Geology of Wisconsin : Survey of 1873-1879. Volume IV 1882

Wisconsin. Chief Geologist
[Madison, Wisconsin]: Commissioners of Public Printing, 1882

GEOLOGY OF WISCONSIN.

FORWARD

1873–1879.

PLATE, III.

EROSION CLIFF ON THE MISSISSIPPI.
Near Trempealeau.

GEOLOGY

OF

WISCONSIN.

SURVEY OF 1873-1879.

VOLUME IV.

PART I. THE UPPER MISSISSIPPI REGION.
II. THE LOWER ST. CROIX REGION.
III. DESCRIPTION OF FOSSILS.
IV. ORE DEPOSITS OF SOUTHWESTERN WISCONSIN.
V. QUARTZITE OF BARRON AND CHIPPEWA COUNTIES.
VI. THE FLAMBEAU REGION.
VII. CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY.
VIII. SUPERFICIAL GEOLOGY OF THE UPPER WISCONSIN VALLEY
IX. CHARACTER AND METHODS OF THE GEODETIC SURVEY.

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.
1882.

David Atwood, Madison,
Stereotyper and Printer.

Seifert, Gügler & Co., Milwaukee,
Lithographers.

To His Excellency the Hon. J. M. Rusk,

Governor of Wisconsin:

Sir — It is with pleasure that I present herewith the fourth volume of the final report of the Geological Survey of Wisconsin.

Most respectfully,

Your obedient servant,

T. C. CHAMBERLIN,

Chief Geologist.

Beloit, June 5, 1882.

PREFACE.

IN the preface of the preceding volumes, sufficient explanation has been made of most matters requiring consideration in such connection. For reasons explained in the preface of Vol. III, and for others that have arisen since, the earlier portions of this volume have rested in type, awaiting the completion of the remainder, for a length of time much to be regretted. Consideration of this fact is due to the authors of Parts I, II and III.

The atlas accompanying this volume includes, besides those relating to its subject matter, the general maps that more properly belong with Vol. I, with which no atlas will be issued. They are here included for economy and convenience of distribution. The maps accompanying Vols. II, III and IV are intended to be combined to form a single atlas. If bound in folio, as planned, it will be reduced to a convenient size.

The leading contributors to the volume are the late Moses Strong, whose posthumous manuscript forms Part I; Prof. L. C. Wooster, who prepared Part II; Prof. R. P. Whitfield, who contributed the palæontology, forming Part III; Prof. F. H. King, who prepared Part VI; Prof. R. D. Irving, the author of Part VII; Dr. J. E. Davies, who gratuitously furnished Part IX, and the writer, who prepared Parts IV, V and VIII.

Besides these leading contributions, acknowledgments are due Prof. I. M. Buell, who rendered much valuable assistance in the work preliminary to the preparation of Part IV, in the distribution of specimens, the preparation of the index, and in other ways; to Mr. A. C. Clark, for field observations that form in part the basis of Parts VII and VIII; to Mr. J. Wilson, who prepared the crevice maps of the atlas; to Mr. C. R. Vanhise for microscopical work, elsewhere acknowledged; and to Mr. R. D. Salisbury for assistance in reading proof and preparing index.

Especial attention is called to the gratuitous contribution of Dr. Davies, which, though brief, represents work of much ultimate importance to the state. The prosecution of the geodetic survey in our state at this time and under its present efficient management, is due to the existence of the geological survey, and to the request of its first director, the late Dr. Lapham. With the relative cheapness of land that has prevailed in the past, our people have been, naturally enough, comparatively indifferent with regard to exact surveys; but with the growing appreciation of real estate, the precise determination of salient points, which may be made the basis of an exact system of land surveys, will come to have a value, not now, perhaps, adequately realized.

T. C. C.

BELOIT, June 6, 1882

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BY T. C. CHAMBERLIN.

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PART I.

GEOLOGY

OF THE

MISSISSIPPI REGION

NORTH OF THE WISCONSIN RIVER.

BY MOSES STRONG.

INTRODUCTION.

The following report comprises the results of the examinations of the geological survey which were made by me during the years 1873–74–75–76, in the western part of the state, north of the Wisconsin river, the portion to the south having been already reported upon. Before entering on the geological portion of the report, I wish to present a brief synopsis of the examinations of the several years, and of the conditions under which they were made.

Examinations of 1873. Acting under the instructions of the late Dr. I. A. Lapham, then chief geologist, towns 9, 10, 11, 12 and 13, of ranges 2 and 3 east, were examined. They comprise the eastern range of Richland county and the western range of Sauk county. Only a short time was devoted to this territory, as the greater part of the season was consumed by the examination of the country south of the Wisconsin river.

Examinations of 1874. In the summer of 1874, under the same instructions, a short time was devoted to range 2 west, extending from the Wisconsin river, in town 9, to the north line of town 22; including a large portion of the valley of the Kickapoo river, and forming a total of fourteen townships.

Examinations of 1875. The examinations of this year were conducted under the instructions of Dr. O. W. Wight, chief geologist during the year, and comprised the following territory: That part of Richland county which is contained in ranges one east and one west; the counties of Vernon, Monroe, La Crosse and Trempealeau, as far as the north line of town 20. This includes the country which is bounded by the Mississippi and Wisconsin rivers, the east line of range one east, and the north line of town 19. The area is equal to sixty one townships, or two thousand nine hundred and sixteen square miles.

The part of Richland county described was first examined and completed. The survey then passed into Crawford county and made all necessary examinations there. Ranges three and four west in Vernon county were then finished, and the survey crossed back to the fourth principal meridian. Ranges one east and one west in Vernon and Monroe counties were then completed; and the survey next proceeded to finish Monroe county, by examining ranges three and four west. The corps then proceeded to the south part of Vernon county not yet examined, and worked northward, completing Vernon county, then La Crosse, and finally that part of Trempealeau county previously described.

The field examinations were commenced on the first of May and continued during the summer and fall. As the country is in many places rather sparsely inhabited, it was found most convenient to travel with a camping outfit, examining the country on horseback and returning to camp at night, making an average daily ride of about twenty-five miles. In this manner we were enabled to reach all parts of the country, many places being inaccessible to any four-wheeled conveyance. The camp usually remained in each place about a week, and was then moved in whatever direction the progress of the work required.

Examinations of 1876. The examinations of this year, under the direction of the present chief geologist, consisted of two periods, of which the first was devoted to the sedimentary formations in the vicinity of the Mississippi river, embracing a tract of about twenty-five townships, situated in Buffalo, Pepin and Pierce counties, extending along the river from Trempealeau to Prescott, forming an area about 80 miles in length and from 10 to 15 in width.

The second period was passed in the examination of the country underlaid by the copper series, of which a description is given in a preceding volume.

The following table includes all the territory in the western part of the state described in Part I of this report, and refers only to paleozoic formations:

Range	1	East,	Towns	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19.
"	2	"	"	8, 9, 10, 11, 12, 13.
"	3	"	"	8, 9, 10, 11, 12, 13.
"	1	West,	"	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19.
"	2	"	"	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19.
"	3	"	"	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19.
"	4	"	"	7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19.
"	5	"	"	7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18.
"	6	"	"	6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18.

Range	7	West,	Town	11, 12, 13, 14, 15, 16, 17, 18, 19, 20.
"	8	"	"	16, 17, 18, 19, 20.
"	9	"	"	17, 18, 19, 20.
"	10	"	"	19, 20, 21, 22.
"	11	"	"	19, 20, 21, 22, 23.
"	12	"	"	20, 21, 22, 23, 24.
"	13	"	"	21, 22, 23.
"	14	"	"	22, 23, 24, 25.
"	15	"	"	23, 24, 25.
"	16	"	"	23, 24, 25.
"	17	"	"	24, 25, 26.
"	18	"	"	24, 25, 26.
"	19	"	"	25, 26, 27.
"	20	"	"	26, 27.

The entire area above described comprises about 140 townships, or 5,040 square miles.

