{1}{3}$	
N. hf.	5	39	N.	16	W.	Wis.	45	$\frac{3}{4}$	......	

CHAPTER II.

LITHOLOGY.*

The following descriptions of rocks, written early in 1875, are of specimens collected from the Menominee iron district, by Major T. B. Brooks and myself, during the autumn of 1874.

The following lithological classification is taken from Dr. F. Zirkel's work on Petrographie:

I. Simple rocks.
II. Quartzose rocks.
III. Silicate rocks.
IV. Iron ores. (See also Economic Chapter.)
V. Carbonaceous rocks.
VI. Granitoid rock.

For convenience of reference a table will be found at the end of this chapter, which gives in each set of columns the descriptive number and the corresponding collection number now attached to the specimen.

Calcareous rocks.

These are represented by only two specimens, Nos. 1 and 2. The first is a coarse granular limestone, holding apparently slender blades of cyanite. The other is a pinkish gray, very fine grained, siliceous marble.

Quartzose rocks.

Under this heading are described, first, the purer quartzites and quartz-schists, then the micaceous quartz-schists and mica-schists. The reason for bringing the mica-schists under this heading, is that the three named schists are often present in the same bed, and pass so gradually into each other, that it is very difficult to define their division line, except, perhaps, in a few isolated cases, where even then it might be questionable if such a division were desirable.

Next in order are two varieties of the mica-schists, staurolitiferous and garnetiferous, and finally the talcose, chloritic and specular quartz-schists.

Amphibolites.

These rocks are composed chiefly of amphibole, with quartz and feldspar in variable quantities. Mica, chlorite, lime, pyrite and magnetite are often present as accessories; also viridite as a secondary product of alteration. By reason of well characterized differences in these rocks, I have divided them into four classes, viz.: Amphibole rock, actinolite schist, hornblende schist, and hornblende rock.

* This chapter was prepared early in 1875.

The first, the amphibole rock, is light to dark-green, fine-grained, very compact, and rings when struck with the hammer. It is usually massive and strongly jointed. Under the microscope, the amphibole presents a bushy structure, resembling actinolite. As accessories may be counted chlorite, pyrites, quartz, mica and lime.

2. ACTINOLITE-SCHISTS. — These vary greatly in structure and texture; some are minutely fibrous, others are coarsely so. Many are highly ferruginous, others are very siliceous. The principal ingredients, however, are actinolite and quartz with chlorite, talc, and sometimes anthophyllite. Mica, pyrite and magnetite are often contained as accessories.

3. HORNBLENDE-SCHISTS. — They have usually a greenish to grayish-black color, fine-grained texture. Schist planes are strongly marked, though not always apparent in the hand specimen. To the touch they have a raspy feel. Their principal ingredients are amphibole and quartz, with feldspar (sometimes prominent), mica, chlorite, magnetite, lime and pyrites, as accessories. Some of them, when holding considerable feldspar, resemble hornblende-gneiss.

To form a separate division under this name would be hardly feasible from our present data, and for that reason I have considered them all under the above heading.

4. HORNBLENDE-ROCKS. — These vary greatly in texture and somewhat in the proportion of the essential ingredients, namely, amphibole, quartz and feldspar, with mica chlorite, magnetite and pyrite as accessories.

Greenstones.

The members of this group differ from those of the amphibolites in their more basic nature, and in containing but very little, if any, quartz.

Their principal ingredients are pyroxene and triclinic feldspar (diabase) or amphibole and triclinic feldspar (diorite). Chlorite is usually present as an accessory, but sometimes as an essential mineral (chloritic diorite). To distinguish the members of this family I have divided them into four groups, viz: Diabase, diorite, hornblende-diorite and chloritic-diorite.

The diabases are represented by only one specimen in my suite, which in appearance resembles some of the hornblende schists. Its presence is very interesting since it is the first pyroxenic rock I have met in the Lower Huronian series.[1]

The diorites are well represented. They range from an aphanitic to a coarse granular porphyritic texture. Their color varies greatly, depending on the percentage of amphibole or chlorite. They are usually massive, showing only obscure signs of bedding, and often resemble very much the hornblende rocks of the amphibolites. So strong is this similarity in many instances, that it is impossible to decide between them by the eye alone.

Schists and slates.

Under this broad title are included the chloritic, talcose and argillaceous schists and slates.

They represent, I believe, nearly all the varieties we have met in the Huronian series.

Commencing first with the chloritic schists, we find them closely allied to the greenstones. Their manner of association would, in many instances, refer their origin to the greenstone-ashes, while on the other hand is suggested the possibility of a transition of the former into the latter (assuming that the greenstones of this section are metamorphic). Passing hastily[2] the many varieties of chloritic schists and slates, we meet in the order described, the talcose and argillaceous schists and slates.

[1] A better microscopic section of 1025, App., C. Mich. Geol. Rep, shows it to be a calcareous diorite.

[2] The general aphanitic and obscure character of these rocks renders it very difficult, in the absence of analyses and with only a few microscopic sections, to say anything definite about them.

Lastly are considered the rich and lean iron ores, the carbonaceous rocks and granites.

No. 1 (Sp. 2086[1]).—**Crystalline limestone or marble.** 800 N., 600 W.,[2] Sec. 34, T. 42, R. 30, Mich.

Grayish-white. Coarse granular crystalline texture. Massive, uneven conchoidal fracture. On weathered surface can be seen several partially altered crystal fragments, resembling those of cyanite. They remain in the insoluble residue after treatment with acid.[3] Placing the residue under the microscope and bringing the edge of these insoluble pieces parallel with either of the principal planes of the crossed nicols, they remain light, and only become dark when the edge makes quite an angle with the crossed nicol planes.

No. 2 (Sp. 2068). — **Siliceous marble.** 900 N., 0 W., Sec. 32, T. 40, R. 30, Mich.

Light pinkish-gray. Dull, vitreous luster, approaching a semi-enamellar texture. Subconchoidal fracture. Traversing the rock are narrow gray, siliceous seams, that are best observed on a weathered surface.

The veins cross each other, and vary in width from the thickness of a sheet of paper to one-eighth of an inch.

Weathers to a light drab. Hardness, about 4.5. Sight effervescence in cold acid, but on warming becomes brisk, and finally leaves a large siliceous residue, which, examined under the microscope, is seen to consist of irregular, angular crystalline fragments. BB.[4] becomes pale lemon color without fusing.

Quartzose rocks.

No. 3 (Sp. 2083). — **Quartzite.** 0 N., 1,000 W., Sec. 17, T. 41, R. 30, Mich.

Grayish white. Even, arenaceous, semi-saccharoidal texture. Dull, vitreous luster. Somewhat jointed. One surface is broadly corrugated, resembling ripple or glacial markings. The corrugations measure about one inch from crest to crest. Sp. Gr. 2.68. Resembles, at first glance, a highly indurated sandstone.

No. 4 (Sp. 2085). — **Quartzite.** 2,000 N., 1,000 W., Sec. 3, T. 41, R. 30, Mich.

Grayish-white, mottled with pale-green. Raw, vitreous texture. The greenish mineral has a fibrous, often radiated, structure. Taking a few of these acicular crystals and examining them under the microscope, they appear to be those of actinolite.

No. 5 (Sp. 2187). — **Quartz-conglomerate.** 1750 N., 500 W., Sec. 25, T. 40, R. 17, Wis.

The predominating color is grayish-white, with several bluish-black fragments of crypto-crystalline quartz.

Unevenly distributed through the mass are bright, glistening, pinkish-red scales, that give the specimen often the appearance of aventurine quartzite. Some of the fragments are an inch across. Surrounding many of the larger quartz grains are thin, pale-greenish, talcy layers.

No. 6 (Sp. 2093).— **Chloritic quartzite.** S. W. qr. of N. E. qr., Sec. 23, T. 41, R. 31, Mich.

Dark green, sprinkled with light gray, medium grained, even textured, strongly jointed. With a good lens can be seen numerous bluish grains, having a conchoidal fracture, which are probably those of quartz.

Under the M.[5] in polarized light, the grains of quartz in a section of the rock appear

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[1] Spec. No. (2086) is the number that is now attached to the specimens.

[2] 800 N. and 600 W. are respectively the number of paces. The outcrop from which the specimen was taken is located from the southeast corner of the section, 2000 paces being considered equal to one mile.

[3] Hydrochloric acid.

[4] Before the blow pipe.

[5] M. equals Microscope.

somewhat rounded, and average about one-fourth of an inch across. The matrix lying between the grains is composed of altered fragments of feldspar, small quartz grains and leaves of chlorite. The cement forms about one-half the entire mass.

With a power of 500 ×[1] can be seen in the quartz a few dancing bubble cavities.[2] Heating the slide to 100° C, the bubble becomes quiet, but does not disappear.

Spec. 2095, from S. W. qr. of N. E. qr., Sec. 23, T. 41, R. 31, Mich., is very similar to 2093.

No. 7 (Sp. 2158).—**Chloritic quartzite.** (Provisional.) N. W. qr. of N. W. qr., Sec. 16, T. 41, R. 31, Mich.

Greenish-gray, mottled with gray. The base has a fine-grained texture, thickly strewed with small rounded grayish grains of quartz, and minute black scales of chlorite or mica. An occasional small crystal facet is visible, resembling that of feldspar. Weathers to a light drab.

No. 8 (Sp. 2074).—**Arenaceous quartzose schist.** Four Ft. Falls, N. E. qr. of N. W. qr., Sec. 14, T. 39, R. 19, Wis.

Very pale greenish-gray, mottled with brown. Fine-grained, arenaceous texture. The brownish spots appear to be due to the decomposition of some ferruginous mineral. Schistose structure. Coursing through the specimen, is a vein of glassy quartz nearly an inch in width.

No effervescence in acid. BB. infusible. The specimen resembles a calciferous sandstone.

No. 9 (Sp. 2216).—**Quartzose schist.** 50 N., 1300 W., Sec. 23, T. 39, R. 17, Wis.

Light bluish-gray. Aphaiutic marbly texture. Under the lens it appears arenaceous. Schistose structure not very distinct. Cleaves with difficulty into thick plates. On splitting planes it is often talcy.

No. 10 (Sp. 2081).—**Arenaceous quartzose schist.** 1250 N., 1750 W., Sec. 30, T. 41, R. 30, Mich.

Dark gray, fine-grained, arenaceous texture. Some portions are brownish, which is evidently due to decomposition. Disseminated in the gray portions of the rock are minute bunches of oxide of iron, as may be seen by examining carefully a fresh scratch made with the knife point.

BB. fuses at 6, to a blebby enamel.

No. 11 (Sp. 2162).—**Micaceous quartz-schist.** S. W. qr. of Sec. 35, T. 42, R. 32, Mich.

Silvery grayish-green on cleavage planes, and shimmering luster. On edge, dark grayish-green; fine-grained arenaceous texture. Weathers nearly a quarter of an inch from surface to a light grayish-drab. Schistose structure. Cleaves readily into even thick plates. Somewhat jointed. Under the M., the section appears composed chiefly of small, angular grains of quartz, interspersed with numerous greenish leaves of chlorite and a few brownish ones of mica; also several opaque grains of magnetite.

No. 12 (Sp. 2163.)—**Micaceous quartz-schist.** Paint River Portage. S. W. qr. of Sec. 35, T. 42, R. 32, Mich.

Dark steel-gray; fine-grained, even, arenaceous texture. Schistose structure. Somewhat jointed. Slightly friable. A fresh cleavage surface has a sparkling luster. With a strong lens can be seen very minute black scales of mica. BB. fuses at 4.5 to a pale green glass.

No. 13 (Sp. 2205).—**Micaceous quartz-schist.** 1520 N., 850 W., Sec. 22, T. 39 R. 17, Wis.

Dark gray. Fine-grained arenaceous texture. Weathers to a light grayish-drab. Schistose structure. Cleaving into plates about half an inch in thickness. Inter-

[1] 500 x equals 500 diameters.

[2] Dancing bubble cavities are cavities nearly filled with liquid and a moving bubble.

spersed in the specimen are numerous white scales of mica; also several tiny black ones. BB. fuses at 5 to a blebby glass. Under the M., in the polarized light, a section of the rock presents a fine quartzy base, interspersed with a few large quartz grains; also light and dark-colored micas, muscovite and biotite. An occasional altered fragment of feldspar and a grayish patch of calcite can be recognized. The schistose structure is very apparent. With a power of 500 diameters may be seen, scattered through the section, numerous minute crystals resembling those of rutile.

No. 14 (Sp. 2206). — **Micaceous quartz-schist.** 1640 N., 620 W, Sec. 22, T. 39, R 17 Wis.

Dark gray. Fine-grained, arenaceous texture. Schistose structure. The cleavage planes are finely corrugated. With the lens can be recognized numerous small scales of black and white mica; the former greatly in excess of the latter. Effervesces briskly in acid for a moment. BB. infusible. Under the M. it presents a very arenaceous base. The grains are small and elongated, averaging about one-four-hundredth of an inch across. The longer axis of the grains have a common trend. Scattered through the section are numerous leaves of brown mica; also a few fragments of chlorite.

No. 15 (Sp. 2223). — **Micaceous quartz-schist.** 900 N., 50 W., Sec. 24, T. 39, R. 17, Wis.

Dark steel-gray, sprinkled with light gray. Fine-grained texture. Cleaves readily into thick plates. With the strong lens are visible numerous black scales of mica. Scattered over the surface are several particles of iron pyrites; also bunches of calcite. Under the M., between the crossed nicols, it presents an indistinct, very fine-grained, arenaceous base, strewn with numerous brownish leaves of biotite and a few partially decomposed crystals of orthoclase.

No. 16 (Sp. 2281). — **Micaceous quartz-schist.** 1200 N., 1825 W., Sec. 23, T. 39, R. 17, Wis.

Light-gray, slightly tinged with blue. Very fine-grained texture.

Under the loupe it appears arenaceous, interspersed with minute dark scales of biotite. Schistose structure; the cleavage planes, owing to the fragile nature of the rock, are not very even. On the surface are visible small bunches of bronze-colored mica.

Weathers to a light-drab. No effervescence in acid. BB. fuses at 6 to a white enamel. Under the M., between the + nicols, it presents a very pretty chromatic field. The grains of quartz are quite small, averaging not more than $\frac{1}{5000}$ of an inch across. Interspersed through the section are several leaves of brown mica biotite; also colorless ones resembling talc. An occasional highly altered fragment of some mineral, apparently that of orthoclase, can be recognized.

With a power of 500 × can be seen a few minute, plain and twin crystals, resembling those of rutile. They are quite small, averaging about $\frac{1}{3000}$ of an inch in length and $\frac{1}{20000}$ of an inch in thickness.

No. 17 (Sp. 2231). — **Micaceous quartz-schist.** 1025 N., 1350 W., Sec. 29, T. 39, R. 18, Wis.

Light yellowish-drab; very fine, arenaceous texture. Schistose structure. The splitting planes usually glisten with minute scales of mica.

Disseminated in the mass can be seen, under a strong lens, numerous leaves of dark-brownish biotite.

No. 18 (Sp. 2233). — **Micaceous quartz-schist.** 1600 N., 600 W., Sec. 29, T. 39, R. 18, Wis.

Dark-gray, mixed with black. Fine-grained texture; somewhat arenaceous. Schistose structure; the schist planes being often covered with thin films of lime. Scattered through the rock are numerous scales of black mica. The specimen examined on the edge resembles, slightly, Sp. 2226.

BB. fuses at 4.5 to a greenish bead. Under the M., the rock appears somewhat altered. With the + nicols can be recognized numerous small brownish leaves of biotite, grayish patches of lime, fragments of amphibole, chlorite, a great many grains of quartz and partially decomposed feldspar; also several slender forms of some opaque mineral.

No. 19 (Sp. 2159). — **Mica-schist.** 1,000 N., 1,000 W., Sec. 8, T. 41, R. 31, Mich.

Mixture of dark and light gray. Fine-grained, arenaceous texture On cleavage surface it has a bright, shimmering luster. Schistose structure, cleaving into thick plates. The scales of mica are quite small, but easily recognized under the loupe.

No. 20 (Sp. 2161). — **Mica-schist.** Paint Portage, N. W. qr. Sec. 36, T. 42, R. 32, Mich.

Pearly greenish-gray, and bright, shimmering luster. Finely corrugated, schistose structure. The cleavage surface appears somewhat knotty. On the edge of a fresh fracture it presents an arenaceous texture; cleaves readily into thick plates.

No. 21 (Sp. 2145). — **Chloritic mica schist.** 500 N., 2,000 W., Sec. 9, T. 41, R. 31, Mich.

Grayish-green; on cleavage planes it presents a bright, shimmering texture. Very fissile, splitting readily into thick plates. The grayish scales of mica are quite small, but are easily recognized with the loupe. Examined on the edge, across the lamination it shows a grayish, very arenaceous texture. Under the microscope, it presents a highly arenaceous base, interspersed with brownish and greenish leaves of mica and chlorite.

Sp. 2146, Cedar Rapids, 1,250 N., 900 W., Sec. 8, T. 41, R. 31, Mich., is a variety of Sp. 2145, containing more chlorite, is less siliceous, and has a crumpled or wavy schistose structure.

No. 22 (Sp. 2160). — **Staurolitiferous mica-schist** (Prov.) 450 N., 1,850 W., Sec. 31, T. 42, R. 31, Mich.

Pearly, greenish-gray, and bright, shimmering luster. Corrugated, wavy, schistose structure. On cleavage surface it appears knotty. On weathered surface are prominent, numerous crystals resembling those of staurolite; the crystals in the hand specimen are very imperfect, but one fragment is apparently a portion of a twin or cross crystal of staurolite.

See specimen 61, State Collection, App. B., page 209, Vol. II, Mich. Geol Survey, 1873.

No. 23 (Sp. 2220). — **Garnetiferous chloro-mica-schist.** 1775 N., 500 W., Sec. 25, T. 39, R. 17, Wis.

Mixture of grayish-green and light-gray. Fine grained texture. On the edge can be seen numerous crystals of red garnet, many of which are one-eighth inch across. Disseminated in the mass are small scales of brown and black micas; light greenish mineral or substance is visible under a strong loupe. No effervescence in acid. BB. fuses at 4.5 to a black magnetic bead.

Under the M., the section appears to be an aggregation of quartz-grains, chlorite, mica, garnet, fragments of feldspar, and magnetite. The chlorite is light green. The mica, dark brown and is largely contained. Only a little feldspar can be recognized; there are, however, several grayish patches that remain light between the + nicols, which may be due to decomposed feldspar. The garnets are readily distinguished by their form and by their becoming dark between the crossed nicols.

No. 24 (Sp. 2213). — **Talcy quartzose schist.** 600 N., 1000 W., Sec. 24, T. 40, R. 17, Wis.

Silvery gray, tinged with pink. Indistinct, medium grained texture. Schistose structure; the cleavage planes are usually covered with silvery scales of talc. No effervescence in acid. BB. infusible.

Under the M., the grains of quartz appear to vary greatly in size, the larger ones being about one-eightieth of an inch across. Lying between the quartz-grains is the nearly colorless talcy mineral; it is often minutely fibrous, but usually in slender scales.