Character of the examinations. The examinations of the several years were conducted with as much minuteness as could be expected with reference to the great extent of territory to be explored, of which there is hardly a square mile that has not been examined in some locality. The territory explored during the several years is especially favorable to geological examination, on account of the almost entire absence of glacial drift. The denudation of the country has presented numerous exposures of all the formations, and made the study of their stratigraphical relations a comparatively easy task; and by taking advantage of these conditions, the contour lines of the several formations have been traced out over the entire district, and delineated with much accuracy.

Barometrical observations. The elevations obtained from these observations were very unsatisfactory for two reasons: First, the points of known elevation were so far apart, that in the time consumed in traveling from one to the other (seldom less than a day, and often more), irregular atmospheric changes would take place, so great as to render worthless nearly all intermediate observations. Second, the weather during the greater part of the seasons has been so variable as to make all observations of little value; the fluctuation of the barometer in a couple of hours frequently corresponding to a difference of a hundred feet in elevation. Elevations might have been obtained by the cotemporaneous observation of persons situated at different points; this, however, would have consumed much time, and occupied the corps to the exclusion of other duties, which the value of the elevations did not seem to warrant. The barometer was, therefore, chiefly employed to determine the dip and thickness of the strata, and to assist in making geological sections.

GEOLOGY OF THE MISSISSIPPI REGION.

CHAPTER I.

PHYSICAL GEOGRAPHY AND SURFACE GEOLOGY.

In this chapter it is designed to describe briefly the principal characteristics of each township, with reference to the general features of the country, its watersheds, streams, springs, prairie, forest, soils and subsoils, clays, underlying formations, agricultural products and population. It is believed that in this manner a much clearer and more correct knowledge can be obtained of the character of the country, than from any general remarks on the entire territory. Each range will also be considered separately, beginning at the south and proceeding north. Area maps H and I, of the geological atlas, should also be referred to.

RANGE ONE EAST.

Town 9, Orion. The town is very hilly and rough except in the northern and eastern part, in the valleys of Ash creek and Pine river; well watered, containing numerous fine springs; large white oak timber upon the ridges. Soil often clay, quite sandy in the valleys and clay upon the ridges, producing good crops of winter wheat. The underlying formations are Potsdam sandstone and Lower Magnesian limestone. Of these, the Potsdam covers about two-thirds of the township. The principal village is Orion. The population is 733.[1]

Town 10, Richland. The greater part of this township lies in the valley of Pine river, and is therefore comparatively level, except in the northeast part. It is well watered and timbered. In some parts of the valley the soil is sandy, in other parts clay, according as it has been derived from the Potsdam, or is the remains of the denudation of the more recent formations. The formations are Potsdam sand-

[1] Census of 1880.

stone and Lower Magnesian limestone; the latter covering an area of only about one-sixth of the township. The principal village is Richland Center. The population is 2,048.

Town 11, Rockbridge. Pine river passes through the center of this township from north to south. It is very well watered by numerous small streams, among which are Fancy creek, West Fork of Pine river, Scott's branch and Buck creek. It is heavily timbered throughout with oak, elm, maple, basswood, and some small pine in the valley. The land is very hilly, and the ridges are very high above the main valley. The soil is chiefly clay, not very sandy. The formations are the same as in town 10. The Potsdam covers about two-thirds of the township. The principal village is Rockbridge. The population is 1,200.

Town 12, Henrietta. This township is very well watered by Pine river, Melancthon, Soule's and Hawkins creeks, and by great numbers of fine, large springs issuing from the sandstone. It is very hilly and heavily timbered. The formations are Potsdam sandstone and Lower Magnesian limestone, of which the former covers rather more than half the township. There are no villages. The population numbers 1,005.

Town 13, Greenwood. The watershed or dividing ridge between Pine river and the Baraboo passes through the township in a northwesterly direction from sections 36 to 18. This causes considerable high, rolling land. The remainder of the town is very hilly and rough. It is heavily timbered with maple, elm and basswood. The soil is a clay loam and produces good crops of winter wheat and other cereals. The formations are Potsdam and Lower Magnesian; the former occupying two-thirds of the township. A small one of St. Peter's sandstone exists in the north half of section 21. There are no villages. Population 1,050.

Town 14, Hillsboro. The town is well watered by numerous branches of the Baraboo river, and contains many fine springs. The country is rolling, but the hills are not so high or so steep as in the previous towns, and the valleys are quite wide. The country is well settled. The timber is chiefly white oak, and confined to the ridges. The formations are Potsdam and Lower Magnesian; the latter is found only on high ridges, and its area does not exceed one-seventh of the whole. The principal village is Hillsboro. Population 1,218.

The following is a general section, showing the structure of the country in this and adjoining towns. It is taken at the tunnel of the Chicago and Northwestern Railway, near the corner of towns 14 and 15, ranges 1 E. and 1 W:

	Feet.
Lower Magnesian limestone on the top of the ridge	100
Yellow and white sandstones	60
Dolomitic and arenaceous shales	20
Blue sandstone, composed of sand, lime and clay in varying parts; very hard when fresh, but softening on exposure	10
Green sand	2
Hard and compact yellow and white sandstone to the bottom of the valleys	250
From ridge to valley	442

Town 15, Glendale. Watered by the small streams which form the north and south forks of the Baraboo. The ridges are high and rolling, and usually timbered with white oak; soil clay. The valleys are wide and frequently contain a soft, black, swampy soil, and are in other parts sandy. The township is sparsely settled. The formation is almost exclusively Potsdam; there is a small area of Lower Magnesian in the western part and on the ridge dividing the forks of the Baraboo, amounting to about four square miles. The principal villages are Glendale and Kendall. Population 1,401.

Town 16, Clifton. There is a high and narrow dividing ridge in this township, extending from section 6 south to section 30, and thence east to section 36. The remainder of the country is hilly and broken, sloping to the stream. The timber consists chiefly of scattering groves of oak; and the country greatly resembles the southern part of the state. The soil is clay, somewhat mixed with sand; and the township is cultivated only in the valleys. The formations are Potsdam and Lower Magnesian; the latter being confined to a narrow strip along the dividing ridge. Population 884.

Town 17, Byron. The township has considerable high ridge land in the southern part, but in the central and northern parts it is low and swampy, with occasional isolated hills of sandstone 150 feet high. It contains considerable hay meadow. There are but very few inhabitants in the northern part of the town. The soil in the southern part is clay, the timber white oak. This township lies entirely in the Potsdam sandstone. The only village is Leroy. Population 415.

Town 18, La Grange (in part). There are no hills or ridges in the township. The country consists of tamarack swamps, cranberry marshes, hay meadows, and sandy, barren, pine flats. It is drained by the north fork of the Lemonweir, and is devoid of roads and inhabitants. The geological formation is Potsdam.

Town 19, New Lynne. The description of town 18 will apply equally well to this township. It is chiefly valuable for cranberry marshes. Some fine timber is also obtained here. Population 140.

RANGE TWO EAST.

Town 9, Buena Vista. The greater part of the township is comprised in the valleys of Pine river and Bear creek; consequently it is situated chiefly in the Potsdam. The Lower Magnesian is only found capping the hills and forming the ridges. Population, 1,075.

Town 10, Ithaca. In this township the Potsdam occupies the valleys of the streams, even to their sources, but not covering more than one-third of the surface area. The summits of the ridges attain an average elevation of 500 feet above Lake Michigan. The township is well watered by numerous small streams and springs. Population, 1,110.

Town 11, Willow. This township is in general heavily timbered and well watered, containing much good agricultural land. The Potsdam is confined to the valley of Willow creek and its small tributaries, forming about one-fourth of the surface rock of the township. The strata do not rise from the Wisconsin river northward as rapidly as the streams, consequently in town 11 the Lower Magnesian limestone becomes the formation of the greater part of the country, and it is here that the head waters of most of the streams are found. Population, 901.

Town 12, Westford. The ridge which divides the waters flowing into the Baraboo river from those of the Wisconsin passes through this township from section 36 to section 18. The country is heavily timbered, and well watered except on the ridges. The Potsdam sandstone covers about half of the township, in the northern and eastern portions, and the Lower Magnesian the remainder. Population, 1,002.