With a power of 500 × can be seen in the quartz, dancing bubble cavities.

No. 25 (Sp. 2089).—**Chloritic quartzose schist.** 750 N., 1000 W., Sec. 18, T. 40, R. 19, Wis.

Dark grayish green. Fine grained texture. Schistose structure rather obscure; cleaves into rhombohedral shaped masses. Hardness 3. to 4. Streak powder yellowish green. Effervesces briskly in acid for a moment. BB. fuses at 5. to a black glass.

No. 26 (Sp. 2090).—**Chloritic arenaceous schist.** 750 N., 1000 W., Sec. 18, T. 40, R. 19, Wis.

Grayish greenish black. Weathers to a dirty greenish drab. Even, fine-grained texture. With a strong loupe the minute greenish black scales of chlorite are barely visible. Hardness, 3. to 4. Slight effervescence in acid.

Under the M., nearly all the chlorite becomes dark between the + nicols; only a few fragments that are cut only slightly oblique or nearly parallel to the principal crystalline axis, afford any light. The minute chromatic grains of quartz are easily recognized; also, small granules of lime, which are often united, forming small grayish patches in the field. A little magnetite is visible.

No. 27 (Sp. 2091).—**Chloritic arenaceous schist.** 900 N., 100 W., Sec. 18, T. 40, R. 19, Wis.

Dark greenish black, sprinkled with gray. Somewhat jointed. Irregular schistose structure. Hardness about 3.5. Slight effervescence in acid. BB. fuses at 4, with intumescence to a dark green, magnetic glass. Under the M., in the polarized light, the grains of quartz and chlorite are easily recognized, and appear to be almost equally divided; the former are angular and average about $\frac{1}{400}$ of an inch in size. Scattered in the section are a few grayish patches, probably lime. In the common light the brown leaves of mica are plainly visible. Thickly disseminated in the section, are minute opaque particles resembling magnetite.

No. 28 (Sp. 2225).—**Chloritic quartz-schist.** On Pine river. Sec. 30, T. 39, R. 18, Wis.

Dark gray. Fine-grained texture. Schistose structure. On the surface are visible several facets of feldspar; also very minute silvery scales. With a strong loupe can be recognized numerous small black leaves of mica. Feeble effervescence in acid. Under the M., in the polarized light, portions of the section present a dim, grayish texture, while others are very arenaceous. Several large fragments of highly altered crystals of feldspar are contained; also a few of chlorite or mica. With a power of 500 × can be seen several minute, rutile-like crystals. See No. 16 (Sp. 2281).

No. 29 (Sp. 2222).—**Chloritic quartzose schist.** 150 N., 1540 W., Sec. 24, T. 39. R. 17, Wis.

Deep greenish-gray and grayish-white. Dull, semi-vitreous luster. Cleaves not easily into plates, having pitted surfaces. A fresh fracture is often strewn with white, talcy scales. Somewhat jointed. Under the M., in the polarized light, very similar to No. 28 (Sp. 2225). With a power of 500 ×, the section appears thickly scattered with very minute simple and twin crystals resembling rutile. See No. 16 (Sp. 2281).

No. 30 (Sp. 2232).—**Chloritic quartzose schist.** 1150 N., 1050 W., Sec. 29, T. 39, R. 18, Wis.

Grayish-green, tinged with purple. Fine-grained, slightly glistening texture. Schistose structure. With the loupe can be seen a pale greenish mineral resembling talc. No effervescence in acid. BB. portions of it fuse at 5. to a yellowish gray glass, Under the M., between the crossed nicols, can be seen numerous grayish patches, apparently those of decomposed feldspar. Scattered in the section are small, pale greenish colorless leaves, resembling those of chlorite. The small grains of quartz are easily recognized. With a power of 500 × are visible the minute rutile-like crystals.

No. 31 (Sp. 2058). — **Chloritic quartzose schist.** 1650 N., 0 W., Sec. 15, T. 38, R. 20, Wis.

Light greenish-gray; aphanitic texture. Cleaves readily into thick slates.

The cleavage surface usually shimmers with minute scales. The joints are often filled with calcite and quartz. Hardness, about 4.5. BB. fuses at 4.5 to a very pale-green glass.

Under the M., between the + nicols, it presents an indistinct arenaceous texture. In the plain light, with a power of 500 ×, can be seen numerous pale-greenish leaves of chlorite, also rutile-like crystals. This latter fact is rather interesting since some twenty miles intervene between this and the other specimens holding apparently rutile.

No. 32 (Sp. 2224). — **Specular quartzose schist.** 1650 N., 350 W., Sec. 19, T. 39, R. 18, Wis.

Grayish-white and bright, metallic steel-gray. Fine-grained, arenaceous texture. The surface in a side fracture has a slightly mottled appearance, owing to lenticular shaped bunches of arenaceous quartz. The quartz forms the base of the rocks through which is disseminated the minute scales of specular ore, and the two are often in irregular layers.

No. 33 (Sp. 2184). — **Specular quartzose schist.** 200 N., 1800 W., Sec. 32, T. 40, R. 18, Wis.

Bluish-gray and grayish-white, banded with specular ore. Fine-grained, arenaceous texture.

The specular layers examined under the loupe appear to be a mixture of chlorite and specular ore. Somewhat friable. Sp. Gr. 2.80. The specimen resembles some of the magnetic schists at the Michigamme mine of the Marquette Iron district. (See economic chapter.)

Amphibolites.

No. 34 (Sp. 2132). — **Chloritic amphibole rock.** 1800 N., 1950 W., Sec. 7, T. 39, R. 19, Wis.

Dark grayish green; aphanitic texture. Very jointed, cleaving often into thick plates, but usually in three directions unequally inclined to each other. Hardness about 5. Streak powder grayish white. Sp. Gr. 3.03. Very feeble effervescence in acid. BB. fuses at 4. to a black glass. Under the M., the amphibole presents a fibrous, bushy structure resembling actinolite.

The chlorite is evenly distributed in pale greenish leaves.

An occasional grayish patch of lime and a few grains of quartz are easily recognized. With a power of 500 × are visible numerous opaque particles, probably those of magnetite.

No. 35 (Sp. 2136). — **Amphibole rock.** Upper Twin Falls. Sec. 2, T. 39, R. 19, Wis.

Light green; very compact aphanitic texture. Conchoidal fracture; very jointed and rings when struck with the hammer. Disseminated in the rock are thin scaly patches of pyrites. Hardness about 5.5. Sp. Gr. 3.06. BB. fuses at 3.5 to a black magnetic bead. Under the M., very similar to No. 34.

No. 36 (Sp. 2155). — **Amphibole rock.** 1840 N., 100 W., Sec. 16, T. 40, R. 18, Wis.

Grayish green; fine grained, even texture; massive and jointed; conchoidal fracture. Weathers to a greenish drab. Sp. Gr. 3.06. BB. fuses at 4. to a black bead. Under the M., very similar to No. 34.

No. 37 (Sp. 2172). — **Amphibole rock.** 525 N., 300 W., Sec. 9, T. 40, R. 18, Wis.

Dark grayish green. Medium grained, indefinite crystalline texture. Very jointed and somewhat chloritic. Conchoidal fracture. Weathers to a light drab. Hardness about 5. Sp. Gr. 3.00. No effervescence in acid. BB. fuses at 4. to a black bead. Under the M. similar to No. 34.

No. 38 (Sp. 2173).—**Chloritic amphibole rock.** 400 N., 250 W., Sec. 9, T. 40, R. 18, Wis.

Dark grayish green. Fine grained, even texture. Under the loupe it appears somewhat arenaceous. The hand specimen is very jointed and apparently schistose. Weathers to a snuff brown. Hardness 3.4. Sp. Gr. 2.70. No effervescence in acid. BB. fuses at 4. to a black, blebby glass. Under the M. very similar to No. 37, only it contains more chlorite.

No. 39 (Sp. 2175).—**Chloritic amphibole rock.** 300 N., 200 W., Sec. 9, T. 40, R. 18, Wis.

Bright grayish green; fine grained, even texture; uneven fracture; very jointed. The cleavage planes are usually covered with tiny glistening scales, resembling those of brown biotite. Coursing through the specimen is a narrow grayish drusy seam of lime and quartz. Hardness 4.5. Sp. Gr. 2.95. BB. fuses at 4. to a black glass. Under the M. very similar to No. 35.

No. 40 (Sp. 2171).—**Chloritic amphibole rock.** 730 N., 410 W., Sec. 9, T. 40, R. 18, Wis.

Dark green; fine grained, somewhat crystalline texture. Schistose structure. Cleaves readily into thick plates. The surface is slightly pitted and the jointing planes across the lamination are finely corrugated. Hardness, 4.5. Sp. Gr. 3.00. No effervescence in acid. BB. fuses at 4. to black magnetic bead. Under the M. it presents a confused structure, composed of more or less fibrous fragments of amphibole, numerous grains of quartz and a few fragments of feldspar. With a power of 500 × can be seen scattered among the dark green amphibole, greenish leaves of chlorite.

No. 41 (Sp. 2177).—**Chloritic amphibole rock.** 1650 N., 1450 W., Sec. 15, T. 40, R. 18, Wis.

Dull, dark grayish green; fine grained texture. Jointed and somewhat schistose structure. On some of the splitting planes are minute brownish scales of mica, and on schist-planes are small light gray to greenish leaves resembling those of chlorite. Hardness about 3. BB. fuses at 4. to a black glass. Under the M., apparently a chloritic variety of No. 36.

No. 42 (Sp. 2178).—**Chloritic amphibole rock.** 1630 N., 1000 W., Sec. 15, T. 40, R. 18, Wis.

Bright grayish green; fine grained, even texture. Very similar on fresh fracture to No. 39. Somewhat schistose, with very little chlorite on cleavage planes. Slightly jointed, with a thin coating of calcite and a few scattered grains of copper pyrites in the joints. Hardness 4–5. Sp. Gr. 2.97. BB. fuses at 4. to a dark green glass. Under the M. resembles No. 36.

Sp. 2180, from 1900 N., 0 W., Sec. 15, T. 40, R. 18, Wis., is very similar to No. 42.

No. 43 (Sp. 2198).—**Actinolite schist.** 1735 N., 950 W., Sec. 34, T. 40, R. 17, Wis.

Grayish-green. Fibrously reticulated structure. The small slender acicular crystals of actinolite are plainly visible, and have a common trend, which imparts to the rock an imperfect schistose structure.

Uneven jagged fracture. BB. intumesces briskly, and fuses at 4.5 to a black mass. Under the M., the amphibole appears in long slender crystal fragments, all of which lie nearly in the same direction. Numerous grains of quartz are contained, which are usually grouped in bunches. An occasional fragment of orthoclase can be seen, also fibrous, bushy clusters of viridite. The section is stained in spots by thin films of hydrated oxide of iron.

No. 44 (Sp. 2238).—**Actinolite schist.** 1330 N., 1050 W., Sec. 28, T. 39, R. 18, Wis.

Silvery greenish-gray. Very coarse, fibrously radiated crystalline texture. The fan-shaped bunches of actinolite are often an inch or more in length. It is somewhat decomposed and has a talcy, greasy feeling. On cleavage surfaces it is quite soft.

In the bed the entire mass was very soft and easily cut with a knife, but since it was collected, it has dried and become quite hard. BB. fuses at 4–5. to a black, metallic, magnetic bead. It is probable that it is partially changed into viridite and chlorite.

No. 45 (Sp. 2207). — **Actinolite schist.** 1370 N., 640 W., Sec. 22, T. 39, R. 17, Wis.

Dark grayish-green; fine crystalline texture. Under the lens, it presents a closely woven reticulated mass. The majority of the actinolite crystals have a common trend, which gives the rock an imperfect schistose structure. Effervesces briskly in acid for a moment.

BB. fuses at 4.5 to a black magnetic glass.

Under the M. it presents a fibrously reticulated mass. In the plain light the actinolite has a very pale greenish color, and with the polarizer shows but little, if any, dichroism. Between the + nicols is visible a bushy, colorless mineral resembling talc, in which the optical bisectrix and crystallographic axes coincide. A few grains of magnetite can be seen.

No. 46 (Sp. 2189). — **Anthophyllo-actinolite schist.** 0 N., 1075 W., Sec. 35, T. 40, R. 17, Wis.

Pale grayish-green; fine fibrous structure. The acicular crystals are often grouped in radiated bunches so common to anthophyllite. Schistose structure, cleaving readily into thick, irregular plates. BB. fuses at 4. with intumescence to a black, blebby mass. Under the M., it presents a fibrously reticulated mass. The anthophyllite is easily recognized by the parallelism of the optic bisectrix and crystal axes. The actinolite is readily distinguished from the anthophyllite in the section, by the inclination of the optic bisectrix and principal crystal axis, provided the section is not taken pendicular to the symmetrical plane of the crystal. (See Rosenbush, 263 and 307.)

This rock resembles very much the anthophyllitic schists (XVII) of the Michigamme series. See Spec. 58, Mich. State Coll., Vol. II, page 209, which, under the microscope, peris seen to be a mixture of actinolite and anthophyllite.

No. 47 (Sp. 2191). — **Ferruginous actinolite schist.** 1,200 N., 140 W., Sec. 28, T. 40, R. 17, Wis.

Banded with light green and buffish-white. The former have a fibrous, often radiated structure; the latter is a fine-grained, arenaceous quartz. A narrow band of the actinolite bordering on the quartz has a beautiful silvery-gray texture.

The cleavage surfaces are sometimes covered with a lustrous coating of a hydrous oxide of iron. Splits readily into plates from one-eighth to an inch in thickness. BB. fuses at 5 to a black magnetic mass.

No. 48 (Sp. 2186). — **Magnetic anthophyllo-actinolite schist.** 400 N., 500 W., Sec. 25, T. 40, R. 17, Wis.

A fresh fracture presents the different shades of greenish-gray, and often sparkles with minute facets of magnetite. Fibrously radiated structure. Somewhat decomposed. Strongly magnetic, and very siliceous. Under the M., very similar to No. 46.

No. 49 (Sp. 2240). — **Magnetic anthophyllo-actinolite schist.** 1500 N., 1050 W., Sec. 28, T. 39, R. 18, Wis.

Deep green tinged with purple. Fine reticulated crystalline texture. The purplish tint is due to the partial decomposition of the fibrous mineral and magnetite.

Schistose structure cleaving readily into corrugated plates of variable thicknesses. Sp. Gr. 3.35. No effervescence in acid. BB. fuses at 4. Under the M., in the polarized light, the rock appears to be a mixture of actinolite and anthophyllite, the former, however, predominating. See No. 46. A few fragments and grains of garnets are contained.

No. 50 (Sp. 2203). — **Quartzy actinolite schist.** 1920 N., 1150 W., Sec. 22, T. 39, R. 17, Wis.

Grayish-white mixed with dark-green. Fine-grained and somewhat arenaceous; dull vitreous luster. The bands or layers of actinolite are apparently mixed with chlorite. Under the lens the minute fibrous crystals of actinolite are easily recognized.

BB., the greenish mineral, fuses at 4. to a magnetic glass.

No. 51 (Sp. 2057). — **Hornblende schist.** 1600 N., 1400 W., Sec. 16, T. 38, R. 20, Wis.

Greenish-black sprinkled with gray. Very fine-grained crystalline texture. Schistose structure in hand specimen not very apparent; the rock, however, in place is decidedly so, with strong bedding planes, and is traversed by irregular veins and dykes of granite. BB. fuses at 4.5 to dark-green glass. Under the M. it presents a pale-green, slightly dichroitic, reticulated mass of imperfect acicular crystals of amphibole, averaging about 1-300 of an inch in length. In the polarized light can be recognized numerous grains of quartz which are angular and vary greatly in size, the largest measuring not more than 1-200 of an inch across.

No. 52 (Sp. 2129). — **Hornblende schist.** 200 N., 700 W., Sec. 8, T. 38, R. 20, Wis.

Dark grayish-green; medium to fine-grained, highly crystalline texture. Obscure schistose structure. Uneven fracture, that has a rough, raspy feel. The surface sparkles with numerous facets of amphibole. Under the loupe can be distinguished thickly disseminated in the base, very minute grayish grains, probably those of quartz, as the speeimen scratches feldspar. Sp. Gr. 3.05. Feeble effervescence in acid. BB. fuses at 4. to a black glass.

Under the M., between the + nicols, it presents a very pretty field, composed principally of fragments of amphibole, quartz and feldspar. The former is often apparently twinned, and is in excess of the other minerals; the latter, the feldspar, is usually striated.

Sp. 2121, from 175 N., 700 W., Sec. 8, T. 38, R. 20, Wis.

Sp. 2123, from 2000 N., 1870 W., Sec. 16, T. 38, R. 20, Wis.

Sp. 2124, 1000 N., 1970 W., Sec. 15, T. 38, R. 20, Wis.

Are all very similar to No. 52.

No. 53 (Sp. 2125). — **Chloritic hornblende schist.** 1670 N., 1000 W., Sec. 16, T. 38, R. 20, Wis.

Grayish-green; fine-grained, arenaceous texture. Schistose structure, with narrow grayish quartz bands. It is possibly an altered variety of No. 52. Sp. Gr. 2.95. BB. fuses at 3.5 to a black glass.

Under the M., in the polarized light, it appears to be a fine-grained aggregation of irregular shaped fragments of amphibole, chlorite, quartz and feldspar. The amphibole is very pale green, and is only slightly dichroitic. The chlorite is perhaps a shade lighter, and can only be distinguished from the amphibole by the position of the opt. bisectrix to the principal cryst. axis. The grains of quartz are angular and quite small. The feldspar is scattered in the section in indistinct fragments that are somewhat altered.

No. 54 (Sp. 2201). — **Hornblende schist.** 1900 N., 1050 W., Sec. 22, T. 39, R. 17, Wis.

Dark grayish green thickly sprinkled with grayish white; fine grained texture. Schistose structure; the cleavage planes being often slightly corrugated. Deposited in the joints are bunches and layers of calcite. The finely disseminated amphibole is barely visible under a strong lens; the grains of quartz are more easily recognized. The specimen has a rough raspy feel. Sp. Gr. 2.93. Brisk effervescence in acid. BB. fuses at 4. to a black glass. Under the M., between the + nicols, it appears to be about an equal mixture of dark green amphibole and quartz; an occasional grayish fragment of calcite can be recognized, also numerous minute crystals of rutile.

Sp. 2226, from 1250 N., 1000 W., Sec. 30, T. 39, R. 18, Wis., resembles No. 54.

No. 55 (Sp. 2204). — **Hornblende schist.** 1870 N., 1200 W., Sec. 22, T. 39, R. 17, Wis.

Dark grayish green with grayish white. Medium grained crystalline texture. Slightly banded schistose structure. The bands consist of grayish white arenaceous quartz and calcite, with bunches of bronze colored mica. Associated with the latter are small bright crystals of tourmaline, which may be recognized by their crystal form and deportment with flour spar and bisulphate of potash. Brisk effervescence in acid. BB. fuses at 4. to a black magnetic glass. Under the M., between the + nicols, the large crystal fragments of amphibole are plainly visible; also arenaceous seams of quartz and grayish patches of calcite; they are all unevenly distributed in parallel layers.

No. 56 (Sp. 2208).— **Hornblende schist.** 1000 N., 670 W., Sec. 22, T. 39, R. 17, Wis.

Very similar to No. 54. Under the M., in the polarized light, it appears to be an aggregation of bushy fragments of amphibole, grains of quartz and an occasional fragment of striated feldspar. The amphibole is dark green and strongly dichroitic; the quartz grains are small and angular, and are grouped in bunches. They have a limpid, slightly chromatic texture. A few grains of magnetite are visible.

No. 57 (Sp. 2209).— **Hornblende schist.** 1350 N., 1500 W., Sec. 26, T. 39, R. 17, Wis.

Dark grayish green; fine crystalline texture, slightly banded with quartzy layers, cleaving easily into plates about one-eighth of an inch thick. The surface is finely corrugated and has a silvery gray luster, and is porphyritic with acicular crystals of amphibole. Sp. Gr. 2.88. No effervescence in acid. BB. fuses at 4. to a black magnetic bead. Under the M. the section appears to consist of amphibole, quartz and a few grains of magnetite. The amphibole is in large slender fragments. The grains of quartz, as in No. 56, appear small and angular, and between the + nicols present a limpid chromatic texture.

No. 58 (Sp. 2210).— **Hornblende slaty schist.** 1200 N., 950 W., Sec. 30, T. 39, R. 18, Wis.

Grayish-green; even crystalline, somewhat arenaceous texture. Under the loupe the finely disseminated acicular crystals of amphibole are plainly visible. Splits readily into even plates of variable thickness.

The cleavage planes are often covered with tiny glistening scales of yellow mica, and scattered in these micaceous layers are shining jet black crystals of hornblende. On a fractured edge it resembles No. 54. No effervescence in acid. BB. fuses at 4. to a black glass.

No. 59 (Sp. 2219).— **Hornblende schist.** 1595 N., 400 W., Sec. 25, T. 39, R. 17, Wis.

Dark gray; schistose structure. On splitting planes are minute scales of mica. With the loupe may be seen several cleavage facets of a pale greenish amphibole; also numerous minute grains of silica. Weathers to a light drab. No effervescence in acid. BB. fuses at 4. to a black magnetic bead. Under the M., in the polarized light, it presents a field thickly covered with long, somewhat bushy fragments of amphibole. The base consists of small angular grains of quartz. Scattered in the sections are several opaque grains of magnetite.

No. 60 (Sp. 2217).— **Quartzy hornblende schist.** 1525 N., 400 W., Sec. 26, T. 39, R. 17, Wis.

Dark grayish-green, equally mixed with grayish-white. The former is due to amphibole, and the latter to quartz with a little calcite. Medium grained and massive. Conchoidal fracture. Somewhat jointed. With the lens many of the quartz grains present a bluish tinge. Sp. Gr. 2.80. Effervesces briskly in acid for a few moments. BB. fuses at 4. to a black magnetic bead. Under the M., similar to No. 57, only it contains more quartz.

No. 61 (Sp. 2218).—**Quartzy hornblende schist.** 1275 N., 0 W., Sec. 26, T. 39, R. 17, Wis.

Grayish-white mixed with greenish-black. Fine-grained, arenaceous texture. The dark-green mineral or substance cannot be recognized with the lens. Numerous facets of calcite crystals are visible. It resembles somewhat No. 60. Brisk effervescence in acid. BB. fuses at 4. to a magnetic glass. Under the M. the section has a micro-granular texture, composed of minute grains of quartz, which average not more than 1-1000 of an inch. Strewn in this base are numerous fragments of amphibole and several leaves of biotite, also a little feldspar.

With a power of 500 × can be seen in quartz grains several fluid inclusions.

No. 62 (Sp. 2211).—**Hornblende-gneiss.** 500 N., 1700 W., Sec. 27, T. 39, R. 17, Wis.

Dark-gray sprinkled with light-gray. Bright crystalline texture and schistose structure, with broadly corrugated planes.

The broad corrugations are sub-corrugated with narrow ribs. On the splitting planes are numerous tiny bronze colored scales of mica. Sp. Gr. 2.93. Feeble effervescence in acid. BB. fuses at 4. to a magnetic bead. Under the M., between the + nicols, the amphibole appears to form about one-half the entire section.

The base of the rock is composed of small angular fragments of feldspar and quartz. The former are often striated and are then easily recognized; when plain, however, and rounded, it is often difficult to distinguish the quartz from the feldspar. A few brownish leaves of biotite are visible.

No. 63 (Sp. 2229).—**Hornblende schist.** 1150 N., 550 W., Sec. 30, T. 39, R. 18, Wis.

Dark green, with seams of grayish-white, coarse semi-fibrous structure. The amphibole is in large, slightly fibrous crystals, that are often bushy and bent. The grayish-white material consists of lime; easily recognized by its hardness and brisk effervescence in acid. Imperfect schistose structure. Fracture jagged and uneven. Sp. Gr. 3.00. BB. fuses at 4. to a black glass.

No. 64 (Sp. 2230).—**Hornblende schist.** 1150 N., 550 W., Sec. 30, T. 39, R. 18, Wis.

Bright grayish green; very fine grained. Conchoidal fracture. The jointing surfaces are sometimes covered with a coating of lime. Under the lens it presents an arenaceous texture, and numerous minute acicular crystals of amphibole can be recognized. Associated with the calcite are often grains of chalcopyrite. BB. fuses at 4. with slight intumescence to a black glass.

No. 65 (Sp. 2188).—**Hornblende rock.** S. E. cor. Sec. 35, T. 40, R. 17, Wis.

Greenish black sprinkled with light gray; very coarse-grained crystalline texture. Massive structure. The amphibole crystals are quite large, some of them being over half an inch across; their cleavage planes are usually warped, and often fibrous.

But very little, if any, feldspar can be distinguished. With the loupe a few particles of pyrites are visible. Sp. Gr. 3.00. No effervescence ln acid. BB. fuses at 4. to a black glass. Under the M. the section appears to consist largely of amphibole, interspersed in a feldspathic quartzy base. The amphibole is in large and small fragments; the latter are thickly strewn in the base. The feldspar (orthoclase) is in plain crystals, and is very much altered. The quartz grains are angular and small. Scattered in the section are several dark brown leaves of biotite; also a few opaque grains of pyrite.

Sp. 2200, from 1900 N., 1000 W., Sec. 22, T. 39, R. 17, Wis. Very similar to No. 65 (Sp. 2188).

No. 66 (Sp. 2181). —**Hornblende rock.** 1925 N., 0 W., Sec. 15, T. 40, R. 18, Wis.

Grayish-green; medium grained texture. Massive structure, slightly jointed. Uneven, rough fracture. On some of the breaking surfaces are patches of bronze colored mica. Disseminated in the rock is apparently considerable chlorite. A few cleavage planes of amphibole can be recognized. Very tough, and not easily broken. Weathers to a light drab. Sp. Gr. 2.97. No effervescence in acid. BB. fuses with intumescence at 4. to a black, slightly magnetic glass. Under the M., in the polarized light, can be seen amphibole, chlorite, quartz, biotite and orthoclase. The amphibole is the principal ingredient and greatly exceeds all the other minerals contained.

Sp. 2167, from 1040 N., 470 W., Sec. 9, T. 40, R. 18, Wis. Very similar to No. 66.

No. 67 (Sp. 2199). —**Hornblende rock.** 750 N., 920 W., Sec. 27, T. 40, R. 17, Wis.

Grayish-green; medium grained crystalline texture. The cleavage facets of the amphibole are plainly visible, some of them measuring one-eighth of an inch in length. Massive; uneven conchoidal fracture. Scattered through the rock are particles of chalcopyrite. No effervescence in acid. BB. fuses with slight intumescence to a black glass.

Under the M., the large, somewhat bushy, fragments of amphibole are easily recognized, and form more than nine-tenths of the rock. Several small, angular grains of quartz resembling vein quartz are contained, also an amorphous viridite from altered amphibole.

No. 68 (Sp. 2212). —**Porphyritic hornblende rock.**[1] 1475 N., 900 W., Sec. 35, T. 40, R. 17, Wis.

Grayish-black; glistening. The base has an aphanitic, slightly sparkling, texture, and is porphyritic with numerous black, slender crystals of hornblende, measuring about one-fourth of an inch in length, which are scattered promiscuously through the mass.

Uneven, conchoidal fracture. Massive and very jointed. In the joints are numerous, very minute, scales of bronze-colored mica. Weathers to a light greenish drab. Hardness, about 4. Feeble effervescence in acid. BB. fuses at 4. to a black magnetic bead.

Under the M., a section of the rock is seen to consist of amphibole, quartz, a little magnetite and few brownish leaves of biotite. The amphibole is in large, slender crystals.

No. 69 (Sp. 2126). —**Feldspathic hornblende rock.** 1500 N., 500 W., Sec. 7, T. 38, R. 20, Wis.

Grayish-green; coarse-grained crystalline texture. On the surface may be seen several facets of crystals, resembling those of augite. The amphibole is easily recognized on a fresh fracture by its cleavage planes.

Scattered through the specimen are patches of lime and bronze colored biotite. BB. fuses at 4. to a black glass. Under the M., in the polarized light, may be recognized the amphibole feldspar, quartz and brown biotite; also a little chlorite. The amphibole is in broken irregular fragments. The orthoclase is more or less altered.

Sp. 2127 from, 750 N., 1250 W., Sec. 7, T. 38, R. 20, Wis., is very similar to No. 69.

No. 70 (Sp. 2130). —**Hornblende rock.** 750 N., 2000 W., Sec. 10, T. 38, R. 19, Wis.

Greenish-black, sprinkled with gray. Coarse crystalline texture. The crystals of amphibole are large and the cleavage, surfaces are usually curved or bent and appear fibrous. The grayish-white particles of silica are easily recognized under the loupe.

[1] Dr. Arthur Wichmann, of Leipzig, has described this rock as a hornblende mica schist. There is probably a confusion of numbers here. These specimens were collected by myself from a low, massive, strongly jointed ledge, with biotite as a *secondary* product deposited in the joints.
C. E. W.

Sp. Gr. 3.03. BB. fuses at 4. to a black magnetic bead. Under the M., very similar to No. 69.

No. 71 (Sp. 2131).—**Chloritic hornblende rock.** (Provisional.) 1200 N., 1900 W., Sec. 20, T. 39, R. 19, Wis.

Dark grayish-green; indefinite fine-grained texture. Somewhat schistose, with thin greenish films on the surface of the cleavage planes. Under the lens can be seen disseminated in the rock considerable chlorite, and coursing through it are grayish seams of lime. BB. fuses at 4. to a black magnetic bead.

Under the M., in the polarized light, portions of the section present a very pretty field, resembling a hornblende schist; others are interspersed with large crystal fragments of orthoclase feldspar. The amphibole, quartz and feldspar are all easily recognized together with amorphic chlorite or viridite.

No. 72 (Sp. 2101).—**Altered hornblende rock.** 1290 N., 1964 W., Sec. 24, T. 39, R. 30, Mich.

Grayish-green; indefinite, approaching an impalpable texture. Somewhat schistose. Very jointed. The fracture is unevenly subconchoidal, and on it may be seen numerous small reddish grains. Hardness, 4-5. No effervescence in acid. BB. fuses at 4. to a black glass.

Under the M., the partially decomposed bushy fragments of amphibole are easily recognized; some of them are apparently twin crystals. Considerable chlorite is contained, also several grains of quartz, and irregular patches of viridite.

No. 73 (Sp. 2174). — **Altered hornblende rock.** 1230 N., 100 W., Sec. 13, T. 41, R. 32, Mich.

Dark gray with a slight tinge of pink; fine to medium grained texture. Under the lens only an occasional crystal facet is visible. Dull, semi-vitreous luster. Uneven fracture; on some of the breaking surfaces is a thin calcareous coating. BB. fuses at 4.5 to a black glass. Under the M., it appears very much altered and has a dirty brownish texture. Between + nicols can be recognized a few fibrous fragments of amphibole, grains of quartz and several grayish patches of lime. With a power 500 × can be seen the pale greenish viridite and an occasional brownish scale of biotite.

Greenstones.

No. 74 (Sp. 2072). —**Diabase.** 600 N., 250 W., Sec. 12, T. 38, R. 19, Wis.

Dark grayish green. Fine grained crystalline texture. An occasional large crystal of striated feldspar is contained. The fracture has a rough, raspy feel. The hand specimen resembles very much a hornblende-schist. With a strong lens numerous minute crystal facets are visible. Weathers slightly to a dirty drab. Sp. Gr. 2.92. Very hard and tough. BB. fuses at 4.5 to a black bead. Under the M., in the polarized light, it presents a very pretty chromatic field. The feldspar is in slender twin crystals. The augite, readily distinguished from amphibole[1] by its non-dichroism, complimentary colors, and position of the optic bisectrix to the principal crystal axis, appears to have been formed after the feldspar, as it encloses numerous feldspar crystals.

No. 75 (Sp. 2114).—**Diorite.** 700 N., 2000 W., Sec. 10, T. 38, R. 20, Wis.

Dark green, mixed with light green; coarse grained, massive, uneven conchoidal fracture. On the surface may be seen numerous facets of amphibole crystals and small, white grains (feldspar). Sp. Gr. 2.91. Feeble effervescence in acid. BB. fuses at 5., with brisk intumescence, to a blebby glass. Under the M., the section in the polarized light appears to have a coarse crystalline texture, composed of triclinic feldspar and a very pale greenish amphibole. The latter is somewhat fibrous. There is a grayish substance contained, probably due to the decomposition of the feldspar.

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[1] See Tschermak. Akademie der Wissenschaften, June, 1869.

No. 76 (Sp. 2116).—**Diorite.** 1630 N., 1430 W., Sec. 15, T. 38, R. 20, Wis.

Dark green, mottled with light green and grayish white. Coarse grained, crystalline texture. Jointed and massive. The cleavage facets of the amphibole are easily recognized. The feldspar, as in No. 75, appears in whitish grains. Under the lens an occasional particle of chalcopyrite is visible. Sp. Gr. 3.00. BB., some portions fuse with brisk intumescence.

Sp. 2268, from Sturgeon Falls, Sec. 27, T. 39, R. 29, Mich., is very similar to No. 76.

No. 77 (Sp. 2265).—**Diorite.** Sturgeon Falls, 1610 N., 460 W., Sec. 27, T. 39, R. 29, Mich.

Dark green, mottled with grayish-white; coarse-grained texture; massive structure. The amphibole is easily recognized with the lens; also minute particles of iron pyrites. The grayish-white mineral is quite hard, and cannot be scratched with the knife; it has an uneven fracture, showing but little if any signs of cleavage. Sp. Gr. 3.08. BB. white mineral fuses at 5. Under the M., between the + nicols, the section appears to consist chiefly of amphibole and feldspar. The latter is very much altered, and often not easily recognized. The amphibole is in small, irregular fragments, that are usually grouped in bunches.

No. 78 (Sp. 2113).—**Diorite.** 800 N., 100 W., Sec. 15, T. 39, R. 30, Mich.

Dark green, mixed with light green and gray; medium-grained texture. Some of the amphibole crystals are quite large. The feldspar forms apparently the base of the rock. Coursing through the rock are seams of calcite, and scattered in these are minute silvery-white scales (probably talc), which give the calcite the appearance of cipolino. A few specks of chalcopyrite can be distinguished with the lens. Sp. Gr. 2.88. BB. fuses at 4. to a black glass.

No. 79 (Sp. 2109).—**Diorite.** 100 N., 0 W., Sec. 13, T. 39, R. 30, Mich.

Greenish gray, mottled with light to dark green. The former, the ground-mass, is apparently feldspathic. The latter, the amphibole, is rather coarse grained. The weathered surface is grayish white and porphyritic, with partially decomposed crystals of amphibole. Massive and jointed. Sp. Gr. 3.00. Brisk effervescence in acid. BB. fuses at 4.5 to a grayish glass. Under the M., the rock has an altered appearance. The amphibole is easily recognized, but the feldspar is very much changed; in some instances only a grayish mass remains, which blends imperceptibly into the base, thereby blurring the outlines of the crystal.

No. 80 (Sp. 2112).—**Diorite.** 500 N., 1500 W., Sec. 14, T. 39, R. 30, Mich.

Dark green; fine grained crystalline texture. Jointed, with chlorite in the seams. Disseminated in the rock are specks of iron and copper pyrites. Only an occasional crystal facet can be seen. Hardness about 5. Sp. Gr. 2.90. Feeble effervescence in acid. BB. fuses at 4. to a black glass. Under the M., in the polarized light, the feldspar and amphibole are easily recognized. The feldspar crystals are striated and often appear quite large. The amphibole is usually in fragments, that are sometimes very small; the smaller ones being scattered through the entire section. The rock is somewhat changed.

Sp. 2122, from 2000 N., 900 W., Sec. 8, T. 38, R. 20, Wis., resembles No. 80.

No. 81 (Sp. 2104).—**Diorite.** 1316 N., 1960 W., Sec. 24, T. 39, R. 30, Mich.

Light-green; fine-grained texture. Uneven fracture and very jointed. On the surface can be seen numerous cubes of pyrite, also thin films or minute scales of hematite. Weathers to a pale-green. Hardness about 4. Sp. Gr. 2.86. Slight effervescence in acid. BB. fuses at 4. to a black glass. Under the M., the amphibole presents a bushy structure. The feldspar is in large fragments. The former, however, is largely in excess of the latter. Considerable chlorite is disseminated in the section; also a few grains of quartz and an occasional small, grayish patch of lime.

No. 82 (Sp. 2070). — **Porphyritic diorite.** Big Quinnesec Falls. N. W. qr., Sec. 8, T. 39, R. 30, Mich.

Grayish-green; porphyritic with large grayish to greenish-white crystals of feldspar, which have a very indistinct cleavage. Cannot be scratched with the knife, and fuses at 4.5-5. The crystals are large, many of them measuring an inch in length. In the greenish base may be distinguished numerous facets of pale-green amphibole. A very little chalcopyrite is contained. Sp. Gr. 2.95. Slight effervescence in acid. BB., the base, fuses at 4. to a dark-green glass.

No. 83 (Spec. 2182).— **Diorite.**[1] 760 N., 1375 W., Sec. 17, T. 41, R. 31, Mich.

Grayish-black; fine-grained texture. The surface is porphyritic with a few slender crystals. Massive structure. Uneven fracture. Weathers to an ash-brown color. Sp. Gr. 2.80. BB. fuses at 4. to a black magnetic bead. Under the M., the amphibole is in small fibrous fragments, and forms apparently the base of the rock. It is somewhat decomposed and is yellowish-brown. Scattered in the base are several large twin crystals of feldspar, that often enclose numerous bright green leaves resembling chlorite.

No. 84 (Sp. 2069).— **Altered diorite.** (Provisional). Big Quinnesec Falls, N. W. qr. Sec. 8, T. 39, R. 30, Mich.

Dark grayish-green; fine-grained texture. Uneven, rough, jagged fracture. Scattered in the rock are numerous glassy grains of quartz, some of which are nearly one-fourth of an inch across. A few crystals of feldspar may be recognized; some of them are very indistinct and are quite large, measuring three-eighths of an inch in length. Very jointed. BB. fuses at 4. to a white, blebby glass.