Town 13, Woodland. This town is quite hilly and heavily timbered. It is well watered in the south by the west branch of the Little Baraboo, and in the north by Plum creek. The geological formation is Potsdam. Population, 1,368.

RANGE THREE EAST.

Town 8, Spring Green (in part). The part of this town lying north of the Wisconsin river comprises about 12 sections of flat, sandy land. The soil is poor and the formation is Potsdam.

Town 9, Bear Creek. All except the southern part is rolling and hilly land, well watered with numerous fine springs, and heavily timbered with hard wood. The settlements are chiefly confined to the valleys. The formations are Potsdam and Lower Magnesian in nearly equal parts. Population of Bear Creek, 808.

Town 10, Bear Creek. The ridge dividing Bear creek from Honey creek passes through the town from sections 3 to 34. Its general elevation being about 550 feet above Lake Michigan. The town is heavily timbered, and well watered by the tributaries of Bear creek. The soil is generally very good. Formations, Potsdam and Lower Magnesian.

Town 11, Washington. This town consists of very hilly ridge land, heavily timbered and well watered. The geological formation is Lower Magnesian, except in the valleys of the streams. The soil is clay. Population, 1,175.

Town 12, Ironton. The southern and central parts of the town consist of high ridge land, much broken by ravines, heavily timbered and well watered. In the northern part of the town the land is not so high. The northern outcrop of the Lower Magnesian crosses this town in a very irregular line. This formation covers about half of the town, and the Potsdam the remainder. Population, 1,310.

Town 13, Lavalle. This town is well watered by the Baraboo river and its tributaries, and contains a great deal of valley land. The soil is generally good, but sometimes quite sandy. The formation is Potsdam, with the exception of a small outlier of Lower Magnesian in sections 29 and 32. The principal town is Lavalle. Population 1,364.

RANGE ONE WEST.

Town 9, Eagle. The streams in this township are the Wisconsin river and Eagle river. The country is quite level in the valleys, but rolling and hilly in the western, northern and northwestern parts. The country is well watered, and heavily timbered with elm, maple and basswood, both on the ridges and in the valleys. The soil is clay, and, in the valleys, nearly all under cultivation. The formations are Potsdam and Lower Magnesian; the former covering about two-thirds of the surface. There are no villages. Population 1,303.

Town 10, Dayton. The ridge dividing the Eagle and Pine rivers passes through the township from north to south, and about a mile east of the center. This gives rise to much high rolling ridge land with clay soil, which is nearly all farmed. The township is well timbered, with large trees, chiefly elm and maple. The geological formations are Potsdam, Lower Magnesian and St. Peters. The first occupies about one-third, the second somewhat less than two-thirds, and the St. Peters sandstone the remainder. The St. Peters occupies isolated areas upon the top of the dividing ridge, often of considerable extent; when not in place, fragments of it are often seen scattered about on the high points; it often forms quite conspicuous mounds. The only village is Boaz. Population of the township, 1,109.

Town 11, Marshall. This town is similar in its general features, soil, timber, hills and streams, to town 10. The dividing ridge between Eagle river and Fancy creek runs in a northwesterly course from section 34 to section 6, and is a fine farming country. The valleys of Fancy creek, west branch of Pine river, and, in fact, of all the streams in this section of the country, are wide in proportion to the size of the streams. Large and beautiful springs are very numerous. The bottoms afford fine farms, and have a rich, black clay loam soil, in some places slightly sandy, but usually largely composed of vegetable mould with a subsoil of sand. The farms on the ridges are more stony, but raise better crops of wheat; they are however, lacking in water. The formations are Potsdam, Lower Magnesian and St. Peters. The latter is found in large isolated areas on the highest parts of the dividing ridge. The population is 989.

Town 12, Bloom. The principal stream is the west branch of Pine river and its tributaries. On the west side of the town lies the dividing ridge between Pine river and the Kickapoo. The country is similar to that of towns 10 and 11. The formations are also the same. The St. Peters is confined to two large outliers on the west side of the town. The villages are Springvale and Woodstock. Population, 1,358.

Town 13, Union. The divide between the Kickapoo and Pine river runs irregularly through the town in a southwest direction, from section 2 to section 32. It is generally narrow, and much cut up with ravines. The soil is clay, with a subsoil of stiff, red clay containing many flints, and often eight or ten feet deep. The valleys are wide, and settled largely by Bohemians. The soil is sometimes sandy and sometimes a black and swampy clay. The township is very heavily timbered with maple, elm and basswood. Good springs are numerous; a very large one was seen on the southwest quarter of section 2. The formations are Potsdam and Lower Magnesian; the area of each is about equal. There are no villages. The population is 741.

Town 14, Forest. The divide between the Kickapoo and Pine river runs nearly north and south from section 35 to section 1. It is much wider and better adapted for farming than in town 13, and is about all under cultivation, producing heavy crops of wheat and oats. The principal streams are Warner and Billings creeks. Their valleys are often half a mile wide, with a rich, black soil, and are occupied by settlers from Bohemia and Ohio. They are heavily timbered, chiefly with maple. The Potsdam sandstone covers about one-third of the country, and the Lower Magnesian the rest. The only village is Mt Tabor. Population of the town, 889.

Town 15, Wellington. The divide before mentioned continues from section 36 to section 1. The ridges are very high and narrow. The timber now changes to large white oaks, and is not nearly so dense as in town 14, and but little elm, maple, etc., is seen. The valleys are narrow and often contain considerable pine timber. The soil is a sandy clay. The Lower Magnesian covers about one-third of the township, and the Potsdam the remainder. Numerous very hard and ferruginous blocks of sandstone were seen lying loose upon the ridges, which were derived from the remains of the St. Peters. Population 1,050.

Town 16, Wilton. The divide between the Kickapoo and the streams running into the Lemonweir passes in an east and west course from section one to section 7. It is a very high rolling ridge, from one-half to a mile or more in width; fine clay soil and well cultivated. The town is watered by the various branches of the Kickapoo, and has many fine springs. The valleys are from one-half to three-quarters of a mile wide, and well settled. The soil is a sandy clay, derived from the shaly layers of the Potsdam. The timber in this township is rather sparse, and consists of oak groves. The Potsdam covers about two-thirds of the township and the Lower Magnesian the remainder. The villages are Wilton and Dorset. Population, 1,099.

Town 17, Tomah. The general slope of this town is from south to north. The timber is mostly confined to the ridges, and consists of small groves of white and black oak. Considerable small, yellow pine grows in the northwestern part. The Potsdam covers the whole of the township, with the exception of a few small spurs of Lower Magnesian in the southern part. The principal village is Tomah. Population, 2,106.

Town 18, Lagrange (in part). About two-thirds of this township consists of tamarack swamp, cranberry marsh, and hay meadow. In the south and west parts there is some farming land with a clay soil and small timber, chiefly oak. The swamps are drained by small, sluggish streams which flow into the Lemonweir. Formation, Potsdam. Population, 839. There are no villages.

Town 19, Lincoln (in part). There are a few sandy ridges in sections 17, 18, 19, 20 and 29, covered with small, scattering oak; the rest of the town consists of tamarack swamps. Formation, Potsdam sandstone.

RANGE TWO WEST.

Town 9, Richwood. This township is very hilly; the ridge dividing Knapp creek and Eagle river runs north and south through the center of the town, and slopes off abruptly on the south to the alluvial bottoms of the Wisconsin river. The principal streams are Bird and Knapp creeks, by which the town is well watered. The timber is very dense, consisting chiefly of maple, elm and basswood; soil, clay. The formations are Potsdam and Lower Magnesian in about equal parts. The principal villages are Port Andrew and Excelsior. Population, 1,515.

Town 10, Akan. The divide between Knapp creek and Eagle river runs from section 35 to section 4. It is quite wide and rolling, and well cultivated. The soil, timber and water are similar to town nine. The formations are Potsdam, Lower Magnesian and St. Peters; the first covering one-third, the second nearly two-thirds, and the St. Peters is found in two isolated areas comprising about 800 acres. There are no villages. Population, 841.