Under the M., it presents a gray crystalline base, interspersed with crystals of feldspar, more or less decomposed, and large rounded grains of quartz that enclose apparently portions of the base, reminding one of quartz contained in some of the volcanic rocks. But little amphibole is contained and that is mostly changed into viridite or chlorite. Disseminated in the base and feldspar crystals, are fibrous particles of viridite.

No. 85 (Sp. 2062). — **Altered diorite.** (Prov.) Little Quinnesec Falls. 1125 N., 25 W., Sec. 15, T. 39, R. 30, Mich.

Greenish, mottled with grayish-white. Medium crystalline texture and massive structure. Interspersed in it are small silvery scales resembling talc. Sp. Gr. 2.88. BB. fuses at 5. to a white enamel. Effervesces slightly in cold acid, but briskly in hot acid, continuing for some time. The solution contains only a trace of magnesia. Under the M., in the polarized light, the section at first glance resembles No. 134. It has, however, a varied structure, some portions present a fine micro-granular texture, composed apparently of small grains of silica; others are bushy, and appear to be of fibrous fragments of chlorite or talc, and actinolite; the former seemingly derived from the decomposition of the latter and the several fragments of highly altered feldspar that are scattered in the section. Strewn through the entire base are numerous grayish patches of lime. Their presence may be due to the change of amphibole.

No. 86 (Sp. 2079). — **Altered diorite or diabase.** S. E. cor. Sec. 9, T. 40, R. 30, Mich.

Grayish-green; fine-grained texture, often shimmering with minute scales of chlorite. Massive and somewhat jointed. On a fresh fracture may be seen with the lens numerous small warty-like projections. Sp. Gr. 2.89. Slight effervescence in acid. BB. fuses at 3.5 to a black glass. Under the M., between the + nicols, the base presents nearly a dark field, thickly strewn with slender twin-crystals of feldspar. The base is

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[1] Here is evidently another confusion of numbers. Dr. Wichmann's 2182 is described as a micaceous hornblende-schist. The rocks of this locality are massive and the outcrops are large. See No. 90 (2149), just east of here on the Wisconsin side of the river.

apparently chloritic, and a few pale-greenish fragments, in which the crystal axis and optic bisectrix coincide, would seem to confirm this. A few fragments resembling those of amphibole are contained. With a power of 500 × the base appears composed largely of small pale-greenish leaves resembling those of chlorite. Their remaining dark or nearly so with the crossed nicols, is owing, perhaps, to their thinness.

No. 87 (Sp. 2133).—**Altered diorite.** 1720 N., 1600 W., Sec. 13, T. 40, R. 31, Mich.

Light green; between medium and fine grained. Very jointed, cleaving into irregular shaped rhombs. Somewhat schistose, with calcite in the cleavage planes. With a strong lens the amphibole may be recognized. Under the M., the rock appears very much altered. The amphibole is easily recognized; but the feldspar is very indistinct and cannot usually be distinguished.

No. 88 (Sp. 2119).—**Hornblende-diorite.** 1100 N., 2000 W., Sec. 8, T. 38, R. 20, Wis.

Dark green; medium grained crystalline texture. Massive. Numerous crystal facets of amphibole are visible, also an occasional one of feldspar; some of the latter are one-fourth of an inch across. With the loupe can be recognized considerable chlorite. Sp. Gr. 3.04. BB. fuses at 3.5 to a black glass. Under the M., it presents a greenish field composed largely of amphibole; but very little feldspar is contained. A few opaque grains of magnetite may be seen.

No. 89 (Sp. 2105).—**Hornblende-diorite.** 1350 N., 1964 W., Sec. 14, T. 39, R. 30, Mich.

Dark green; coarse grained texture. Uneven, rough fracture. Massive. Disseminated in the specimen are numerous grains of magnetite. BB. fuses at 3.5 to a black magnetic glass. Under the M., the section presents a light green texture, with several opaque grains of magnetite. The green mineral, amphibole, has a fibrous, bushy structure, and is mixed with a little chlorite. In the polarized light can be recognized a few apparently twin crystals of amphibole, also fragments of feldspar.

Sp. 2107, from 1200 N., 40 W., Sec. 15, T. 39, R. 30, Mich., is very similar to No. 89.

No. 90 (Sp. 2149).—**Chloritic hornblende-diorite.** 1700 N., 0 W., Sec. 14, T. 40, R. 18, Wis.

Grayish green; coarse grained, crystalline texture. Rough, sub-conchoidal fracture. On the surface are plainly visible numerous crystal facets of amphibole. Disseminated in the mass are several specks of chalcopyrite. BB. fuses at 4. to a black bead. Under the M., in the polarized light, the large fragments of amphibole are easily recognized. The feldspar is mostly striated, and is in small fragments. A large amount of very pale greenish chlorite is contained.

Sp. 2150, from 1475 N., 1475 W., Sec. 20, T. 40, R. 19, Wis., is very similar to No. 90.

No. 91 (Sp. 2051).—**Chloritic diorite.** (Prov.) 1450 N., 800 W., Sec. 23, T. 38, R. 20, Wis.

The base is greenish-black. A fresh fracture often shimmers with greenish to bronze colored chlorite, which is usually fibrous, resembling somewhat asbestus. Its fusibility and yielding water in the matrass distinguishes it from the latter mineral. Coursing through the rock in every direction are narrow, grayish, calcareous seams. Examined on the edge across the bedding, the fracture appears thickly dotted with small, greenish-gray spots, having a hardness of 4.–5., while the base of the rock has a hardness of about 4. A few bright black grains of magnetite can be recognized. BB. fusibility, 5. Under the M., the amphibole and chlorite present a pale greenish texture; the former is only slightly dichroitic, which renders it difficult to distinguish it by this test. The relation of the optic bisectrix to the crystal axis (as is well known) readily separates the two minerals. The base has a grayish cast, and is somewhat fringy. In the polarized light can be seen several highly altered fragments of triclinic feldspar.

No. 92 (Sp. 2118). — **Chloritic diorite.** 0 N., 1160 W., Sec. 10, T. 38, R. 20, Wis.

Dark grayish-green; even, fine-grained texture. Jointed and apparently schistose. In the joints are thin films of chlorite. Hardness about 4. No effervescence in acid. BB. fuses at 4.5 to a black glass. Under the M., in polarized light, the rock presents a very altered appearance. The feldspar is apparently the least changed of the essential ingredients. The outlines of the large fragments of feldspar can be plainly seen; the feldspathic filling, however, is in small, broken fragments. The amphibole occurs as irregular, bushy fragments, but is easily recognized. Scattered in the section are large, nearly amorphous, *patches* of viridite.

No. 93 (Sp. 2063). — **Chloritic diorite.** 1080 N., 350 W., Sec. 15, T. 39, R. 30, Mich.

Light-green, mottled with greenish-white. Indistinct, medium-grained texture. Somewhat schistose. Hardness 4-5. Disseminated in the rock is considerable calcite, which may be recognized under the loupe or by its brisk effervescence in acid. BB. fuses at 4.5 to a green glass. Under the M., between the + nicols, the section presents an indistinct, bushy appearance. A few shadowy outlines of large fragments of monoclinic feldspar can be seen. The small leaves of chlorite or talc are not easily recognized. With a power of 500 × the small pale-greenish leaves are plainly visible. Several small grayish patches of lime are strewn in the section.

No. 94 (Sp. 2052). — **Chloritic schist.** 1200 N., 150 W., Sec. 24, T. 39, R. 30, Mich.

Grayish-green; very fine-grained texture; schistose structure. On some of the cleavage planes are thin films of calcite. Weathers to a greenish drab.

The weathered surface appears to the unaided eye as if it were finely dotted with small holes, not more than one-eightieth of an inch across. Under a strong lens, however, it presents a surface minutely sprinkled with brownish-black specks. A weathered edge of the rock shows plainly the schistose structure. Brisk effervescence in acid. BB. fuses at 4. to a dark green glass. Under the M., it presents a somewhat bushy structure, composed chiefly of chlorite, with a little fibrous amphibole. Scattered in the section are several nearly opaque grayish spots. The specimen is evidently partially decomposed.

No. 95 (Sp. 2053). — **Chloritic schist.** 1175 N., 150 W., Sec. 24, T. 39, R. 30, Mich.

Light green. Weathers greenish to brownish drab. Schistose structure. The cleavage surface appears broadly corrugated, and is minutely specked with grains of magnetite, very similar in appearance to 2052. Hardness, 2–3. BB. fuses at 4. to a dark green glass.

No. 96 (Sp. 2164). — **Chloritic schist.** 75 N., 400 W., Sec. 12, T. 41, R. 32, Mich.

Dark drabish green. Slaty texture and shining luster. Cleaves readily into plates, that are straight in one direction, but across this line it has an indifferent cleavage and is finely and fibrously corrugated. No effervescence in acid. BB. fuses at 4.5 to a magnetic bead.

Sp. 2165, from 1950 N., 450 W., Sec. 13, T. 41, R. 32, Mich., is very similar to No. 96.

Sp. 2168, from 900 N., 450 W., Sec. 9, T. 40, R. 18, Wis., is very similar to No. 96, only it is somewhat slaty in structure.

No. 97 (Sp. 2183). — **Chloritic schist.** 250 N., 0 W., Sec. 31, T. 40, R. 18, Wis.

Bright greenish black. Fine grained texture and steely luster. Cleaves readily into plates about one-eighth of an inch thick. On splitting planes it is brownish red. Streak powder dark green. With the lens may be seen a few octahedrons of magnetite. Hardness about 3. BB. fuses at 4. with intumescence to a black magnetic glass.

No. 98 (Sp. 2108). — **Chloritic schist.** 1130 N., 100 W., Sec. 15, T. 39, R. 30, Mich.

Very dark green, banded with seams of gray quartz, that are often parallel with the lamination of the schist. Impalpable texture. Schistose structure; on cleavage shining. Examined on the edge can be seen in the chloritic laminæ, numerous small specks of iron pyrites. Feeble effervescence in acid. Hardness about 3. BB. fuses at 4. to a black magnetic bead.

No. 99 (Sp. 2078). — **Chloritic schist.** Four Foot Falls. 200 N., 760 W., Sec. 11, T. 39, R. 19, Wis.

Dark green; even, aphanitic texture, and somewhat schistose structure. Strongly and irregularily jointed. Hardness about 3.5. Slight effervescence in acid. BB. fuses at 3.5 to a black glass.

No. 100 (Sp. 2056).— **Chloritic schist.** 900 N., 800 W., Sec. 24, T. 39, R. 30, Mich.

Greenish to ash-gray, mottled with brownish spots. On a fresh fracture can be seen, under a strong lens, small pinkish grains. The schistose structure is rather imperfect; somewhat jointed. No effervescence in acid. BB. fuses at 5. to bottle green glass. The rock is apparently a greenstone ash.

No. 101 (Sp. 2100).— **Chloritic schist.** Sand Portage. 1275 N., 1960 W., Sec. 24, T. 39, R. 30, Mich.

Dark pea green; even, impalpable texture. Schistose structure not very apparent. Fracture more or less indifferent, and often conchoidal. Coursing through the specimen is a seam of pinkish dolomite nearly one-eighth of an inch wide. Hardness about 2.5. BB. fuses at 4.5 to a dark green glass. Under the M., it presents a fibrous, somewhat bushy appearance, interspersed with a few angular grains of quartz and an occasional patch of lime. The bushy mineral is evidently chlorite or viridite, and is apparently altered actinolite. A few opaque grains are visible, some of which transmit a reddish light. They are probably those of hematite.

No. 102 (Sp. 2102). — **Chloritic schist.** 1300 N., 1970 W., Sec. 24, T. 39, R. 30, Mich.

Grayish-green to ash color. Impalpable texture and irregular schistose structure. On the edge and weathered surface may be seen numerous reddish grains. Coursing through the specimen are seams filled with white quartz. Hardness, 3.–4. No effervescence in acid. BB. fuses at 4. to a black glass. The rock is probably a greenstone ash.

No. 103 (Sp. 2110). — **Chloritic schist.** 1125 N., 200 W., Sec. 15, T. 39, R. 30, Mich.

Dark green. Examined with the loupe, it appears to be an aggregation of minute scales of chlorite. Warped schistose structure. On cleavage surfaces often can be seen silver-gray talcy scales. Coursing through it are seams of calcite and quartz; also numerous particles of chalcopyrite. Streak powder dark green. Hardness about 3. BB. fuses at 4.5 to a black magnetic bead.

No. 104 (Sp. 2141). — **Chloritic schist.** 200 N., 1500 W., Sec. 22, T. 40, R. 19, Wis.

Dark grayish-green; aphanitic texture. Irregular schistose structure. Under a strong loupe can be seen numerous minute grayish grains of silica. Hardness about 3. No effervescence in acid. BB. fuses at 5. to a black magnetic enamel.

No. 105 (Sp. 2106). — **Chloritic schist.** 1240 N., 63 W., Sec. 15, T. 39, R. 30, Mich.

Very dark green; aphanitic, somewhat vitreous texture. Irregular schistose structure. Scattered through the rock are numerous grains of magnetite. On the cleavage surface are a few knotty projections, resembling those of black garnet, or possibly altered magnetite. Hardness about 3. BB. fuses at 4.5 to a black magnetic bead.

No. 106 (Sp. 2148) — **Chloritic slaty-schist.** Michigamme Falls. 1700 N., 1600 W., Sec. 16, T. 41, R. 31, Mich.

Greenish ash color; shimmering texture, slaty schistose structure. With the loupe can be seen on the edge considerable silica, and on cleavage planes minute bronze-colored scales of mica. Hardness about 3. No effervescence in acid. BB. fuses at 4.5 to a gray glass. Under the M. it appears arenaceous. The greenish leaves of chlorite are easily recognized, also brownish ones of mica.

No. 107 (Sp. 2065).—**Ferruginous chloritic slaty-schist.** S. E. qr. of S. E. qr. Sec. 32, T. 40, R. 30, Mich.

Dark brownish; aphanitic texture; slaty structure, splitting into thick plates; streak powder light brownish red; very siliceous and somewhat decomposed. Hardness about 2.5. No effervescence in acid. BB. fuses at 4. to a black magnetic bead.

No. 108 (Sp. 2236).—**Micaceous chloritic slaty-schist.** 1400 N., 1550 W., Sec. 28, T. 39, R. 18, Wis.

Bright, dark-grayish green; aphanitic texture; slightly shimmering luster on cleavage planes; splits readily into plates from one-eighth to more than an inch in thickness. Scattered through the specimen are numerous bronze-colored to black scales of mica. To the knife edge it has an arenaceous feel, and the hardness is about 3. No effervescence in acid. BB. fuses at 4.5 to a black magnetic bead. Under the M., between the + nicols, can be seen the mica, chlorite and quartz. In the plain light the chlorite appears pale greenish, and the mica (biotite) light brown. Interspersed in the section are many opaque grains resembling magnetite.

Sp. 2239, from 400 N., 1350 W., Sec. 22, T. 39, R. 18, Wis., somewhat similar to No. 108. Under the microscope very similar to No. 108.

No 109 (Sp. 2097). —**Arenaceous chloritic schist.** Bad Water village, Lot 3, Sec. 30, T. 41, R. 30, Mich.

Dark green, sprinkled with gray; even, fine grained texture. Weathers to a light greenish drab, and on outer weathered surface is often pinkish. Schistose structure, and jointed. The cleavage planes appear often fibrously corrugated. Hardness about 3. No effervescence in acid. BB. fuses at 5. to a dirty green glass.

No. 110 (Sp. 2144).—**Arenaceous chloritic schist.** 850 N., 100 W., Sec. 18, T. 40, R. 19, Wis.

Grayish green Shimmering luster on cleavage planes, and arenaceous on edges. The former are often fibrously corrugated. Brisk effervescence in acid. BB. fuses at 4. to a black glass. Under the M., in the polarized light, it appears to be an aggregation of very pale greenish leaves of chlorite, small grains of quartz and grayish patches of lime. The schistose structure is very apparent.

Sp. 2143, from 330 N., 700 W., Sec. 17, T. 40, R. 19, Wis. Dark grayish green, with calcite in the joints. Very similar to Sp. 2144.

No. 111 (Sp. 2227).—**Arenaceous chloritic schist.** 1250 N., 1000 W., Sec. 30, T. 39, R. 18, Wis.

Dark grayish green; very fine grained, even texture. Slightly glistening. With the loupe it appears arenaceous and the dark green chlorite is plainly visible. The cleavage surfaces are often slightly corrugated. Apparent hardness, about 3. No effervescence in acid. BB. fuses at 5.5 to a black enamel. Under the M., between the + nicols, the rock appears to be about an equal mixture of chlorite and quartz. The fragments or leaves of the former and grains of the latter are quite small. The majority of them measuring not more than $\frac{1}{400}$ of an inch across. A little actinolite and viridite is contained.

Sp. 2228, from same locality as No. 111, appears to be only a finer grained variety of the same.

No. 112 (Sp. 2128).—**Quartzose chloritic schist.** 1250 N., 1000 W., Sec. 7, T. 38, R. 20, Wis.

Grayish-white, mixed with light green, and seams of buff-colored lime. The quartz has a vitreous, watery texture, resembling vein-quartz. The chlorite is largely contained, and is unevenly distributed. Irregular schistose structure, often warped, with talcy layers in the cleavage planes. On weathered surface of the edge, as seen in the bed, it presents a rough, warty appearance, very similar to a volcanic dyke. The bed is about twenty feet wide, and conformed with the strike and dip of the formation with which it is associated. Under the lens, can be recognized copper and iron pyrites.

No. 113 (Sp. 2170).—**Feldspathic chloritic schist.** 750 N., 450 W., Sec. 9, T. 40, R. 18, Wis.

Greenish ash, sprinkled with shades of yellow; very indefinite; medium-grained texture; irregular schistose structure; surface rough and uneven. Hardness about 3. No effervescence in acid. BB. fuses at 4. to a black glassy bead. Under the M., between the + nicols, can be recognized the chlorite and small grains of quartz, also considerable decomposed actinolite and fragments of feldspar.

No. 114 (Sp. 2092).—**Calcareous chloritic schist.** 900 N., 100 W., Sec. 18, T. 40, R. 19, Wis.

Dirty-gray mottled with dark-green. The grayish portion is apparently feldspathic, and the green, chloritic. Irregular warped schistose structure. Hardness 3-5. Brisk effervescence in warm acid. BB. greenish portion fuses at 4.5 to a black glass. Under the M., portions of the section have a grayish texture, interspersed with leaves of chlorite and slender fragments of actinolite; others are schistose with layers of chlorite and small grayish grains. Scattered in the section are fragments of altered feldspar.

No. 115 (Sp. 2247).—**Calcareous chloritic schist.** 1050 N., 900 W., Sec. 28, T. 40, R. 18, Wis.