Town 11, Sylvan. The general features of this town are high, rolling ridges which slope in all directions, to the Kickapoo, Knapp creek, and Eagle river. The ridges are very wide, heavily timbered, soil, clay and well cultivated; raising large crops of winter wheat and other cereals. The Lower Magnesian limestone covers about three-fourths of the township; the Potsdam is found in the valleys; and there are five quite large areas of St. Peters on the highest parts of the ridges. Population, 1,035.

Town 12, Forest. This town is watered by the Kickapoo and Camp creek, and contains numerous fine springs. It is very hilly and has many precipitous cliffs. In other respects it closely resembles town 11. The only village is Viola. Population, 889.

Town 13, Stark. Very rough, hilly, and heavily timbered. Watered by the Kickapoo, Otter, Bear, Jug and Weister creeks and their tributaries. The settlements are mostly confined to the valleys. The Potsdam covers about two-thirds, and the Lower Magnesian one-third of the township. There is one village, Seeleyburg. Population of the township, 954.

Town 14, Whitestown. The principal stream is the Kickapoo, which in this township is but little settled. The best land is on the ridges on the western side of the township. The soil is clay, somewhat sandy in the valleys. The timber is maple, elm and basswood, with occasional white oak groves on the ridges. The formations are the same as those of town 13. The villages are Ontario and Rockton. Population, 830.

Town 15, Sheldon. This township is rolling and hilly, but the hills are neither so steep nor so high as in the towns 13 and 14. It is well watered by branches of the Kickapoo. The timber is much smaller and more scattering than in town 14, and groves of oak timber are more frequent. The township is sparsely settled. The geological formations are the same as in town 13. There are no villages. The population numbers 794.

Town 16, Ridgeville. The dividing ridge between the Kickapoo and Lemonweir crosses the northern part of the town, from section 7 to section 1. It is high, wide, and well timbered with white oak, and nearly all under cultivation. It is well watered by the various small branches of the Kickapoo. The Potsdam covers about one-third of township, and the lower Magnesian the rest. The population is 1,286.

Town 17, Adrian. A high, narrow, and broken dividing ridge between the La Crosse and Lemonweir rivers, traverses this township irregularly from section 35 to section 2. The southern and eastern parts of the town are quite hilly; the northern and western level, and often swampy, frequently containing large tracts of small burnt pines. The soil is very sandy, and the country sparsely settled. The formation is Potsdam, with the exception of three small outliers of limestone. Population, 715.

Town 18, Greenfield. The divide mentioned in town 17, crosses this town from section 35 to section 2. The rest of the town is comparatively level, soil very sandy, timber black oak and small pine. The formation is Potsdam, with the exception of one small outlier of Lower Magnesian. The only village is Tunnel City. Population, 586.

Town 19, Lincoln (in part). The divide mentioned in towns 17 and 18 runs out in this town in a few low, sandy hills which form a range in the southern and central parts of the township. The rest of the town consists of pine barrens and tamarack swamps. The soil is very sandy, the timber small and scattering, and but few inhabitants. The formation is Potsdam. Population, 775.

RANGE THREE WEST.

Town 8, Marietta. Very hilly and rough land. The hills are high, steep, and covered with heavy timber of maple, elm, oak, and basswood. The soil is sandy clay. Formations are Potsdam, Lower Magnesian, and St. Peters sandstone. Population, 1,037.

Town 9, Scott. The divide between Knapp creek and the Kickapoo passes irregularly through the town from section 31 to section 5. The ridge is in some places quite wide, and contains some good farming land. The town is well watered by numerous streams flowing from its centre in all directions. The timber is very large and dense. The Potsdam covers one-third of the township, including all the valleys, and the Lower Magnesian, the rest, excepting a narrow belt of St. Peters along the divide. Population, 1,046.

Town 10, Clayton. The divide mentioned in town 9 continues through town 10 from section 32 to section 3, with numerous lateral spurs and ridges. The town consists chiefly of high, rolling, ridge land with numerous ravines running down to the streams. The soil is clay, and the timber very dense and large, with but little underbrush; the principal trees are maple and elm. Along the crest of the divide in sections 3, 9, 16, 20, are some very conspicuous mounds formed by outliers of St. Peters sandstone. Sink holes are also of frequent occurrence. Water is obtained with difficulty on the ridges. In places wells are sunk from 100 to 165 feet. The formations are the same as in town 9. Population, 1,976.

Town 11, Kickapoo (in part). The eastern and central parts of the town consist of high, wide, rolling ridges; and the western part of steep, rocky bluffs. The town is watered by the Kickapoo on the west and north. Fine springs are very numerous. The valley of the Kickapoo averages about a mile in width. The soil throughout the township is clay, and the timber very heavy. This township is quite thickly populated, and is a good agricultural country. The Potsdam covers about one-third of the town, the Lower Magnesian one-half, and the St. Peters one-sixth. Many loose bowlders of St. Peters are found on the ridges where the formation cannot be found in place. The principal villages are Readstown and Kickapoo Center. Population 1,233. The general section of the formation in this town, from the ridge to the Kickapoo is as follows:

	Feet.
St. Peters sandstone	50
Lower Magnesian limestone	150
Potsdam sandstone	300
From ridge to valley, total	500

Town 12, Liberty. This town is very hilly, being cut up by the Kickapoo, west fork of the Kickapoo, and the Harrison and Bishop branches. The intervening ridges are very high and steep. Settlements are chiefly confined to the valleys. The west fork of the Kickapoo forms a dividing line as regards the timber. On the east side of the stream the timber is very dense, consisting of maple, elm and basswood; but in the country on the west side the timber is thin and small, and consists chiefly of oak groves on the ridges. It is a very striking feature of the country. The formations are Potsdam and Lower Magnesian, and about equally divided. Population, 543.

Town 13, Webster. The general features of this town are similar to those of town 12. It is well timbered and watered. Clay beds are frequently met with in the valleys in the Potsdam, on the surface of which the water comes out in springs for long distances. There is a great deal of handsome scenery on the west fork of the Kickapoo. The formations are the same as in town 12. The principal village is Avalanche. The population of the town is 1,060.

Town 14, Clinton. The ridge dividing the Kickapoo from the west fork runs from section 34 to section 3, making considerable good farming land in the center of the township; in other parts, the land is very broken, with steep hills and deep ravines. The soil is clay, and the timber heavy. The formations are Potsdam and Lower Magnesian in nearly equal parts. Population, 1,008.

Town 15, Jefferson. The ridge dividing the Kickapoo from its streams which run into the La Crosse river crosses the town from section 30 to section 1, in a northeast course. It is wide and rolling, and the best part of the township. The soil on the ridge is clay, but in the valleys it is often quite sandy. The timber is small and scattering, and consists chiefly of oak. The Potsdam covers about one-third of the town, and the Lower Magnesian the remainder. Population, 1,087.

Town 16, Wells. The divide mentioned in town 15 continues on the east side of this town, and together with a smaller ridge running from section 24 to section 6, forms the principal highland. These ridges have a clay soil, and are wide and well settled. The principal stream is in the Leon valley, which is from one-half to a mile and a half wide, with a sandy soil and a large population. The timber consists of small and scattering oak. The Lower Magnesian covers about one-sixth of the town, and the Potsdam sandstone the rest. Numerous blocks of sandstone are found on the highest parts of the ridges, which are probably the remains of the St. Peters. Population, 658.

Town 17, Angelo. The general features of the town are low sandy ridges, small streams and very wide valleys. The principal streams are the La Crosse river and the Leon. The valley of the Leon is one and one-half miles wide, sandy soil, timbered with small pines and black oak. The valley of the La Crosse is similar to the Leon, but rather wider. The soil upon the ridges contains more clay, and supports a heavier growth of timber. The township is well settled in the valleys. Formation, Potsdam sandstone. Population, 469.

Town 18, La Fayette. The central and southwestern parts of the town consist of low, sandy ridges, forming a divide between the La Crosse and Black rivers. The timber on them is small oak. The eastern and northwestern parts of the town are low and swampy, containing pine barrens and tamarack. A fine waterfall was seen on the southwest ¼ of section 23. The water of a small creek falls over a slanting ledge of sandstone, about ten feet high; it would make a fine water power. Formation, Potsdam.

Town 19, La Fayette. The character of this town is similar to the preceding one. Sections 1, 2, 3, 4, 5, 10, 11, 12, 13, 14, 18, 19, 21, 25, 26, 29, 30, 35, 36 and some parts of other sections, are flat, dry, pine barrens, with a very sandy soil, and no inhabitants. The rest of the township consists of low hills and ridges, rising about 200 feet above the streams. They support a small growth of black oak, and the soil is better that in the valleys. The township is thinly inhabited. Formation, Potsdam. Population 402.

RANGE FOUR WEST.

Town 7, Union (in part). The part of this town which lies north of the Wisconsin river consists almost exclusively of the alluvial bottoms of that river and the Kickapoo. It is densely timbered with elm, maple, basswood, butternut, etc., with a deep, black, swampy soil. The hills which inclose the rivers are found along the north line of the town. The formations are Potsdam and Lower Magnesian.

Town 8, Union. There is a high ridge running in a northeasterly course through the town, from which the ground slopes to the Kickapoo and Wisconsin rivers. The country is very hilly, the ridges narrow and broken by deep ravines. The soil is clay, and the timber very large and dense. The town is well watered by the Kickapoo and its several branches. There are a great many large springs in the valley of the Kickapoo. The Potsdam covers about one-sixth of the town, the Lower Magnesian two-thirds, and the St. Peters sandstone and Trenton limestone one-sixth.

The general section of this town taken from the ridge to the Kickapoo is:

	Feet.
Trenton limestone	30
St. Peters sandstone	100
Lower Magnesian limestone	180
Potsdam sandstone	170
Total from ridge to valley	480

Town 9, Haney. A large part of the town is occupied by the valley of the Kickapoo, which is from one-half to a mile wide. The stream is about 200 feet wide, very crooked and sluggish. On each side of the river the country is very hilly and thinly inhabited. The valley of the Kickapoo and the country to the east of it has the heavy timber, maple, elm, etc.; but west of the valley the hills are smooth and bare, many of them showing terraces of the Potsdam, and the timber is white oak in groves on the tops of the ridges. The formations are, Potsdam one-third, Lower Magnesian two-thirds, and some ridges and mounds of St. Peters on the eastern side. Population, 636.

Town 10, Utica (in part). The general features of this town are similar to those of town 9. The valley of the Kickapoo is wider, more sandy, and less heavily timbered. Fine springs are very numerous. Formations: Potsdam and Lower Magnesian in about equal parts.

Town 11, Franklin (in part). This town is composed chiefly of high, rolling, ridge land, with a clay soil, and mostly under cultivation. In the central part of the town the soil is rather sandy, owing to a long belt of St. Peters which crosses the town from section 4 to section 34. The timber consists of groves of large white oak. The formations are, Potsdam one-sixth, Lower Magnesian two-thirds, and St. Peters sandstone one-sixth.

Town 12, Franklin (in part). The divide between the Kickapoo and the Mississippi passes through the town from section 30 to section 5. The land is high and rolling, and covered with groves of small timber, chiefly black and white oak. It is well watered by numerous small streams, and is fine farming land. The soil is a sandy clay, and mostly under cultivation. There are numerous mounds of St. Peters on the ridges. Small sink holes are also quite frequent. Formations: St. Peters and Lower Magnesian in nearly equal parts. Population, 1,319.

Town 13, Viroqua. The divide continues from section 32 to section 5. The greater part of the town is a high, rolling prairie, well watered by numerous small streams and springs. The soil is clay, and produces heavy crops. The timber is rather thin and small, consisting chiefly of black oak. The country resembles that of the Lead region. The formations are the same as in town 12. The principal town is Viroqua. Population of the township, 2,368.

Town 14, Christiana. The topographical features of this town greatly resemble those of town 13. The divide continues from section 35 to section 1, and is very high, wide and level. The soil is a deep clay owing to the absence of any sandstone formation. The timber is a small second growth of black oak, and is chiefly confined to the ravines. It is very difficult to obtain water on the ridge, as it lies from fifty to one hundred and fifty feet deep. The formation is chiefly Lower Magnesian. The principal towns are Bloomingdale and Coon Prairie. The population numbers 1,305.

Town 15, Portland. The ridge which divides the waters of the La Crosse from Raccoon creek runs in a northwest course from section 36 to section 6. There is a great deal of rolling and hilly ridge land, which is settled mostly by Norwegians. The soil is clay, and the timber chiefly small, brushy oak, with occasional groves of large white oak. The ridge land is destitute of water; but the rest of the town is well watered by small streams. The timber in the valleys is much larger and heavier, and consists of oak, elm and maple. The Lower Magnesian covers two-thirds of the town, and the Potsdam the remainder. Loose blocks of sandstone of frequent occurrence on the ridges. Population, 1,056.

Town 16, Leon. The valley of the Leon and its branches occupies the eastern half of the town. The valleys are about a mile wide, and all under cultivation. The soil in the northern half of the town is very sandy, but less so in the southern and western parts, where there is a good mixture of clay. In the southern and western parts there are some high limestone ridges, with a scanty growth of burr oak. The timber in the northern and eastern parts consists of small black and burr oak. The formation is chiefly Potsdam. Population, 748.

Town 17, Sparta. The greater part of the town lies in the valley of the La Crosse river, and is very flat and level. The ridge land is very hilly and broken, and is contained in sections 3, 4, 5, 8, 9, 10, 15, 17, and is covered with large white oak. North of the La Crosse river, the soil contains considerable clay, and there are many fine farms. South of the La Crosse river the soil is very sandy, but under cultivation. The sand in these valleys is often as much as thirty feet deep, before coming to the hard sandstone; this is seen in digging wells. Formation, Potsdam. The principal town is Sparta. Population of the township, 3,457.

Town 18, Oakdale. The divide between the La Crosse and Black rivers passes through this town from east to west. It consists of very high and narrow ridges timbered with oak, and uninhabited. The town is well watered in the southern part, and nearly all cultivated. The soil is clay, and affords many fine farms. This is also true of the eastern tier of sections. The north part of the town consists chiefly of sand barrens and swamps, and is very poor land. Formation, Potsdam, with the exception of one small outlier of Lower Magnesian in section 28, which furnishes the town with lime. Population, 733.

Town 19, Little Falls. The only good farming land in this township is situated in the following sections: 1, 2, 4, 5, 6, 8, 9, 11, 12, 13, 14, 19, 20, 21, 22, 23, 28, 29, 32, 33, and it is only about half of these that are available for agricultural purposes. The soil in these parts is a sandy loam, but in the rest of the town it is very sandy. The lowlands about the streams are covered with small pines and tamarack; the hilly land in the central and western parts of the town, with white, black and burr oak. The only village is Cataract. Population, 706.

RANGE FIVE WEST.

Town 7, Wauzeka. This is a very hilly township. It is watered by the Wisconsin river, Grand Gris and Little Kickapoo. The valleys and sides of the ravines are heavily timbered with elm, maple, basswood, butternut, etc. There are two very high and wide ridges in the northern and northwestern parts of the town, where the soil is clay, rather shallow, and the timber smaller and more scattering. The township is rather thinly inhabited. All the formations, from the Potsdam to the Galena limestone, inclusive, are represented. The principal town is Wauzeka. Population 1,055.

Town 8, Eastman (in part.) The high ridge which divides the Kickapoo and Mississippi rivers passes through the west side of the town. From it the country slopes to the east in wide, regular ridges, and deep, narrow ravines. The soil throughout the town is clay. The timber is small, and consists of groves of small black oak. Much of the country is prairie, and devoid of timber. The town is inhabited largely by Norwegians. The geological formations are the same as in town 7. The only village is Batavia. Population 1,459.