Greenish-gray, spotted with a shade of buff. Fine-grained texture. Under the loupe the groundmass appears arenaceous and is interspersed with greenish and grayish, irregular shaped particles; schistose structure. Weathers deeply; on surface dirty-drab to brown; below the surface, ochreous yellow. The small spots noticed above average about 1-16 of an inch and effervesce briskly in acid, and are partially dissolved. Hardness about 4. BB. fuses at 4. to a black glass. Under the M., the grayish, often slightly banded crystals of calcite are easily recognized. The chlorite is in crystalline scales and large amorphous patches. Disseminated in the rock are numerous small grains of quartz.

No. 116 (Sp. 2087).—**Magnetic mica-schist.** 2000 N., 2000 W., Sec. 8, T. 41, R. 30, Mich.

Greenish-black, sprinkled with gray. Fine-grained, even texture. Cleaves readily into thick slates, the surfaces of which are often covered with small bronze colored scales of mica. Strongly magnetic. Hardness about 3. Streak powder dark green. BB. fuses at 4.5 to a black magnetic scoriaceous mass.

No. 117 (Sp. 2117).—**Talco-chloritic schist.** 1700 N., 1430 W., Sec. 15, T. 38, R. 20, Wis.

Light pearly grayish-green. Talcy, shimmering luster. Warped schistose structure, splitting readily into thin scales. Interlaminated with these are thin grayish dolomitic seams. Hardness about 3. BB. fuses at 5. with brisk intumescence to a black glass.

No. 118 (Sp. 2142).—**Talco-chloritic schist.** 200 N., 1650 W., Sec. 22, T. 40, R. 19, Wis.

Light grayish-green, with a purplish brown tint. Talcy, slaty structure and warped schistose, fibrous texture. Hardness about 2.5. No effervescence in acid. BB. fuses at 4.5 to a dark green glass.

No. 119 (Sp. 2044).—**Talco-chloritic schist.** (Provisional.) S. W. qr. of N. E. qr. Sec. 23, T. 41, R. 31, Mich.

Light grayish-green; very even talcy, shimmering luster; slaty schistose structure, cleaving readily into irregular plates. On the splitting planes is often a thin film of lime. Slightly jointed. Hardness about 3. BB. fuses at 5.5 to a green enamel.

No. 120 (Sp. 2054). — **Talco-chloritic slaty-schist.** 1150 N., 150 W., Sec. 24, T. 39, R. 30, Mich.

Pearly pale greenish gray. Slightly shimmering, slaty texture. Cleaves into imperfect slates. The edges of a fracture appear banded with alternate layers of greenish and pinkish gray, averaging about one-sixteenth of an inch in thickness. The former are chlorite and have a hardness of 2 to 3. The latter are apparently feldspathic with a hardness of 4 to 6. Weathers deeply; on the outer surface to a brownish drab; below the weathered surface for nearly one-half an inch it is stained a dark brown. The cleavage planes are finely corrugated. Very brisk effervescence in acid, continuing for some time. BB. fuses at 4–5 to a light grayish green glass. Under the M., the pale greenish chlorite is hardly distinguishable from the grayish talc. In the polarized light the lime is easily recognized by its rhombic striations, and that, between the + nicols, it affords a dark field, when the principal plane of the prisms is parallel to a diagonal bisecting either of the angles of the rhomb. This distinguishes it from the talc in the section, since it becomes dark when the edge of one of the fragments coincides with the principal plane of either of the crossed nicols. Numerous grains of quartz and a few fragments of feldspar are contained.

Sp. 2055, from 1050 N., 150 W., Sec. 24, T. 39, R. 30, Mich., is very similar to No. 120.

No. 121 (2075). — **Chloritic slate.** (Provisional.) Four Foot Falls. 1900 N., 1000 W., Sec. 14, T. 39, R. 19, Wis.

Dark-green; on cleavage surface often a pearly grayish-green. Cleaves readily into thin, wavy sheets; besides these broad corrugations may be observed minute fibrous ones, resembling at first glance fine striations. Hardness about 3. BB. fuses at 5. to a dirty yellowish-green glass.

No. 122 (Sp. 2147). — **Chloritic slate.** (Provisional.) 1375 N., 750 W., Sec. 14, T. 40, R. 18, Wis.

Dark-green; slaty texture and shining luster. Very fissile, cleaving readily into thin, more or less perfect slates. Streak powder green. Hardness about 3. No effervescence in acid. BB. fuses at 4.5 to a black magnetic bead.

No. 123 (Sp. 2137). — **Chloritic slate.** 800 N., 250 W., Sec. 12, T. 40, R. 31, Mich.

Dark grayish-green; aphanitic texture; slaty structure, cleaving into imperfect slates. On the surface of the plates it has a drabish-bronze, shimmering texture. Hardness about 3. BB. fuses at 4. to a black magnetic bead.

Sp. 2179, from 1800 N., 50 W., Sec. 15, T. 40, R. 18, Wis., is apparently a less altered variety of No. 123.

No. 124 (Sp. 2251). — **Pyritiferous chloritic slate.** 430 N., 1500 W., Sec. 36, T. 40, R. 17, Wis.

Bright greenish-black; aphanitic texture. Not very fissile, but still may be split with a little care into irregular plates about an eighth of an inch thick. Under the lens nothing definite as to its composition can be made out. On a side fracture are visible several thin seams of iron pyrites. Hardness 3.5–4. BB. fuses at 4.5 to a black magnetic mass. Under the M., the pale-greenish chlorite and large leaves of brown mica are easily recognized. Thickly strewn in the section are fine particles and ragged shreds of carbon. Numerous grains of quartz are contained.

No. 125 (Sp. 2140). — **Pyritiferous chloritic slate.** 580 N., 1810 W., Sec. 12, T. 39, R. 19, Wis.

Greenish-black; aphanitic texture. Slaty structure, cleaving into more or less perfect slates. It has a hardness of about 4, and rings when struck with the hammer. Disseminated in it are iron pyrites, often in narrow seams, but usually in scattered bright yellow cubes. Pale-greenish streak powder. Brisk effervescence in acid for a few moments. BB. fuses at 4. to a black magnetic bead. Under the M., with a power of

120×, the section presents a dirty appearance, affording but very little light between crossed nicols. With a higher power it appears to consist largely of minute pale-greenish leaves of chlorite.

No. 126 (Sp. 2190). — **Pyritiferous chloritic slate.** 300 N., 2000 W., Sec. 26, T. 40, R. 17, Wis.

Dark greenish black; aphanitic texture, slightly sparkling with minute black shining specks. Interlaminated with the slates are thin seams and elongated particles of iron pyrites. Cleaves easily into imperfect slates. Along the splitting planes it is somewhat decomposed. Hardness, about 3. Streak powder, a dirty green. No effervescence in acid. BB. fuses at 4. to a black magnetic bead.

No. 127 (Sp. 2077). — **Talcose schist.** 2000 N., 1000 W., Sec. 36, T. 40, R. 31, Mich.

Light pea-green; talcy texture. Weathers to a deep red. Irregular warped schistose structure. Hardness 2 to 3. BB. fuses at 4.5 to a very pale green glass.

No. 128 (Sp. 2270).— **Talcose schist.** Sturgeon Falls. 40 N., 230 W., Sec. 27, T. 39, R. 29, Mich.

Light grayish green; talcy texture. Corrugated warped schistose structure. The cleavage planes are often minutely forellated.[1] Weathers to an ochreous brown. Hardness about 3. Slight effervescence in acid. BB. fuses at 4. to a black glass.

No. 129 (Sp. 2263). — **Talcose schist.** Sturgeon Falls. 1670 N., 500 W., Sec. 27, T. 39, R. 29, Mich.

Light grayish-green; foliated, talcy texture and warped schistose structure; slightly fibrous. Has a greasy feel, and is quite soft. Brisk effervescence for a short time. BB. fuses at 5.5 to a grayish enamel.

No. 130 (Sp. 2064). — **Talcose schist.** Little Quinnesec Falls. 1070 N., 370 W., Sec. 15, T. 39, R. 30, Mich.

Light gray; warped schistose structure. The cleavage surface has a talcy, silvery-gray, shimmering luster. Effervesces briskly in acid for a few minutes. Hardness about 2.5. BB. fuses at 5. to a pale green glass. Under the M., in the polarized light, the fibrous talc is easily recognized. The base of the rock appears to consist largely of small grains of quartz. Interspersed in it are several grayish patches of lime.

No. 131 (Sp. 2073). — **Talcose schist.** Big Quinnesec falls. N. W. qr. Sec. 8, T. 39, R. 30, Mich.

Light pearly grayish-green. A fresh fracture has a talcy, shimmering luster. Warped schistose structure, and finely corrugated. On the edge may be seen a few grains of glassy quartz. Interlaminated with the talcy folia are hard layers, resembling those of felsite. BB. fuses at 5. to a white enamellar glass.

No. 132 (Sp. 2082). — **Chloro-talcose schist.** (Prov.) 1250 N., 1750 W., Sec. 30, T. 41, R. 31, Mich.

Greenish-gray; even, impalpable texture. A fresh fracture sparkles with minute scales resembling those of talc. Uneven schistose structure. Hardness, 1–2. Batters under the hammer. Apparently somewhat decomposed. No effervescence in acid. BB. fuses at 5. to a greenish enamel.

No. 133 (Sp. 2067). — **Chloro-talcose slate.** (Prov.) S. E. qr. of S. E. qr. Sec. 32, T. 40, R. 30, Mich.

Ash-gray; on the edge it has a slight brownish tinge. Cleaves into thick curved slates. On cleavage surfaces, slightly shimmering. Quite soft and partially decomposed. No effervescence in acid. BB. fuses at 5. to a magnetic bead. Under the M., between the + nicols, it presents an even crystalline texture. The base is composed of minute crystalline particles, and an amorphous substance. The former are in small grains and slender crystals, the longest of which are not more than 1-1000 of an inch.

[1] Spotted like the skin of a trout.

A few of these slender crystals can be recognized as actinolite, from the inclination of the optic bisectrix to the principal crystal axis. The amorphous substance has a dirty brownish appearance.

No. 134 (Sp. 2061).—**Chloro-talcose schist.** (Prov.) Little Quinnesec Falls. 1140 N., 225 W., Sec. 15, T. 39, R. 30, Mich.

Purplish to greenish-gray. To the unaided eye it presents an aphanitic crystalline texture. Schistose structure. The surface of the cleavage planes is usually corrugated, and on a fresh one, may be seen numerous very minute white scales, resembling those of talc. Weathers to a reddish-brown. Feeble effervescence in cold acid, but brisk in hot. BB. fuses at 4. to a black, slightly magnetic bead. Under the M., in the polarized light, the section presents a semi-granular crystalline texture, and is interspersed with numerous grayish patches, resembling dolomite. The base of the rock is composed principally of small grains of silica, and a grayish substance that becomes dark between the + nicols. There are numerous small fragments, resembling those of chlorite or talc.

No. 135 (Sp. 2071).—**Talcy feldspathic slaty-schist.** Big Quinnesec Falls. N. W. qr. Sec. 8, T. 39, R. 30, Mich.

Flesh color on the edge, and silver gray and flesh color mottled with dark green on cleavage surface. The edge appears slightly banded with irregular (not continuous) dark green thin layers. It appears studded on the edge with a few grains of quartz and feldspar; the laminæ folding around them. The silver gray color is due to very thin layers of talc. The pinkish portion is apparently feldspathic, and has a hardness of 5.6, and fusibility a little above 5., fusing to a white enamellar glass. Under the M., between the + nicols, it appears crystalline. Some portions of the section are composed of minute grains of quartz, others have a soft gray fleecy fibrous texture, while others are micro-granular and are stained brownish, evidently due to decomposition. Scattered in this varied base are several highly altered crystals of feldspar and large grains of quartz, enclosing apparently portions of the base. A little chlorite and magnetite may be recognized. The fibrous portion of the section noticed above resembles talc. With a power of 500 × can be seen in the quartz grains numerous dancing bubble cavities.

No. 136 (Sp. 2157).—**Chloro-argillaceous slate.** N. E. cor. Sec. 16, T. 40, R. 18, Wis.

Light pearly pea green; slaty texture. Weathers to a brownish red. Slaty schistose structure; cleaves readily into slates more or less perfect. Hardness about 3. No effervescence in acid. BB. fuses at 4.5 to a greenish glass.

Under the M., between the × nicols, portions of the section appear dark, owing to a thickly disseminated brownish substance; others have a soft, gray, micro-granular texture. With a power of 500 × can be seen a pale greenish mineral, resembling chlorite.

No. 137 (Sp. 2237).—**Chloro-argillaceous slate.** 1325 N., 1050 W., Sec. 28, T. 39, R. 18, Wis.

Light bluish-black; impalpable slaty texture. Cleaves readily into imperfect slates. Emits a strong clay odor when breathed upon. Hardness about 3.5. BB. fuses at 4.5 to a gray blebby glass.

No. 138 (Sp.2185).—**Chloro-argillaceous slate.** (Prov.). 500 N. 1840 W., Sec. 33, T. 40, R. 18, Wis.

Greenish slate color; very even, aphanitic texture. Cleaves readily into plates from one-eighth to three-quarters of an inch thick; the latter have a smooth conchoidal fracture and are jointed. Hardness about 3.5. Under the M. it presents a greenish brown base; between the + nicols, the section appears thickly strewn with minute crystalline grains resembling silica.

No. 139 (Sp. 2244).— **Chloro-argillaceous slate.** 2000 N., 600 W., Sec. 28, T. 39, R. 19, Wis.

Slate color. Aphanitic, impalpable texture. Bright, shimmering luster. Very fissile, splitting into thin, regular plates. Hardness 2.5 to 3. BB. fuses at 5.5 to pale greenish gray glass.

No. 140 (Sp. 2253).— **Chloro-argillaceous slate.** Lake Hanbury. Sec. 16, T. 39, R. 29, Mich.

Bluish black; aphanitic texture. Imperfect slaty texture, somewhat shaly and jointed. On the jointed surface it appears irregularly banded at an oblique angle to the cleavage. Whether these indistinct bands are the bedding planes, is difficult to decide from the small hand specimens. Lying in the splitting planes are thin seams of pyrites. BB. fuses at 5. to a pale greenish gray glass.

Iron ore rocks (See ECONOMIC CHAPTER).

No. 141 (Sp. 2076).— **Siliceous magnetic ore.** Mouth of Pine river. 1300 N., 1480 W., Sec. 22, T. 39, R. 19, Wis.

Broadly banded with metallic steel gray, and dark purplish brown to grayish brown. The former are layers of steely magnetite; the latter are an admixture of magnetite and the sesquioxides of iron and arenaceous quartz. Streak powder dark purplish brown. Strongly magnetic. Sp. Gr. 3.00.

No. 142 (Sp. 2243).— **Garnetiferous magnetic ore.** 1150 N., 950 W., Sec. 28, T. 39, R. 18, Wis.

Bluish black, mottled with garnet. Indistinct, medium grained texture. Bright metallic luster. The garnets, easily recognized by their color, fracture, hardness and fusibility, are in irregular shaped bunches and grains. Some of them are half an inch across. Somewhat schistose in structure. Strongly magnetic. Sp. Gr. 4.17.

No. 143 (Sp. 2154). — **Steely specular iron ore.** Eagle Mine. 25 N., 10 W., Sec. 20, T. 40, R. 18, Wis.

Brownish purple. Aphanitic texture. Irregular banded structure. Coursing through the ore and disseminated in it are seams and fragments of vein quartz. Hardness about 5. Streak powder red. Sp. Gr. 3.60.

No. 144 (Sp. 2156). — **Steely specular ore with vein quartz.** 1870 N., 1950 W., Sec. 15, T. 40, R. 18, Wis.

The ore is bluish to purplish brown, and the quartz is grayish white. The former has an aphanitic to flinty texture and the latter a vitreous texture. Disseminated in the specular ore are radiated clusters of brown iron ore. Sp. Gr. 3.36.

No. 145 (Sp. 2241). — **Siliceous hard hematite.** 1500 N., 1050 W., Sec. 28, T. 39, R. 18, Wis.

Dark shade of purple; aphanitic steely texture. Some portions of it, by very careful observation with a strong lens, appear to be an altered variety of No. 49 (Sp. 2240). Schistose structure. Very hard and siliceous; some of the fractures across the lamination are covered with a thin iridescent film, possibly that of an oxide of manganese. Streak powder red. Sp. Gr. 3.20.

No. 146 (Sp. 2066).— **Flag ore or banded siliceous ferruginous slate.** S. E. qr. of S. E. qr. Sec. 32, T. 40, R. 30, Mich.

Dark metallic purplish blue, banded with grayish brown. The former layers have an aphanitic texture and bright metallic luster. They are composed of a jasper oxide of iron and afford a brownish powder. The latter are arenaceous. Sp. Gr. 3.47.

No. 147 (Sp. 2080). — **Flag iron ore.** 1600 N., 1000 W., Sec. 20, T. 40, R. 30 Mich.

Purplish steel gray; flaggy or jointed schistose structure. Under the lens, it presents, a fine grained arenaceous texture and semi-metallic luster. Slightly friable. Streak powder purplish brown. Sp. Gr. 3.00.

No. 148 (Sp. 2152).— **Banded ferruginous schist.** 640 N., 1900 W., Sec. 21, T. 40, R. 18, Wis.

Grayish white banded with shades of brown. Schistose structure. Coursing through the specimens are seams of vein quartz. The thin layers of oxide of iron are very much decomposed and mostly changed to a hydrous yellow oxide. Some of the layers or bunches of quartz have an arenaceous appearance. When scratched with the knife it leaves a shining streak.

Carbonaceous rocks.

No. 149 (Sp. 2134).— **Carbonaceous argillaceous schist.** 250 N., 160 W., Sec. 11, T. 39, R. 19, Wis.

Bluish black. Impalpable texture. Very jointed and schistose structure. In the joints is usually a lemon to buff colored substance, apparently due to the decomposition of the iron pyrites, irregularly disseminated in the rock. The specimen is evidently highly carbonaceous. No effervescence in acid. Streak powder black. Hardness about 4.5. BB. fuses at 5. with slight intumescence to a gray blebby glass.

No. 150 (Sp. 2197).— **Siliceous plumbaginous schist.** 425 N., 500 W., Sec. 25, T. 40, R. 17, Wis.

Grayish-white and bluish-black. Irregular schistose structure. The quartz is in thick, uneven bands. The graphitic layers are easily recognized by their luster and shining black streak. The rock is highly ferruginous, as it fuses at 5. to a black magnetic enamel.

No. 151 (Sp. 2153).— **Plumbaginous schist.** 650 N., 1900 W., Sec. 21, T. 40, R. 18, Wis.

Bluish-black dull to graphitic texture. Very fragile. Irregular warped schistose structure. Hardness about 2.5. Streak shining. Gives a black powder, and soils the fingers when handled. No effervescence in acid. BB. becomes grayish-white without fusing. Moistened with cobalt solution it becomes blue.

Sp. 2196, from 500 N., 600 W., Sec. 25, T. 40, R. 17, Wis., is similar to No. 151 (Sp. 2153).

Sp. 2169, from 800 N., 450 W., Sec. 9, T. 40, R. 18, Wis., is very similar to No. 151, only it fuses at 4.5 to a light gray glass.

Granites.

No. 152 (Sp. 2084). — **Protogine-granite.** S. E. qr. of S. E. qr., Sec. 17, T. 41, R. 30, Mich.