The general section of this town, from section 32 on the ridge, to section 36, on the Kickapoo, is as follows:

	Feet.
Galena limestone	20
Blue limestone	25
Buff limestone	20
St. Peters sandstone	100
Lower Magnesian limestone	180
Potsdam sandstone	100
From ridge to river, total	445

Town 9, Seneca. The divide continues from the last town, from section 31 to section 3. It is very high, wide, and rolling, with numerous subordinate ridges, and affords many fine, rich farms. The town is well watered by numerous small streams, and springs are found quite near the summit of the divide, issuing from the numerous clay layers in the Trenton limestone. The soil is clay, frequently rather sandy. The timber is oak, small but quite abundant. All the formations, from the Galena limestone to the Potsdam, are present; the St. Peters and the Lower Magnesian are the prevailing ones. The principal villages are Seneca and Lynxville. Population, 1,446.

Town 10, comprising parts of Utica, Freeman and Seneca. The divide continues a nearly north and south course from section 34 to section 3. The general features of the country are very similar to those of town 9. Much of the town is prairie. The soil is a deep clay, and the timber light. With the exception of the principal ridge, the country is very hilly and the valleys very deep and narrow. The population is largely foreign. The formations are Potsdam, Lower Magnesian and St. Peters; the last two being the principal ones. The principal towns are Mt. Sterling and Fairview. Population of Utica, 1,496.

Town 11, comprising parts of Franklin, Sterling, Freeman and Utica. This is chiefly a prairie country; the divide is high, wide, and rolling, extending from section 35 to section 1. There are no large streams in the town, but numerous small ravines running east and west from the divide. Small springs are quite numerous, and the greater part of the town is available for agricultural purposes. The population is chiefly Norwegian. The formations are St. Peters and Lower Magnesian, in about equal parts.

Town 12, east half Franklin, west half Sterling. The county is very hilly and broken, watered by the branches of the Bad Axe river. The valleys average about a quarter of a mile in width, with a rich, loamy soil, and are mostly meadow land. The ridges are wide and well cultivated; soil, clay; timber, small oak. The population is Norwegian. The formations are Potsdam, Lower Magnesian and St. Peters; the second being the principal one.

Town 13, Jefferson. The town is well watered by two branches of the Bad Axe river, flowing through the central and northern parts of the town. The southern and eastern parts are a fine prairie country; the northern, central and western parts are heavily timbered with maple, elm, oak, etc. This timber is confined to the higher parts of the ridges, the timber about the streams being comparatively small and sparse. This is a fine farming country, and produces large crops. The township is well settled, the population being partially foreign, and in part native. The formations are the same as in the previous town. The principal village is Springville. Population, 1,284.

Town 14, Coon. The country in this town is chiefly rolling ridge land, but broken by numerous streams and small ravines. It is well watered by the several branches of Raccoon creek. The valleys of the two principal branches are from one half to one mile wide, with a rich, loamy soil, and sandy subsoil. Toward the head of the streams and on the ridges, the soil is clay, and the timber large white oak. The formations are Potsdam, Lower Magnesian and St. Peters; the second being the principal one. Population, 983.

Town 15, Washington. This town consists of high, wide, hilly ridges, forming the divide between the La Crosse river and Raccoon creek. Fine springs are quite numerous, and the town is well watered; the principal stream is Raccoon creek. The valleys average about a quarter of a mile in width; the soil in them is a rich, sandy loam, and the timber, elm and maple. On the ridges the timber is usually small and sparse, but in the central part of the town there are some large groves of white oak. The soil is clay, and nearly all under cultivation. The town is inhabited chiefly by Norwegians. The Potsdam covers about one-third of the town and the Lower Magnesian the rest. Population, 1,008.

Town 16, Bangor. The country in this town is of two kinds: very high, steep and narrow ridges in the west, south and east; and low, flat, wide valleys in the northern and central parts, on the La Crosse river, Dutch and Wiant creeks. The soil is clay upon the ridges, which are seldom wide enough for farming, and are covered with small oak timber. In the creek valleys the soil is a rich, sandy loam, becoming more sandy in the northern part of the town. The township is well inhabited. The Potsdam covers about two-thirds of the town, and the Lower Magnesian the remainder. The principal town is Bangor. Population 1,196.

Town 17, Burns. The only parts of this town which are inhabited and available for farming purposes are the valleys of the La Crosse river and the Burnham and Adams creeks. These comprise about one-half of the township, have a rich, loamy soil, and produce heavy crops of the cereals and of hops. The Adams valley is very sandy. The valleys are well watered but devoid of timber. The alluvium is often very deep on the sides of the valleys, and near their heads where they become narrow. Masses of chert, which have been derived from the denudation of the Lower Magnesian on the ridges, are sometimes found in the alluvium at a depth of thirty-five feet below the surface. The soil on the ridges is shallow and sandy, and they are usually covered with white and black oak. The formation is almost entirely Potsdam. The population of the town is 1,020.

Town 18, Farmington (in part). This is a very hilly township. The hills are highest and steepest in the southern part, but become less so on proceeding north, and finally become low, sandy ridges, and then a sand flat on the northern line of the town. The timber is thin and sparse, and is chiefly black oak. The eastern side of the town is much more sandy than the western. The best part of the town is the Lewis valley, which has considerable good land, and a clay soil. The township is thinly inhabited Formation, Potsdam.

RANGE SIX WEST.

Town 6, Prairie du Chien (in part). That part of the town which lies north of the Wisconsin river consists of the rich alluvial bottom lands of that stream, with numerous sloughs and swamps. The bluffs which inclose the river on the north commence near the north line of the town. It is well timbered, soil, clay. Formation, Lower Magnesian.

Town 7, Prairie du Chien. The high ridge which divides the Kickapoo and the Mississippi begins in this town and runs northeast, passing out at section 2. The ridge is wide, level, and heavily timbered with white, black and burr oak. The soil is clay. The town is well watered, and springs are quite numerous. On the west side is the valley of the Mississippi, from one to two miles wide, between the bluffs and the river. Its soil is sandy, and the inhabitants largely French. All the formations are present, from the Galena to the Lower Magnesian inclusive. This town includes most of the city of Prairie du Chien, with 2,777. inhabitants. Population of the town, 724.

Town 8, Eastman (in part). The land in this town is very hilly and rough, being composed of long, straight ridges, which run east and west, and become quite narrow as they approach the Mississippi on the west. The best land is found on the east side of the town. There are a great many good springs arising near the ridge, which in the course of a half mile sink into the ground, so that the large ravines, although deep, seldom have any water in them. The soil is clay, and, in the western part, quite stony. The timber is small and rather sparse. Formations, Galena limestone to Potsdam Sandstone, inclusive. The general section of this town, from section 23 to the Mississippi river, is as follows:

	Feet.
Galena limestone	50
Trenton limestone (blue and buff)	40
St. Peters sandstone	110
Lower Magnesian limestone	250
Potsdam sandstone	20
From ridge to valley, total	470

Town 9, Seneca (in part). The bend of the Mississippi river causes this to be a fractional town, containing only about twelve square miles. It is composed of steep and rocky bluffs, forming the ends of ridges, often making perpendicular cliffs and escarpments of rock for long distances along the bank of the river. It is covered with small timber, and not much settled. The ridges are very high, narrow and steep, and from them beautiful views of the river are obtained. The formations are the same as in the preceding town.

Town 10, Freeman (in part). This is also a fractional township, and contains about twenty square miles. It is well watered by the Mississippi river, and Sugar, Buck, and Copper creeks. Fine, large springs are very numerous. The soil throughout the town is clay, and the timber small but abundant. The valleys and ridges are wide and afford fine farms. The population is almost exclusively Norwegian. The formations are Potsdam and Lower Magnesian in about equal parts. The population of Freeman is 1,544.

Town 11, comprising parts of Freeman, Wheatland and Sterling. This town consists chiefly of high, rolling, ridge land, having an elevation from 400 to 550 feet above the Mississippi. The principal ridge is very wide, and runs east and west through the northern part of the town, with numerous smaller ridges running north and south. The soil is clay, in some parts rather sandy; the timber small but abundant. Water is very scarce on the ridges. The only stream is Rush creek, in the southern part of the town: it has a rich and fertile valley about half a mile in width, and all under cultivation. The population of the town is Norwegian. The formations are Potsdam, Lower Magnesian and St. Peters; the two latter predominating.