Flesh color to grayish-white; unevenly sprinkled with dark green. The first is due to the orthoclase, easily recognized by its broad, plain cleavage facets. The second, the quartz, best seen on a weathered surface, where decomposition has rendered the irregular grains prominent. The latter, the dark-green mineral, is quite soft and apparently much altered, and resembles chlorite. On the jointing or cleavage surfaces may be seen minute silver-gray scales very similar to those of talc. Under the M., the crystals of orthoclase appear plain; some of them are partially decomposed and enclose often grains of quartz. The quartz grains are angular and large. The chlorite is in pale-greenish leaves and is scattered in the matrix; also in the grains of quartz. With a power of 500 × can be seen a few dancing bubble cavities. There are other cavities containing a stationary bubble, even when heated above 100° C.; the latter inclusions in many respects resemble those of glass. The refractive index of the filling is nearly equal to that of the quartz, as only a faint narrow line forms the division, while the bubble is outlined by a broad dark ring. It is possible that these may be filled with a highly saturated saline liquid. The bubbles of the fluid cavities remain lively when heated, but do not disappear.[1]

No. 153 (Sp. 2129). — **Granite.** 500 N., 0 W., Sec. 12, T. 38, R. 19, Wis.

The feldspar is grayish to reddish-white. Many of the crystals are quite large, measuring an inch across. The quartz is in irregular shaped masses, and has a dull, vitreous luster, and forms apparently the groundmass of the rock. The mica is brownish-black to black, and is scattered promiscuously in the specimen. Under the M., it presents a coarse, granular structure. The feldspar crystals (orthoclase) appear large. They show well the different shades of decomposition, from a slight cloudiness to a dull-gray mass. The quartz presents a clear watery chromatic texture, and an angular patchy structure. The dark-colored mica is easily recognized, and, like hornblende, is often strongly dichroitic. The position of the bisectrix to the crystal axis readily distinguishes it. With a power of 500 × can be seen in the quartz grains numerous inclusions, similar to those in No. 152.

No. 154 (Sp. 2271). — **Protogine.** (Prov.) 1230 N., 850 W., Sec. 27, T. 38, R. 21, Wis.

Grayish-pinkish-red on edge and end fracture, and yellowish-gray on cleavage, sprinkled with greenish-black, and tinged with an indistinct pinkish red. Cherty felsitic texture. Schistose structure. Cleaving readily into plates. Under the lens, no crystals of the essential minerals are visible. As accessories may be recognized numerous cubes of iron pyrites. A thin coating of lime often covers the splitting planes. Slight effervescence in acid for a moment. BB. fuses at 4.5 to a white pearly glass. Under the M., the section appears to be very much altered, only the grains of quartz remain unchanged. Between the + nicols it presents a grayish, patchy appearance. A few decomposed fragments, resembling feldspar, may be seen; also a little talc and chlorite. What the rock originally was is difficult, from the small hand specimen, to decide. In composition and texture, it resembles protogine.

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[1] See C. E. Wright's Annual Report for 1877.

COLLECTION AND DESCRIPTIVE NUMBERS.

I. *Arranged according to collection numbers.*

Collec. Nos.	Des. Nos.	Collec. Nos.	Des. Nos.	Collec. Nos.	Des. Nos.
2051	91	2119	88	2188	65
2052	94	2120	52	2189	46
2053	95	2122	80	2190	126
2054	120	2125	53	2191	47
2056	100	2126	.....	2197	150
2057	51	2127	69	2198	43
2058	31	2128	112	2199	67
2059	000	2129	153	2201	54
2061	134	2130	70	2203	51
2062	85	2131	71	2204	55
2063	93	2132	34	2205	13
2064	130	2133	87	2206	14
2065	107	2134	149	2207	45
2066	146	2136	35	2208	56
2067	133	2140	125	2209	57
2068	2	2141	104	2210	58
2069	84	2142	118	2211	62
2070	82	2143	110	2212	68
2071	135	2144	110	2213	24
2072	74	2145	21	2216	9
2073	131	2146	.....	2217	60
2074	8	2147	122	2218	61
2075	121	2148	106	2219	59
2076	141	2149	90	2220	23
2077	127	2152	148	2222	29
2078	99	2153	151	2223	15
2079	86	2154	143	2224	32
2080	147	2155	36	2225	28
2081	10	2156	144	2226	54
2082	132	2157	136	2227	111
2083	3	2158	7	2228	111
2084	152	2159	19	2229	63
2085	4	2160	22	2230	64
2086	1	2161	20	2231	17
2087	116	2162	11	2232	30
2089	25	2163	12	2233	18
2090	26	2164	96	2236	108
2091	27	2165	96	2237	137
2092	114	2166	69	2238	44
2093	6	2167	66	2239	108
2094	119	2169	151	2240	49
2097	109	2170	113	2241	145
2100	101	2171	40	2243	142
2101	72	2172	37	2244	139
2102	102	2173	38	2247	115
2104	....	2174	73	2251	124
2105	89	2175	39	2263	129
2106	105	2177	41	2265	77
2107	89	2178	42	2268	76
2108	98	2179	123	2270	128
2109	79	2180	42	2271	154
2110	103	2181	66	2281	16
2112	80	2182	83		
2113	78	2183	97		
2114	75	2184	33		
2116	76	2185	138		
2117	117	2186	48		
2118	92	2187	5		

II. *Arranged according to descriptive numbers.*

Des. Nos.	Collec. Nos.
1	2086
2	2083
3	2068
4	2085
5	2187
6	2093, 2095
7	2158
8	2074
9	2216
10	2081
11	2162
12	2163
13	2205
14	2206
15	2223
16	2281
17	2231
18	2233
19	2159
20	2161
21	2145
22	2160
23	2220
24	2213
25	2089
26	2090
27	2091
28	2225
29	2222
30	2232
31	2258
32	2224
33	2184
34	2132
35	2136
36	2155
37	2172
38	2173
39	2175
40	2171
41	2177
42	2178, 2180
43	2198
44	2238
45	2207
46	2189
47	2191
48	2186
49	2240
50	2203
51	2057
52	2120, 2121, 2123, 2124
53	2125
54	2221, 2226
55	2204
56	2208
57	2209
58	2210
59	2219
60	2217
61	2218
62	2211
63	2229
64	2230
65	2188, 2200
66	2181, 2167
67	2199
68	2212
69	2126, 2127
70	2130
71	2131
72	2101
73	2174
74	2072
75	2114
76	2116, 2268
77	2265
78	2113
79	2109
80	2112, 2122
81	2104
82	2070
83	2182
84	2069
85	2062
86	2079
87	2133
88	2119
89	2105, 2107
90	2149, 2150
91	2051
92	2118
93	2063
94	2052
95	2053
96	2164, 2168, 2165
97	2183
98	2108
99	2078
100	2056
101	2100
102	2102
103	2110
104	2141
105	2106
106	2148
107	2065
108	2236, 2239
109	2097
110	2144, 2143
111	2227, 2228
112	2128
113	2170
114	2092
115	2247
116	2087
117	2117
118	2142
119	2094
120	2054, 2055
121	2075
122	1472
123	2137, 2179
124	2251
125	2140
126	2190
127	2077
128	2270
129	2263
130	2064
131	2073
132	2082
133	2067
134	2061
135	2071
136	2157
137	2237
138	2185
139	2244
140	2253
141	2076
142	2243
143	2154
144	2156
145	2241
146	2066
147	2080
148	2152
149	2134
150	2197
151	2156, 2199, 2169
152	2084
153	2126
154	2271

CHAPTER III.

WESTERN AND SOUTHERN EXTENSION OF THE MENOMINEE RANGE.

This chapter embraces the continuation of the Huronian series to the west of the ground covered mutually by Major T. B. Brooks and myself in 1874. It is purposed, however, to give only a general outline of this later field work, since a detailed geological description would be but an uninteresting repetition of the same essential points already given by Major Brooks in a previous chapter[1] of this report. I will give a geological cross section along the line A–B (see map), and project into it from either side, the different strata, so as to make our section as complete as possible.

This can be done without relying altogether on the lithological characteristics of the rocks, as will be seen from the plan of our field operations, which consisted of running parallel north and south lines, one-quarter to one-third of a mile apart, and taking on these lines magnetic observations with the dial compass and dipping needle at every one hundred steps. We noted also the topography, the soil, and the timber. See table at the end of chapter, giving quality and quantity of timber, etc.

By means of the lines of attraction which we crossed, and in some instances traced out, we were thus enabled to connect widely separated outcrops.

We will now begin with the youngest member of our geological section, the upper granite. That this granite is younger than the lower Huronian, I think admits of no doubt. We find the latter dipping under the former, and veins of the former penetrating the latter; but that it belongs to the lower Huronian, is in my mind an open question (see page 256). It may be said that this upper granite in the Menominee district, as far as we know, is usually underlaid by formation XIX of our cross section, but we must remember that XIX is a wide belt.

This granite is massive, rarely if ever shows any signs of bedding, though an apparent stratification or grain is sometimes visible; that is, the longer axes of the feldspar crystals appear to have a common trend, but this may be due to pressure.

[1] Chapter II, Pt. VII, this Vol.

Outcrops of the upper granite are very numerous south of the two Quinnesec falls; but exposures of it in range 17 and westerly therefrom, near its junction with the lower Huronian, are exceedingly rare; still, the topography of the country, the quality of the soil and timber, and frequency of large angular boulders of granite immediately outside of the lower Huronian area, indicate very well the character of the underlying rock.

The most westerly ledge of granite I have seen, on the Menominee range, was in Sec. 27, T. 41, R. 13 E., or about three miles south of Brulè lake. North of this, about one mile, is a hornblende rock. In ranges 13, 14 and 15, we found in the Pine river numerous large granite boulders, and in Sec. 9, T. 39, R. 14, on the river, is a ledge of gneissoid granite, strike N. 80° E., and dip high to south.

In ranges 16 and 17, immediately south of the hornblende schists, the granite boulders appear; the soil is then of a poorer quality, the softer kinds of timber predominate, and the topography changes. Low rounded hills or oblong ridges and deep amphitheater-like depressions (pot holes) are quite common. The water of the swamps, unlike that of the clear spring water within the Huronian area, has a brackish taste. An observing person, in passing from the Huronian to the granite, cannot fail to note the strong contrast.

The upper granite is well represented by the granite ledges south of Quinnesec falls (see description No. 153, page 717), and, also, by the most westerly outcrop we have just noted of this rock. This latter is reddish gray in color, mottled with dark patches of fine particles of biotite. The essential minerals, quartz, feldspar and mica, are easily distinguished. The grains of quartz are glassy to dull gray and seldom exceed one quarter of an inch in size. The feldspar constitutes about one-half the entire mass. The crystals are pale red to grayish white; some of them are half an inch across. The mica is disseminated in irregular shaped leaves through the matrix of the rock; it is very dark green or black. A weathered surface is usually rough from knotty projections of the quartz, and just beneath this surface, for an eighth of an inch, the feldspar is more or less changed into kaolinite. The mica appears less altered and retains, usually, its dark color. The rock is massive and jointed, presenting only faint and doubtful lines of bedding.

Under the microscope, the above minerals are easily made out; with a power of 600 diameters may be seen numerous fluid inclusions, some of which are saline, and out of their solution has crystallized a small cube of salt. The tiny cubes are perfectly transparent, and their outlines are extremely fine, and require a good defining microscope to distinguish them. This, however, is what we would naturally expect when we consider how small must be the difference of the refractive index of the salt crystal and the saturated solution out of which it has formed; and for the same reason, the bubble in these appears much darker than in the simple fluid cavities. Another difference too may be noted, and that is, the bubble of these saline solutions has but very little movement, while those of the other kind are usually very lively. This, no doubt, might be explained by the difference of the densities of the fluids, and possibly there might be established a scale of the comparative saturation by the rate of vibration of these tiny bubbles. It is highly probable that all of these inclusions contain more or less salt, even when no crystal is present, since there is an evident degree of difference in the saturation, from the fact that the relative size of the cubes and that of the cavity varies greatly; some of them in the large cavities being very minute, while in others they occupy one-fifth of the included space.

One very interesting and, I think, important fact in connection with these saline inclusions, which I have already noted in my report on the Penokee iron range, is, that I have always found them present in the upper granite of that district, and as yet I have not observed any in the lower or Laurentian granite of our Lake Superior region (see pages 255 and 256).

Another rock which we may as well note here is a gneissoid granite, of which mention has been made in this chapter. It is reddish gray in color, medium grained in texture, and is highly feldspathic. But very little quartz is contained, and the leaves of biotite have a parallel arrangement.

Under the microscope can be recognized plain and striated feldspar, grains of quartz and leaves of biotite. The orthoclase is frequently very much altered. In the quartz grains a few fluid cavities are contained, though I cannot detect any holding a crystal of salt. Still, some of the bubbles are very dark, and are nearly motionless, which leads us to suspect that their liquid is somewhat saline.

The next rock we will consider is a garnetiferous hornblende gneiss, XIX (?) located on Pine river, and near the junction of the lower Huronian and granite, in the S. E. qr. of the S. W. qr. of Sec. 4, T. 39, R. 16, Wis. The ledges here cross the river obliquely, and form some rough rapids and low terrace falls. The gneiss is plainly bedded and has a strike of N. 62° W., and dips nearly vertically. Apparently interstratified and intersecting it are veins of feldspathic granite. These granitic sheets, in some instances, occupy as much space as the gneiss. The feldspar crystals are very large, many of them measuring three inches across. But very little quartz or mica is present in the granite. Under the microscope may be seen in the granite slender crystals of tourmaline, which are strewed promiscuously through the section, lying within the quartz, feldspar and the matrix.

The gneiss does not appear in the least contorted. In it, along the bedding planes, are gashy-like bunches of feldspar, the largest of which are three inches long by one inch wide. It is grayish-black in color, and medium to fine-grained in texture. A fresh surface sparkles with the black, shining facets of hornblende, and when examined closely, very small reddish grains of garnet may be seen.

Under the microscope the hornblende appears to be the predominating mineral, the quartz next, then the plain and striated fragments of feldspar. The garnets are easily recognized by their becoming dark between the crossed nicols. The quartz contains numerous fluid inclusions.

To the northeast of here about one mile, and in the south bank of the Pine river is another low ledge of hornblende gneiss or schist, XIX.[1] It is plainly stratified, has a strike of N. 86° W., and dips high to the south. It therefore underlies the gneiss we have just described.

This latter gneiss is very similar to those south of Pine river in Secs. 26 and 27, T. 39, R. 17, Wis. See lithological description No. 62, page 702.

The gneiss is dark to light green. It is highly crystalline; examined on the side fracture, the bright shining needles of hornblende have a parallel arrangement. The larger crystals measure an eighth of an inch in length and are very narrow. The cleavage of the rock is quite even and perfect. It often resembles a hornblende schist. The fracture across the cleavage is rough and raspy to the touch; *under the microscope* the schistose structure is plainly visible. The base of the rock is feldspathic, composed of small partially altered crystals of feldspar and granules of quartz, which fill up the interstices between the large amphibole fragments. The feldspar and hornblende often occur in twin crystals.

This brings us to the typical hornblende schists, which we have considered as belonging to No. XIX of our section; in fact, the hornblende schists, as far as I have observed, constitute, on the south side of the Huronian series, at least nine-tenths of No. XIX. They form

[1] The Roman numerals employed in this chapter represent the different members of the Huronian series. The designation was first employed by Major T. B. Brooks, in his geological report of Michigan, 1873, and I have endeavored, in the cross section A–B, to correlate the Menominee series with the Michigan. In comparing proof sheets of this volume, it appears that Major Brooks' Bed No. XV is the same as my No. XIII. This difference applies only to the Middle Huronian.

a wide and important belt in the series. They are plainly stratified and nearly always present the same appearance, and therefore are quickly recognized. We first found these schists in south and south-east of the two Quinnesec falls and traced them west for four miles, where they disappear beneath the heavy sand drift. When we met them again nearly nine miles to the west, across this covered area, they seemed like old, familiar friends. We then traced them for ten miles in a west-northwesterly direction, where they disappeared once more under the heavy drift which keeps them concealed for at least twenty miles farther, or to the westerly limit of our field work.

On the north side of the Huronian series, immediately north of the Menominee river, the hornblende schists are represented by mica schists, which resemble the upper mica schists of the Marquette Iron district. See lithological description No. 22, also Major Brooks' description of the same.

The general strike of our hornblende schists is well illustrated on map XXX, whereon is located, as near as may be, from our present data, the position and course of the lower Huronian series. The dip of the hornblende schists vary from forty-five to seventy degrees to the south and southwesterly. These schists are usually of a greenish-black color sprinkled with gray, are fine-grained to aphanitic in texture. Examined under a strong lens they appear highly crystalline, and the surface frequently sparkles with innumerable facets of shining, black, needle-like crystals of amphibole. Schistose structure very plain, even in hand specimens. Cleaves quite readily and sometimes into thin plates. Somewhat jointed.

One specimen, from the center of Sec. 16, T. 39, R. 17 E., a fair representative of the hornblende schists, appears, *under the microscope*, composed chiefly of irregularly broken crystals of hornblende, with grains of quartz and fragments of feldspar lying between, and apparently forming the base of the rock. South of this locality about one-quarter of a mile, is a much finer-grained hornblende schist, which, *under the microscope*, in the polarized light, presents a finely quartzose base, thickly strewn with acicular crystal fragments of actinolite.

For a fuller description of these hornblende schists, see Nos. 51 to 61, inclusive, pp. 700–702.

In the center of the north half of the N. W. qr. of Sec. 16 is an actinolite schist, interstratified with the hornblende schists, and intersecting it are veins of granite. The actinolite schist has a fine crystalline texture. The crystals of actinolite are easily recognized. It has an irregular schistose structure, and weathers to a lighter drab.

Under the microscope, the section appears densely crowded with slender blades of actinolite, which have a common trend. There are several small clusters and narrow seams, filled with angular grains of quartz; still the actinolite constitutes, at least, nine-tenths of the rock.

The next member given on our section is No. XVII; between this and No. XIX would naturally come No. XVIII, but I have never found anything in the western portion of the Menominee range in Wisconsin that would separate Nos. XVII and XIX. We find occasionally a narrow bed of actinolite schist along the junction, but it occurs also interstratified with the hornblende schist. No. XVII is a massive diorite; it is a very tough rock and not easily fractured. It seldom ever shows the faintest signs of bedding, and therefore resists well the destroying agencies of nature, and for this reason frequently forms high, steep ridges, having the same trend as the formation.

These ridges often terminate very abruptly, owing to the strongly jointed character of the rock. The diorite, like the hornblende schists, is one of the important members of our series.

It occurs in south of the Quinnesec Falls and in Secs. 26 and 27, T. 39, R. 17 E., and northwesterly therefrom, along the north side of the hornblende schist, to the northwest quarter of Sec. 35, T. 40, R. 16 E, where it disappears under the heavy drift; boulders of it, however, are scattered over the surface for nearly a mile beyond this point.