Town 12, comprising parts of Sterling, Genoa and Harmony. The principal stream is the Bad Axe river, which, with its numerous small tributaries and springs, supplies the town abundantly with water. The valley averages about half a mile in width, with a rich loamy soil, and sandy subsoil, all under cultivation. The timber in the valleys is small and scattering black oak. The ridges are wide and rolling, soil, clay, and timber, large white oak. The population is Norwegian. The formations are the same as in town 11. Population of Sterling, 1,382.

Town 13, Harmony. There are two high, rolling ridges in this town, each about a mile in width, running in an east and west course; one in the northern and one in the southern part of the town. The soil on each is clay, and they are nearly all under cultivation. The timber on the southern ridge is small and scattering black oak; on the northern ridge it consists of groves of large white oak. The northeast quarter of the township is especially heavily timbered, and furnishes considerable timber to sawmills. Water is very scarce in the vicinity of the ridges. There is but one stream, the north fork of the Bad Axe, which runs westerly through the center of the town. Its valley is about half a mile wide, soil rather sandy, nearly all farmed. The formation is Lower Magnesian with the exception of a narrow strip of Potsdam in the valley of the Bad Axe. The only village is Newton. Population, 1,062.

Town 14, Hamburg. The general topographical features of this town are about the same as in the previous one; consisting of high, broken ridges, and one principal stream. The soil on the ridges is clay, and produces good crops, the timber is white and black oak. The valley of Raccoon creek varies from half a mile to a mile in width. The soil is a rich loam with sandy subsoil, and is nearly all under cultivation. There are numerous small hills and benches of alluvium in the valley, the materials of which appear to have been derived from the hills above during the progress of denudation, and have since been partially cut away by the changes in the stream, so that exposures are frequently seen as much as fifty feet thick, of irregularly stratified clay and sand. About one-third of the township is covered with Potsdam, and the remainder with Lower Magnesian. The principal village is Chaseburg. The population of the township is 1,156.

Town 15, Greenfield. This town, like most of those in the vicinity of the Mississippi river is very rough and hilly. The ridges run east and west, and are very high and narrow. Water is obtained with difficulty on them. The soil is clay, and the timber, small oak. The farms are chiefly confined to the valleys and ravines, which are well watered. The main stream is the Mormon "Coolie." Its valley is inhabited by the Germans. The formations are the same as in town 14. The population numbers 869.

Town 16, South half Barre, north half Hamilton. The greater part of this town is low, flat and level, and lies in the valleys of the La Crosse river and Bostwick creek. The only hilly portions are in the southern and eastern parts. The soil is chiefly clay, but contains considerable sand mixed with it. The timber is small black oak, and is confined to the ridges and sides of the valleys. Low hills of sandstone are seen occasionally in the valleys. There is some black, swampy land about the La Crosse river, which is used chiefly for hay meadow. This township is quite thickly inhabited. The formation is chiefly Potsdam. The population of Barre is 656.

Town 17, Hamilton. This town is flat and level in the southern part, in the vicinity of the La Crosse river, and becomes more hilly and broken in the northern, until a high dividing ridge is reached, running east and west from section 1 to section 6. With the exception of this ridge, which is high and narrow, the township is well watered. The ridges are chiefly valuable for the oak timber which grows on them, as there is but little land on them which is available for farming purposes. The soil in the valley is clay, containing considerable sand, and is nearly all under cultivation. The formation is chiefly Potsdam. The principal village is Salem. The population of the town of Hamilton is 1,661.

Town 18, Farmington (in part). This town is very hilly and rough, but the hills are not as high as in the country south of the La Crosse river. The best land is found in the valley of Fleming creek, which runs from section 25 to section 18. The valley varies from one-half to a mile in width, and is all farmed. The soil in sections 23, 24, 25, 26, is very sandy, but in sections 18, 19, 20, 21, 22, it is a deep clay and contains but little sand. Timber, consisting of white and black oak, is very plenty on the ridges throughout the town. The northern part of the town slopes to the Black river, and in the vicinity of that stream it is very sandy, but about the base of the hills, a mile south of the river, there are some very good farms. The formation is nearly all Potsdam. The principal village is Mindora. The population of Farmington is 1,686.

RANGE SEVEN WEST.

Town 11, north half Wheatland, south half Freeman. This is a town made fractional by the Mississippi river, and containing about sixteen square miles. It is very hilly, and the best land lies on a high and narrow ridge in the eastern part of the town, which is parallel to the river, and about 500 feet above it. The river runs close to the bluffs, which are high and precipitous. The soil is clay, and the timber white oak. The formations are Potsdam, Lower Magnesian and St. Peters, the second being the prevailing one. The principal villages are De Soto and Victory. The population of Wheatland is 917.

Town 12, Genoa (in part). This is also a fractional town of about 22 square miles. It is well watered by the Mississippi and Bad Axe rivers, and their small tributaries. About the larger streams there is a great deal of low, flat, swampy land, chiefly valuable for hay-meadow. The soil is clay throughout the town, and the timber chiefly small oak. The valley of the Bad Axe frequently contains very large and thick beds of alluvium. The ridges lie about 500 feet above the river, and form a rolling prairie country, with small groves of oak. All the formations from the Trenton to the Potsdam, inclusive, are present; the Trenton consists of a small outlier in the southeast part of the town. The population of Genoa is 919. The general section of this town from the ridge to the Mississippi river is as follows:

	Feet.
St. Peters sandstone	80
Lower Magnesian limestone	230
Potsdam sandstone	150
Total from ridge to valley	460

Town 13, south half Genoa, north half Bergen. There are about twenty-four square miles contained in this town, of which the greater part is hilly and broken, and inhabited by Italians; as even the name of the town (Genoa) seems to imply. The ridge dividing Raccoon creek and the Bad Axe river passes northeasterly through the town, and forms the better part of the farming land. It is much cut up with ravines, and has but little timber. The soil is clay, and produces good crops of wheat. The formation is chiefly Lower Magnesian. The only village is Genoa, formerly known as Bad Axe City.

Town 14, Bergen. The western half of this town lies in the valley of the Mississippi, and is an alluvial bottom, consisting of swamps, sloughs, hay-meadows and timbered islands. The eastern half of the town comprises the valleys of Raccoon creek and Chipmunk "Coolie," each about a mile wide, and the intervening ridge. The farms are chiefly confined to the valleys. The soil is clay on the ridges, and more sandy in the valleys. The timber is small, and confined to the ridges. The formations are Potsdam and Lower Magnesian in about equal parts. Population, 1,014.

Town 15, Shelby. In the eastern part of this town are some high and narrow ridges, covered with white oak, and terminating in precipitous cliffs facing the Mississippi. The rest of the town is the flat sandy valley of the river, in the northern part of which is the city of La Crosse. The only portions of the valley which are not too sandy to cultivate are those which lie within half a mile of the bluffs, where the soil has derived much lime from the wash and denudation of the adjacent bluffs. The Lower Magnesian covers about one-sixth of the town, and the Potsdam the remainder. Population of the city of La Crosse, 14,505. Population of the town of Shelby, 796.

Town 16, Campbell. The valley of the Mississippi, La Crosse, and Black rivers, occupy the greater part of this township. There are some high ridges capped with limestone in the southeast quarter of the town, and some low, sandy hills in sections 1, 2, 3. The soil in the valleys is very sandy except along the foot of the hills and in sections 10, 11, 12, 13, 14, 15. These sections lie near the La Crosse river, and have a clay soil which is mostly under cultivation. The timber consists of small black oak. The formation is Potsdam sandstone. The principal towns are North La Crosse and Onalaska. Population of Onalaska, 826. Population of the town of Campbell, 885.