North of Pine river, in range 17, is another parallel belt of diorite; which I think forms the basin rock of a synclinal. See map and geological cross section A–B. It will be noticed on the map, that this range of diorite begins immediately west of Loon lake and extends thence northwesterly out of Sec. 36 and across Secs. 35, 27 and 28.

We did not find a continuous ledge of diorite over this entire area, but outcrops of it were very common, and the south side of this belt is traversed by an almost unbroken line of magnetic attractions; thus clearly indicating the location of the covered rocks.

North of this range the greenstones again form, apparently, the basin rock of what appears to me to be another synclinal. See cross section A–B. We do not find these rocks outcropping on the line of our cross section; but the magnetic attractions, with the strike of the rocks to either side, enable us to determine very nearly where the diorite range passes.

To the east, on the south bank of the Brulè river, between the Michigamme and Paint rivers, are large ledges of amphibole rock. See descriptions, Nos. 34 to 42 inclusive, pp. 697, 698. It is possible that these amphibole rocks represents the diorites. North of the Brulè, on our line A–B, diorite occurs again, this time dipping to the north. The diorites, owing to their massive structure, are not as welcome to the sight of the field geologist as the hornblende schists and other plainly bedded rocks. It is in vain that we sometimes try to make ourselves believe that the jointing seams are lines of stratification, for the chances are that a little further investigation will develop on the other side of the ledge another set of similar seams, having a reverse strike and dip. Still, the diorites have their redeeming qualities, since their very massiveness permits them to rear their rounded and scarred heads above the surface, thereby indicating the relative position of the other rocks, and thus indirectly reveal to us that which we wish to know.

Within the diorite formation and parallelly traversing its general trend, is a line of magnetic attraction. See map and cross section A–B. Whether these attractions are due to a covered bed of commercial iron ore or to rocks carrying magnetite, can only be determined by actual explorations.

Let us now examine the diorites a little more closely. Some of them are very fine-grained, others are coarsely so. Very dark green is the prevailing color. They weather to a light drab, and sometimes quite deeply. The weathered surface is usually rough, with warty-like projections of hornblende. The hornblende cleavage planes, in the coarser varieties, can be readily made out.

Under the microscope, the amphibole appears as the most abundant mineral. It is the least altered, and in some sections it is twinned. The feldspar is frequently partially decomposed, and presents then a micro-granular mass.

The larger crystals often enclose fragments of amphibole. As accessory minerals may be added, a little magnetite, and in some instances a few grains of quartz. For detailed descriptions, see Nos. 75 to 93, pp. 704–708.

Referring again to our cross section A–B, No. XV appears as the next member marked thereon. No. XVI is apparently wanting. This latter member, Major Brooks has provisionally designated in his Mich. Rep. as a limonitic schist, but my impression is, that it is only decomposed pyritiferous lenses of No. XV.

No. XV is represented by chloritic schists (see lithological descriptions, Nos. 121 to 126), by chloro-argillaceous slates (Nos. 136 to 138), and by plumbaginous schists (Nos. 149 to 151).

The most westerly outcrop of No. XV in our south range was on the south side of Pine river, a little north of the center of Sec. 28, T.

39, R. 18 E. (see No. 137). On our next range to the north (see map), we find it outcropping along the south side of the diorites in Secs. 36, 35, 26 and 27, T. 40, R. 18. Again in the next range to the north, it outcrops immediately south of the Commonwealth in Secs. 34, 33, 32 and 31, T. 40, R. 18 E., also in Sec. 25, T. 40, R. 17 E. Again in the next northerly range, about the Eagle mine location, is an abundance of plumbaginous schist; also in this same range near the southwest corner of Sec. 13, T. 40, R. 17.

In our next range to the north, we find along the south side of the Brulè river, near the northeast corner of Sec. 16, and in the northeast quarter of Sec. 14, T. 40, R. 18, chlorite and argillaceous slates. See Nos. 136 and 122.

In Sec. 12 on the Brulè river, and along its north side opposite to Secs. 11, 2 and 3, T. 40, R. 17, and Secs. 33 and 34 of T. 41, R. 17, are many outcrops and narrow ridges of chloritic and chloro-argillaceous slates. The plumbaginous schists are seldom found outcropping, but when they come .near the surface, the black soil and small fragments of the rock reveal their presence, and by a little digging the loose ledge is soon reached. With the slates it is different; they sometimes form a sharp, narrow ridge, or on the other hand a low outcrop; and where a stream crosses the series, we frequently find in passing over the slates a narrow gorge. This is owing to their highly jointed nature. The bed of the stream at these points is usually thickly strewn with fragments of the slate. For the economic value of the plumbaginous schists, see page 688.

We now reach No. XIV of our section A–B, which is represented in town 39 and ranges 16 and 17 by actinolite schist. In our most southerly range we find, on the north side of XIV, a narrow belt of magnetic attractions, extending northwesterly through Secs. 8, 5 and 6 of T. 39, R. 17, and Secs. 36, 35 and 27 of T. 40, R. 16 E. See map. On our next range to the north, the magnetic attractions bear about the same relation to XIV. The actinolite schists of XIV are rather soft and easily weathered, and therefore the outcrops of it are not frequent. Near the center of Sec. 36, T. 40, R. 16, the Pine river cuts through this member, affording at this point, a fine water power with a fall of some ten feet, which could be easily increased to fifteen or twenty feet. The formation crosses the river at nearly right angles, and the ledges ascend quite rapidly on either side from the river, thereby forming natural wing walls for a dam to be used either for mill purposes or log driving. The formation has a strike of N. 75° W., and dips 70° to the southwest. We have here two varieties of this rock; one is plainly schistose and the other is more compact and resembles a hornblende rock. The first is a chloro-actinolite schist, of a dark grayish-green color. Examined on its edge with the lens, it presents a densely reticulated mass, made up of small, pale-greenish needles of actinolite.

The schistose structure is very perfect, and the schist planes have a talcy appearance. When breathed upon, the rock emits a strong clay odor, due probably to partial alteration of some of its mineral ingredients.

Under the microscope, a section of the rock shows a thickly matted mass of actinolite and pale green chlorite; also viridite, which gives a dark field between the crossed nicols.

The compact variety noted above is medium-grained in texture, and is dark green, sprinkled with gray. The amphibole can be readily made out with the lens. *Under the microscope*, the principal minerals appear to be amphibole or actinolite, with an occasional large imperfect crystal of orthoclase, which, apparently, was the last mineral ingredient formed, as it contains fragments of amphibole and portions of the quartzose base. With a high power may be seen some very perfect crystals of amphibole; also brownish leaves of biotite, and a few grains of magnetite. No. XIII possesses much more interest on our south range than No. XIV. It is a micaceous hornblende schist. To define the dividing line between this and XIV on the one side, and No. XII on the other side, is hardly possible, though on the cross section A–B I have provisionally done so.

On the south range there is but little difference in these three members, but for convenience we will consider the micaceous hornblende schists of this range, with the supposed interstratified belts of iron ore, as No. XIII. On the next range, to the north, No. XIII is represented by actinolite schists. The magnetic belts are easily traced. It would seem more consistent here, perhaps, to consider Nos. XII, XIII and XIV as one member. For the location of these see map, also economic chapter, page 685, relating to magnetic belts. The outcrops of the micaceous hornblende schists in the south range are usually low and are not extensive. The rock is plainly bedded.

In the center of the S. W. qr. of Sec. 5, T. 39, R. 17, is a ledge of garnetiferous mica schist, in which the hornblende appears to be nearly wanting, though it very soon passes into the typical micaceous hornblende schists. This mica schist has a dark greenish color and an uneven schistose structure. The surface of the cleavage planes are rough and knotty with garnets, the leaves of mica folding around and enveloping them. On the weathered surface, the garnets are more or less decomposed; many of them are so altered that only small ochreous bunches remain. *Under the microscope*, the specimen appears composed of brownish leaves of biotite thickly scattered in a very quartzose base. The garnets are easily recognized and are irregularly checked. Yellowish and reddish membranes of the oxides of iron are present, also an opaque, ragged substance resembling carbon

The typical micaceous hornblende schist is very dark green in color, fine-grained in texture. Cleavage quite regular, and on the surface may be seen the bright scales of mica and an occasional small rounded projection of garnet.

Under the microscope, the brownish leaves of biotite and fibrous hornblende appear to be about equally contained, and are disseminated in a quartzose base of small angular grains. A little magnetite is present.

The most westerly ledge of this rock we saw was near the center of the N. E. qr. of Sec. 27, T. 40, R. 16. It outcrops easterly from here about one-fourth of a mile on a high, broad ridge, which no doubt is composed entirely of this same rock. It preserves its micaceous character, but is, perhaps, more of an actinolite schist than a hornblende schist. It is light to dark green, and has a fine crystalline texture. The acicular crystals of hornblende and brownish leaves of mica are readily distinguished. The cleavage along the schist planes is very irregular. The mica occurs also in thin seams.

Under the microscope the base of the rock appears highly quartzose. Besides the hornblende and biotite may be seen a few grains of magnetite. For other detailed descriptions, see Nos. 13–18, pp. 693–694.

No. XII, as has already been noted, is represented in the first two southerly ranges by actinolite schists.

The schists are light-green with bronzy scales of biotite in the cleavage planes. Schistose structure very regular in one direction, but across this it is warped and irregular. They resemble very much the mica schists. *Under the microscope*, the base appears arenaceous, and is densely filled with radiated bunches of actinolite. A little magnetite and numerous leaves of biotite are contained.

It will be noticed that these actinolite schists have a strong resemblance to the micaceous hornblende schists, and it is very questionable whether it is best to separate them.

The next range to the north, which corresponds to the Commonwealth range, No. XII, is represented by banded quartzite sand quartz conglomerates. See descriptions, Nos. 5, 32 and 33, pp. 692, 697. This quartzite I consider is the true representative of formation XII. It is often jaspery, and then resembles the jasper which constitutes the foot wall of the specular and magnetic ores of the Marquette Iron district.

There are very large ledges of this rock in Sec. 31, T. 40, R. 18; also in Sec. 25, T. 40, R. 17. That in Sec. 25 gives evidences of considerable disturbance. It is more or less contorted, and in places is banded, either with jasper or lean magnetic ore. By referring to the map, it will be noticed that, in order to join the quartzites located 250 paces south of the center of Sec. 31 with those in the southeast quarter of Sec. 25, we must presuppose a sharp N. N. W. bend in the formation, or possibly a fault and throw. S. S. W. from here, about six miles, in Secs. 22 and 27, the formation makes fully as sharp a turn to the northwesterly as is required to unite these quartzites into one belt. Again, the contorted character of the quartzites, already noted in Sec. 25, affords us still further proofs of an unusual disturbance. The axial line of this northwesterly bend apparently passes N. N. E. from the center of the northwest quarter of Sec. 27, T. 39, R. 17, through Loon lake (see map) and then possibly takes a more northerly direction, or continues the same course, but with a more gradual curve in the change of the strike of the formation. This quartzite often contains numerous reddish scales of mica approaching an aventurine quartzite.

In Secs. 25 and 31, the plumbaginous schists and iron ores immediately overlie the quartzite, with no possible chance for No. XIV of our series. My impression is that this short bend has produced, along the axial line, an uplift, and that the quartzite, owing to its hard, unyielding nature, has caused a thinning out of the softer contiguous strata folding around the outer side of the bend.

The next member of our section A–B is a hornblende rock, which I have designated as No. XI. In the south range it outcrops at intervals on the north side of the actinolite schist. The rock is very coarse to fine-grained, and is usually massive. Its color varies from pale-green to greenish-black, and in some of the coarser kinds of the latter shade, where partial decomposition has set in, they have been mistaken by explorers for iron ore.

Under the microscope, they appear composed essentially of hornblende, with small granules of quartz lying between the hornblende crystals. An occasional imperfect crystal of orthoclase may be seen. As accessories may be added a few grains of magnetite and bright red scales of hematite; also viridite as an alteration product.

In our cross section will be noticed, between the first two southerly ranges, a wide, covered area. Within this blank space we find, on the north bank of the Pine river, in the south half of Sec. 34, T. 40, R. 17, outcroppings of talcose, chloritic and sericitic schists. These ledges are low, and could easily be passed unobserved.

The talcose schist is quite soft and easily cut with the knife. Its structure in one direction is quite regular, but across this it is very much warped, and often suggests a muscle structure. In color it varies from a light pearly gray to a pale pea green.

Northwest of this locality, near the west quarter-post of Sec. 29, T. 40, R. 17, and therefore within our covered belt, are several loose, angular boulders of mica schist, and from their number and appearance, I should infer that the parent ledge was near at hand. The rock has a silvery-gray color, tinged with a shade of pale green. On the cleavage planes it has a satin texture. The cleavage planes are slightly corrugated in one direction. An end fracture appears arenaceous. Cleaves quite readily, but batters under the hammer. It is apparently talcy. *Under the microscope*, the base of the rock is composed of small angular grains of silica, and is strewn with colorless leaves of muscovite, brownish ones of biotite and fibrous fragments of viridite, which latter give a dark field between the crossed nicols, even on complete revolution of the microscope table.

This covered belt is probably underlaid by magnesian schist and other easily abraded rocks, and it is possible that some minor folds exist across this portion of our cross section.

EXPLORATIONS ON THE BRULE RIVER.

This covers all the ground we have worked up in detail. We will now launch our birch canoes just above Point river falls, and paddle up the Brulè river, and examine on our way to Brulè lake some of the results obtained in 1876. Our party then consisted of F. H. Brotherton, Esq., an Indian and myself.

The Brulè might be considered a strong current, but it has a splendid bottom, and where the river is shallow, poling is good. The water is cool, and the stream abounds in speckled trout, an attraction to every true woodsman. So abundant were these fish that, at noon, it required only a few minutes to capture enough of them to satisfy our more than greedy appetites.

The first outcrop we saw was a chloritic slate, near the north quarter-post of Sec. 18, T. 40, R. 18, Wis. Its strike is N. 70° W.

The next ledge, also a chloritic slate, is located near the center of the northwest quarter of Sec. 12, T. 40, R. 17. Its strike is N. 50° W.

By reference to the map, it will be seen that the river makes a sharp turn to the south, and then northward until it touches the chloritic slate range, where we then have a northwesterly stretch of nearly three miles. On the Michigan side the banks are high and quite steep, and frequent outcrops of chloritic schist are seen, having a strike of N. 60° W., and a dip high to south. These we have already noted and considered as belonging to No. XV of our cross section A–B.

Along this stretch an extensive windfall crosses, and continues westward for several miles. In lots 2 and 3 of Sec. 26, T. 41, R. 16, also, opposite, on the Michigan side of the river, are several ledges of calcareous chloritic schist, which strike a little north of west and dip to south. The rock is deep green; is fine-grained and has a somewhat slaty texture. Warped schistose structure. Just beneath the surface, where it has been exposed to the action of the water, it is colored a bright yellow, from hydrated oxide of iron. Easily scratched with the knife. Effervesces briskly in warm acid.

Under the microscope it presents a patchy structure from the irregular shaped masses of calcareous material, which is probably dolomitic, as only an occasional fragment shows any striations. The chlorite is best seen in the plain light.

Less than half a mile up the river from these ledges, in lots 2 and 3 of Sec. 35, are the only falls we encountered on our way to Brulè lake. These falls are low, only two or three feet high.

Ledges of dioritic schist cross here with a strike of N. 70° W. Above the falls, for nearly three miles, the river is narrow and deep. To either side may be seen, at a short distance away, a high range covered with hard wood and pine. On the Michigan side opposite lots 2 and 3, Sec. 20, T. 41, R. 16, Wis., is a high, steep ridge with several ledges of chloritic schist, which have a strike of N. 80 W., and dip high to south. Underlying these is a greenstone, which probably constitutes the bed rock of the ridge. The chloritic schists are oölitic from small concretions of calcite and resemble a schalstein. This rock is very dark green. It has a warped schistose structure, and its weathered surface is pitted from the dissolving out of the calcite.

Under the microscope, the base appears composed chiefly of chlorite, and is thickly strewn with small crystals of magnetite and slender needles of actinolite. The calcite is easily recognized. Along the river bed are numerous boulders of quartzite. South of this locality about one mile and a half (see map) is a high range of quartzite extending S. S. E. from just north of the south quarter post of Sec. 19, T. 40, R. 16, Wis., for two miles. This quartzite is calcareous and resembles the siliceous marble of the Quinnesec range. See economic chapter; also lithological description No. 2, page 692. We did not see this quartzite range at this time, as it is not visible from the river, but since then Mr. Brotherton discovered and located it. From his description of it and the specimens which he collected, I should judge, on lithological grounds, that it belonged to the marble range (Formation No. V); still it is possible that it belongs to No. XII of our cross section A–B. I regret that I must leave this question, for the present, unsolved.

Continuing our journey, we find near the center of Sec. 24, T. 41, R. 15, Wis., a low ledge of altered actinolite schist. Strike N. 85° W. and dip to south. The rock is of a greenish ash color, mottled with dark green. Scattered in it may be seen numerous bright cleavage facets of calcite. Effervesces briskly in warm acid for a time, but does not disintegrate. When breathed upon, emits a strong clay odor. *Under the microscope*, it presents a densely reticulated mass of fibrous actinolite. Several amorphous patches of viridite may be seen. A few grains of magnetite are contained.

In lot 4, Sec. 30, T. 41, R. 15, Wis., is a ledge of calcareous chloritic schist, which has a strike of N. 40° W., and dips 45° to the northeast. The course of the river along here is nearly parallel to the strike of the rocks. The schist is light green in color. On the cleavage surfaces it has a satin luster and corrugated schistose structure. Lying in the schist planes are seams of dolomite. Some portions of the ledge are oölitic, and the weathered surface is there minutely pitted.

Under the microscope, the plain patches of dolomite are easily recognized; also the chlorite. With a power of 600 diameters may be seen numerous small crystals of rutile. About one and one-half miles northwesterly from this outcrop the river changes its course to a W. N.-W. direction. North of this point about one mile, along the south line of Secs. 16 and 17, and Sec. 22, T. 42, R. 35 Mich., have been reported to me numerous ledges of reddish quartzite, which from the description I have had of them, appear to belong to formation V.

Passing through the center of the N. W. qr. of Sec. 19, T. 42, R. 35, Mich., in a northwesterly direction is said to be a ledge of slate, and north of this point about two miles is reported iron ore. The country from here to Brulè lake consists of pine plains and barrens.

As the results of our trip down the Pine river have already been given, we will turn our attention to the country south of the Quinnesec Falls.

REGION SOUTH OF THE QUINNESEC FALLS.

It was my intention in 1876 to have crossed the country from the upper Quinnesec Falls, south to the head waters of the Peshtigo river, and then to examine the quartzites in T. 34, R. 17, and their westerly continuation therefrom; but the unfortunate sunstroke already alluded to prevented me from making this interesting trip.

My only recourse then, was to send my assistant, Mr. F. H. Brotherton, whose route is indicated on map No. XXX of atlas by dotted lines.

The location of the quartzite in towns 33 and 34 of ranges 13, 14, 15, 16 and 17, Wisconsin, are from subsequent notes of F. H. Brotherton and his brother, taken while in the employ of the Chicago and Northwestern Railway Co.

The outcrops of greenstone and granite in towns 35, 36 and 37 of ranges 21 and 22, are mainly copied from the government plats. Mr. Brotherton reports ledges of granite along the range line on the west side of T. 37, R. 20, which are very similar to description 153 (Spec. 2129). When Sec. 7, T. 36, is reached, we find outcrops of syenitic granite that resemble, at first glance, a diorite, but on closer inspection the black bunches resembling hornblende are seen to consist chiefly of biotite. This rock is probably the same as that to the northeast of here, which the government surveyors have marked on the United States plats as greenstones. Other outcrops of this rock were found at intervals until near the southwest corner of Sec. 30, T. 36, R. 20 E., where are ledges of chlorite schist, having a strike of S. 60° W. to S. 80° W. Less than a mile south of here granite again makes its appearance, but it quickly disappears, and no more ledges of rock were seen for twelve miles.

In the southeast portion of T. 35, R. 19, are given on the U. S. plats outcrops of granite. See map. In the southwest of T. 34, R. 18, are several ledges of granite also near south quarter post of Sec. 21, T. 33, R. 20. The bedding planes of the granites were very obscure, so much so that no reliable dips were observed. The general trend (which probably corresponds to the strike) varied from S. 60° W. to east and west.

The granites, located south of the greenstones in town 36, resemble very much the Laurentian granite. They are usually coarse grained and have a reddish color. The feldspar, the predominating mineral, constitutes at least four-fifths of the rock. It is easily recognized by its broad cleavage planes. The quartzites reported by Messrs. Brotherton Bros. form a high, broad ridge of some four miles in length, which passes through Secs. 29 and 30, T. 34, R. 17, and Secs. 25, 36 and 35, T. 34, R. 18. The range varies from 300 to 400 feet in height, and is about one-half mile wide. It is a prominent landmark, and can be seen for many miles away.

The quartzite in the north half of T. 33, R. 14, is considered by Mr. Brotherton as identical with those of farther east. The country between these two locations was not examined by their party, but there is every reason to suppose that the quartzite range is continuous across this area.

Crossing the Wolf river at Post lake dam, near the south quarter post of Sec. 9, T. 33, R. 12, is a hornblende schist having a strike of S. 50° W., and a dip of 45° to the southeast. This rock and the quartzites to the east of here, I think, are Huronian, and are probably on the same range. Our data south of the Quinnesec Falls is largely of a negative character, and therefore to attempt to theorize on the geological structure, from the few isolated facts before us, would be quite impracticable. Whether the greenstones already noted in T. 36, R. 19, constitute a southwesterly range or belt of Huronian and possibly unite with our quartzite range farther south, or form a narrow bay, is an open question which we will leave to some future geologist to solve, trusting that the deep drift may not frustrate him in his endeavor.

The economic notes of Mr. Brotherton may be briefly given as follows:

Going south from Upper Quinnesec Falls, the timber on the west range line, to the northwest corner of Sec. 30, T. 20, consists of hemlock, birch, cedar, spruce and some maple. Walking good. For one-half mile south of this we find a thick cedar and tamarac swamp.

Between Secs. 31 and 36 it is swampy to the east (Sec. 31), and hard wood to the west (Sec. 36) of the range line. Along the west line of Sec. 6, T. 37, R. 20, the timber is maple, birch and hemlock, two-thirds hard wood.

Line between Secs. 7 and 12, T. 37, R. 20, first half, cedar and tamarac swamp, remainder swampy on the east side, and hemlock, birch, maple and cedar on the west side of range line.

Secs. 13 and 18, first one-fourth mile, timber small, pine, poplar; remaining three-fourths mile, white and Norway pine, 18 to 22 inches in diameter, rather scrubby. Line poorly marked.

Secs. 19 and 24, open country; some scattering white and yellow pine; has been burnt over. Walking good. Between Secs. 25 and 30, and 31 and 36, also scattering pine, and burnt over, and now grown up to thick brush.

Range line between Secs. 1 and 6, T. 36, R. 19 and 20, for first half mile, burnt windfall, grown up to thick brush. From this point south and southwesterly, Mr. Brotherton describes the country along the route he traveled (see map), a distance of not less than 18 miles, as open pine plains.

NUMERICAL INDEX TO SPECIMENS FROM MENOMINEE REGION.

DESCRIBED BY

MESSRS. BROOKS, WICHMANN, WRIGHT AND OTHERS,

In parts VII and VIII, with comparative table of the different numbers which certain specimens bear, according as they have been classified and described.

The nomenclature given is based largely on Dr. Wichmann's determinations, his results of microscopical examinations of thin-sections being given in chapter V.

Mr. Wright has described in his report, Part VIII, the specimens collected in 1874, numbers 2050 to 2284, duplicates of which were furnished Dr. Lapham for the State collection.

Mr. Julien's descriptions in Mich. Geol. Rep., Vol. II, 1873, are based chiefly on physical characters.

The 162 specimens which are numbered in the right-hand column, and described in chapter IV, constitute a typical suite of Huronian rocks found in the region south of Lake Superior, in Michigan and Wisconsin, and embrace the 81 specimens constituting the Michigan state suite, thirty-five duplicates of which were distributed to various institutions in this country and Europe. See App. B., Mich. Geol. Rep., Vol. II, 1873.

[Specimens marked with a star have been examined microscopically in thin-sections.]

Brooks' Catalogue Nos., bracketed thus, [ ].	Julien's Nos., Mich. Geol. Rep., Vol. II, 1873.	Nos. of Typical Suite, bracketed thus, ( ).	Name.	Page.
1*	....	....	Gneiss	....
21*	....	144	Micaceous Limestone.	594, 612
37*	....	....	Diorite	629
80*	....	....	Magnetite-schist ...	617
113*	....	....	Hornblende-schist .	645
137*	....	....	Quartzose chlorite-schist	647
146*	....	....	Porphyritic Gneiss.	631
177*	....	....	Magnetic Actinolite-schist........	640
192*	....	118	Quartz-Diorite... .	583, 629
221*	....	131	Magnetic actinolite-schist	588, 639
222*	....	....	Actinolitic Limonite..............	618
242*	....	....	Sandstone	656
261	....	....	Chloritic schist. ...	....
308*	....	....	Magnetic actinolite-schist	640
325*	....	....	Feldspathic Hornblende-schist.....	643
327*	....	....	Mica-schist	635
337	....	....	Chloritic schist	518
361*	....	....	Quartzite	614
422	....	....	Diabase	517
432*	....	....	Chloritic Quartzite	615
442*	....	....	Mica-schist	634
464*	....	....	Diorite.............	628
479	....	....	Diorite	522
526*	....	....	Altered Diabase ...	521
527*	....	....	Hornblende-schist..	642
537*	....	....	Micaceous chlorite-schist	648
549*	....	....	Limonite	618
563*	....	....	Altered Diorite.....	629
688	....	....	Black Quartz-conglomerate	509
692*	189	....	Phyllite	654
715	115	....	Gray Quartz-conglomerate	509
716	116	....	Mottled Quartz-conglomerate....	509
717	117	....	Chlorite Quartz-conglomerate ...	509
718	118	145	Greenish Quartz-conglomerate ...	512, 594
719	118	....	Greenish Quartz-conglomerate ...	582
720	118	....	Greenish Quartz-conglomerate ...	582
721	118	....	Greenish Quartz-conglomerate ...	582
727	118	....	Greenish Quartz-conglomerate ...	582
729*	179	89	Micaceous Chlorite schist	647
732*	358	....	Micace's Quartzite	614
734*	151	....	Magnetic Quartz-schist	614
745*	320	....	Hornblende-rock..	641
795*	106	....	Coarse Red Dolomite	613
797*	108	....	Rosy Siliceous Dolomite	613
804	....	....	Clay-slate	514
805*	161	....	Clay-slate	514
807	....	....	Clay-slate	650
810	....	....	Clay-slate	514
814*	192	....	Clay-slate	650
817*	340	....	Calcareous Hornblende-schist....	645
820	....	....	Clay-slate ?	514
821*	331	121	Decomposed Diabase............	584, 626
825	330	....	Decomposed Diabase	518
827*	336	120	Decomposed Diabase............	584, 626
876*	321	....	Serpentine	618
883	157	....	Limonitic Quartz-schist	
834*	312	....	Diabase	625
887	352	99	Brown Wacke or compl'tly decomposed Diabase...	575

Brooks' Catalogue Nos., bracketed thus [ ].	Julien's Nos., Mich. Geol. Rep., Vol. II, 1873.	Nos. of Typical Suite, bracketed thus, ( ).	NAME.	Page.
888	....	....	Diorite	520
889*	345	122	Altered Quartz-diabase	585, 626
891*	149	....	Quartz-schist	664
893*	....	....	Limonite	618
906*	196	....	Quartzose Chlorite-schist	647
911*	351	83	Green Porphyry or Serpentine	570
912*	347	82	Diabase	625
913*	348	82	Diabase	625
931*	....	....	Micaceous Chlorite-schist	648
932*	. ..	....	Compact Chloritic Hornblende-schist	000
944*	298	....	Gneiss	631
982*	200	132	Feldspathic Chlorite-schist	588, 647
983*	221	....	Bluish-gray Clay-slate	650
984	101	97	Ferruginous Crystalline Limestone.	574
990	126	....	Grayish-white Quartzite.	509
996*	350	....	Diabase	627
998*	202	....	Clay slate	650
999	153	....	Magnetic Quartz-schist	506
1081*	226	....	Magnetic Talc-schist	648
1085*	122	....	Quartzose Mica-schist	635
1086	....	....	Hornblende-schist	000
1087*	267	....	Feldspathic Hornblende-schist	644
1088*	174	....	Actinolitic Quartz-schist	615
1089	271	88	Black Hornblende Schist	572
1091*	175	...	Eklogite	649
1099*	327	....	Feldspathic Hornblende-schist	644
1100*	338	....	Calcareous Mica-schist	000
1101*	203	....	Magnetic Mica-schist	635
1102*	204	104	Magnetic Mica-schist	577, 635
1103*	303	....	Feldspathic Hornblende Rock	644
1110*	354	94	Diabase	574, 625
1116*	178	....	Magnetic Actinolite-schist	640
1120	....	. ..	Mica Schist	517
1155*	178	....	Magnetic Actinolite-schist	640
1163*	....	....	Carbonaceous Clay Slate	654
1170*	....	107	Micaceous Augite-schist	578, 645
1174*	....	....	Quartzite	614
1196*	....	....	Jasper-schist	506, 615
1228	253	96	Ferruginous Granite	514
1247*	323	....	Serpentine	617
1249	209	91	Clay Slate	574
1250*	210	...	Chlorite-schist	640
1251	.....	....	Light-bro'n Quartzite	509
1252	257	90	Fine-grained, grayish black Gneiss or Mica-schist	573
1382*	....	....	Diabase	521

Brooks' Catalogue Nos., bracketed thus, [ ].	Julien's Nos., Mich. Geol. Rep., Vol. II, 1873.	Nos. of Typical Suite, bracketed thus, ( ).	NAME.	Page.
1409*	306	....	Syenite	621
1427*	307	....	Diabase	625
1428	325	98	Chloritic Diorite-Wacke	575
1436*	....	....	Siliceous Schist	616
1437	....	....	Lydianstone	510
1441*	....	...	Siliceous Schist	616
1447*	...	. . .	Sandstone	656
1485	166	84	Banded Jasper-schist	571
1486	167	84	Banded Jasper-schist	571
1487*	124	85	Hornstone-Breccia.	572, 656
1500*	158	....	Siliceous Schist	616
1501*	311	....	Diabase	625
1510*	169	....	Chert-schist	615
1526*	....	....	Phyllite	654
1528*	332	....	Hornblende-schist.	643
1558*	....	....	Diabase	532
1614*	....	....	Hornblende-schist.	643
1616*	....	....	Quartz Diabase	626
1617	....	.. .	Banded Argillaceous Slate	514
1621*	....	139	Sandstone	592, 655
1626*	....	143	Siliceous Dolomite.	613
1629*	....	....	Quartzite	614
1635*	....	....	Dolomite	613
1636*	....	....	Hornblende-schist.	641
1641*	....	102	Mica-gneiss	576, 630
1656*	....	....	Mica-gneiss	631
1659*	....	....	Diabase	625
1683*	....	....	Siliceous Schist	616
1713*	....	....	Decomposed Diorite	630
1715*	....	101	Granite	575, 619
1720*	314	116	Syenite	582, 620
1722*	....	....	Garnetiferous Quartzite	614
1726*	....	....	Diorite	630
1730*	....	....	Altered Diorite	630
1732*	....	148	Quartzose, Magnetic Hornblende-schist	592
1741*	....	....	Quartzose Magnetite-schist	617
1744*	....	141	Siliceous Limestone	612
1748	.. .	....	Gneiss	000
1749*	....	....	Granite (Aplite)	619
1752*	....	....	Hornblende Schist.	640
1757*	....	....	Diorite-gneiss	632
1761*	....	....	Feldspathic Hornblende-schist	642
1762*	....	....	Syenite-gneiss	632
2051*	91	....	Feldspathic Hornblende schist	643, 707
2052*	94	....	Chloritic or Hornblende schist	708
2053	95	....	Chloritic Schist	708
2054*	120	....	Talco-chloritic Slaty-schist	712
2055	120	...	Talco-chloritic Slaty-schist	712
2056	100	....	Chloritic Schist	709
2057*	51	....	Hornblende-schist	709
2058*	31	....	Mica-schist	634, 696
2059*	....	....	Decomposed Diabase	626
2061*	134	....	Calcareous Hornblende-schist	645, 714
2062*	85	....	Altered Diorite or Feldspathic Hornblende Rock	706
2063*	93	....	Chlorite schist	708

Brooks' Catalogue Nos., bracketed thus, [ ].	Julien's Nos., Mich. Geol. Rep., Vol. II, 1873.	Nos. of Typical Suite, bracketed thus, ( ).	Name.	Page.
2064*	130	....	Talcose schist.	713
2065	107	....	Ferruginous Chloritic Slaty-schist.	710
2066	146	....	Flag ore....	715
2067*	133	....	Clay-slate..........	650, 713
2068	2	....	Siliceous Marble...	692
2069*	84	....	Porphyritic Gneiss	631, 706
2070	82	....	Diorite Porphyry ..	706
2071*	135	....	Sericite-schist	636, 714
2072*	74	....	Diabase............	625, 704
2073	131	....	Talcose Schist.....	713
2074	8	....	Arenaceous Quartzose schist........	693
2075	121	111	Chloritic Slate or Phyllite..........	712
2076	141	....	Siliceous Magnetic Ore.............	715
2077*	127	112	Sericite-schist	586, 636, 713
2078*	99	....	Micaceous Chloritic Schist...........	709
2079*	86	....	Decomposed Diabase...........	627, 706
2080	147	....	Flag-ore...........	715
2081	10	....	Arenaceous Quartzose Schist......	693
2082*	132	....	Chlorite-schist	646, 713
2083	3	137	Quartzite	692
2084*	152	....	Granite	716
2085	4	...	Quartzite	692
2086	1	142	Granular Limestone	593, 611, 692
2087*	116	109	Magnetic Mica-schist....	579, 635, 711
2088	....	....	Quartzite	589
2089*	25	....	Hornblende schist.	644, 696
2090*	26	103	Feldspathic Mica-schist	576, 636, 696
2091*	27	133	Micaceous Chlorite-schist	584, 648, 696
2092*	114	....	Calcareous Chloritic-schist	711
2093*	6	138	Chloritic Quartzite	591, 692
2094*	119	....	Chlorite-schist.....	646, 711
2095	6	....	Chloritic Quartzite.	693
2097*	109	....	Chlorite-schist.....	646, 710
2098	....	....	Diorite Porphyry..	629
2100*	101	....	Chloritic Schist. ..	709
2101*	72	.. .	Altered Hornblende Rock	704
2102	102	....	Chloritic Schist....	709
2104*	81	....	Diorite	705
2105*	89	....	Porphyritic Hornblende-gneiss ...	632, 707
2106	105	....	Chloritic Schist....	709
2107	89	....	Hornblende-diorite.	707
2108	98	....	Chloritic Schist....	703
2109*	79	....	Diorite........... .	705
2110	103	....	Chloritic Schist....	709
2112*	80	....	Diorite.............	705
2113	78	....	Diorite.............	705
2114*	75	....	Diorite.............	704
2116	76	....	Diorite.............	705
2117	117	....	Talco-chloritic Schist	711
2118*	92	119	Chloritic Diorite or Chloritic Schist.	708
2119*	88	....	Hornblende-diorite.	707
2120*	52	...	Syenite-gneiss.....	632
2121	52	....	Hornblende-schist .	700
2122*	80	....	Altered Feldspathic Hornblende-schist	643, 705
2123	52	....	Hornblende-schist .	700
2124*	52	125	Hornblende-schist.	586, 641, 700
2125*	53	....	Chloritic Hornblende-schist.....	700
2126*	69	....	Feldspathic Hornblende-rock	473, 703
2127	69	....	Feldspathic Hornblende-rock	472, 703
2128	112	....	Quartzose Chloritic Schist...........	710
2129*	153	....	Granite	472, 717
2130*	70	....	Hornblende-rock...	703
2131*	71	....	Chloritic Hornblende-rock	704
2132*	24	....	Chlorite-schist ...	646, 697
2133*	87	....	Altered Diorite	707
2134*	149	....	Carbonaceous Clay-slate	654, 716
2135*	....	....	Calcareous Hornblende-schist	645
2136*	35	....	Amphibole-rock ...	697
2137	123	....	Chloritic Slate.....	712
2140*	125	....	Pyritiferous Chloritic Slate	712
2141	104	....	Chloritic Schist....	709
2142	118	....	Talco-chloritic Schist	711
2143	110	...	Arenaceous Chloritic schist	710
2144*	110	....	Arenaceous Chloritic Schist.......	710
2145*	21	....	Chloritic Mica-schist............	695
2146	21	....	Chloritic Mica-schist............	695
2147*	122	....	Clay Slate..........	650, 712
2148*	106	....	Chloritic Slaty-schist or Mica-schist............	709
2149*	90	....	Chloritic Hornblende Diorite....	707
2150*	90	....	Chloritic Hornblende Diorite....	707
2151	....	....	Quartzite..........	....
2152	148	....	Banded Ferruginous Schist	715
2153	151	115	Plumbaginous Schist	582, 716
2154	143	135	Hard Hematite.....	590, 715
2155*	36	....	Amphibole Rock or Diabase	697
2156	144	....	Hard Hematite.....	715
2157*	136	....	Chloro-argillaceous Slate	714
2158	7	....	Chloritic Quartzite	693
2159	19	....	Mica-schist.........	695
2160	22	....	Staurolitiferous mica-schist.......	695
2161	20	....	Mica-schist	695
2162*	11	....	Mica schist.........	635, 693
2163*	12	....	Mica-schist.	635, 693
2164	96	....	Chloritic schist ...	708
2165	96	....	Chloritic Slaty-schist	708
2166	....	....	Clay Slate...... ..	....
2167*	66	123	Hornblende-rock...	585, 703
2168	96	....	Chloritic Slaty-schist	708
2169*	151	....	Carbonaceous Clay-slate..............	654, 716

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