Town 17, Onalaska. The greater part of this town is very hilly and rough, consisting of deep ravines and high ridges, with oak timber, but too narrow for farming purposes. Sections 7, 18, 19, 20, 29, 30, 31, 32, 33, lie in the valley of the Black river, and are very sandy. They slope in low hills to the river, and, in the vicinity of the stream, become meadow land. They are only cultivated near the foot of the bluffs. The best part of the town lies in the valley of Halfway creek, which is from one half to one mile wide, with a rich clay soil, and all under cultivation. The population is chiefly Norwegian and German. Formation, Potsdam. The principal villages are Midway and Halfway Creek. The population of the town is 1,916.

Town 18, comprising parts of Holland, Farmington, Onalaska and Gale. There is one ridge in this town, running through sections 18, 20, 27, 26, 25. It is high, narrow and uncultivated. The remainder of the town consists chiefly of low, sandy hills, covered with small black oak, which become sandy flats on approaching the Black river, in the north part of the town. The town is well watered by the various branches of Fleming creek, and fine springs are quite numerous. The farms are confined to the small valleys and ravines, in which large deposits of clay and sand are frequently found. The soil is sandy, and the formation is Potsdam. Population of Holland, 874.

Town 19, comprising parts of Gale, Ettrick and Farmington. This town is quite hilly, but the hills are not very high. It is well watered by the Black river, Hardy and Beaver creeks, and by numerous smaller streams and springs. The soil is generally sandy, and supports a growth of small oak timber. The farms are confined to the streams, the valleys of which are quite narrow and occupy deep ravines; their soil contains more clay and is quite fertile. The formation is Potsdam.

Town 20, Ettrick (in part). This township is less hilly than the preceding. The timber is rather small and the soil sandy. It is well watered by the various branches of Beaver creek. The formation is Potsdam. The population of Ettrick is 1,656.

RANGE EIGHT WEST.

Town 17, comprising parts of Holland, Onalaska, and Caledonia. The northeast quarter of this town consists of sandy bottom land, with a very scanty growth of black oak. The rest of the town is a network of sloughs and islands in the Mississippi river. The town is very thinly inhabited. Formation Potsdam.

Town 18, east of Black river, Holland, west part, Caledonia. This town lies altogether in the valley of the Black river, which runs southerly through the center of the town. The town contains but little timber, except a belt about a mile wide along the river, consisting of small black oak. The soil in the town is very sandy but about half of it under cultivation. The formation is Potsdam. Population of Caledonia, 446.

Town 19, Gale (in part). The eastern and western portions of this town are hilly and the central part is occupied by the valley of Beaver creek, which is from one to two miles wide. The soil is quite sandy on the east side of the creek, but less so on the west side. The entire valley is under cultivation and is quite fertile. The timber is white and black oak, rather small and sparse, and confined to the sides of the valleys and the ridges. The ridges are high and narrow, and unfit for farming purposes. One of the best parts of the town is Decora prairie in sections 35 and 36. This is a part of the Black river bottom and is fine farming land. The formation is Potsdam, with the exception of some small outliers of Lower Magnesian in the western part of the town which are utilized for the manufacture of lime. The principal town is Galesville. Population of Gale, 1,786.

Town 20, Ettrick (in part). The land in this township is rolling. The timber is small, and scattering. The soil is sandy and is watered by French creek and its branches. Formation, Potsdam.

RANGE NINE WEST.

Town 18, Trempealeau (in part). This town lies altogether in the valley of the Mississippi, and is very flat and level, with the exception of Trempealeau mountain, in sections 20, 21 and 27. The best part of the town lies in sections 1, 2, 3, 4, 5, 6, where the soil contains some clay, and affords fine farms. The rest of the town is very sandy, and but little cultivated. Very little timber grows in this town; it is known as the Trempealeau prairie. Formation, Potsdam. Population of Trempealeau, 1,567.

Town 19, Trempealeau (in part). Tamarack creek is the principal stream in this town, and runs through it from section 3 to section 33. Its valley is from one to two miles wide, with a black and swampy soil. Where not covered with tamarack, it is a fine hay meadow. The farms are confined to the slopes of the hills adjacent to the valley. The southern part of the town also contains considerable good land. The eastern and western portions are hilly, and but little settled. Formation, Potsdam.

Town 20, Arcadia (in part). This town is well watered by several small branches of Tamarack creek. The town is more hilly and rolling than the preceding, but contains considerable good farming land. The soil is rather sandy. The formation is Potsdam. Population of Arcadia, 3,167.

RANGE TEN WEST.

Town 18. This is a fractional township of fourteen sections, lying along the Mississippi, and consisting of sandy bottom land, intersected with sloughs.

Town 19, Buffalo. This township is very hilly and rough; the ridges are from 300 to 400 feet above the Mississippi, and are well timbered with large white oaks, and much small timber of second growth. The farms are confined to the valleys and crests of the ridges. About two-thirds of the town is covered with Potsdam sandstone, and the remainder with Lower Magnesian limestone, which has sometimes a thickness of 200 feet.

Town 20, Cross (in part). The interior of the township is occupied by the valley of the Trempealeau river, which is from one to two miles wide, being about one-half meadow land and one-half large elm timber. The remainder of the township is very hilly and cut up with deep ravines. The town is well watered by numerous small streams, and the soil is rather sandy. The formation is chiefly Potsdam.

Town 21, Glencoe. This township is very hilly, the central part being occupied by a ridge dividing Muir Creek from the Waumandee river. This ridge is about 580 feet above the Mississippi, and is capped by about 100 feet of Lower Magnesian limestone. Muir creek occupies the eastern part of the township; it has a wide and well cultivated valley, with a rich, black soil; in some places rather swampy. The formations are Potsdam and Lower Magnesian in nearly equal proportions.

RANGE ELEVEN WEST.

Town 19. This is a fractional township through which the Mississippi runs from section 6 to 36, bordered with high and precipitous cliffs. Nearly all of the town consists of high, rolling ridge land lying from 500 to 600 feet above the river. It is well timbered with large white oak and small timber. In the northeast quarter of section 9, the geological section from the ridge to the bed of the river is as follows:

	Feet.
St. Peters sandstone	50
Lower Magnesian limestone	200
Potsdam sandstone	350
Total from ridge to bed of river	600

The Lower Magnesian is the principal surface rock.

Town 20, Cross (in part). This town is well watered by Eagle creek and its branches in the central part, and by the Waumandee river in the western part. The other parts of the town are very hilly, and consist of dividing ridges lying about 550 feet above the streams. The soil on the ridges is clay, which in some places is suited to the manufacture of brick. One brick yard was seen in the southeast quarter of section 32. The valley of the Waumandee is from a mile to a mile and a half wide, and well settled; the soil is largely of quaternary origin, and is very fertile. The formations are, Potsdam one-third, Lower Magnesian two-thirds.

Town 21, Waumandee (in part). The valleys of the Waumandee and its tributaries occupy a large part of the town, and afford much good agricultural land. The hills are not so high or so steep as in the country further south. The ridges are well timbered. Formations, Potsdam two-thirds, Lower Magnesian one-third. Population of Waumandee 950.

RANGE TWELVE WEST.

Town 20, Milton (in part). This is a fractional town lying along the Mississippi, which runs from section 6 to 34. There is a strip of flat, sandy land about two miles wide lying between the river and the inclosing bluffs, which is cultivated next to the bluffs, the soil there containing more clay. About one-fourth of the township has the Lower Magnesian for the surface rock, the remainder is Potsdam. The population of Milton is 441.

Town 21, Belvidere (in part). This town consists chiefly of high ridge land, much intersected with ravines. The divide between Beef river and the Waumandee passes through the town and has a pretty uniform elevation of about 600 feet above the Mississippi. The ridges are wide and well settled, with clay soil and white oak timber. The Lower Magnesian is the principal formation. The population of Belvidere is 723.

Town 22, Alma (in part). The southern half of the town is similar to town 21. Beef river flows through the town from section 2 to 19. Its valley is about a mile and a half wide, rather swampy, and chiefly devoted to hay meadow. The farms are on the terraces which form the foot of the bluffs on either side of the river. The town is well watered by numerous small streams. The formations are Potsdam and Magnesian, in nearly equal parts. Population of Alma, 731.

Town 23, Modena. The greater part of the town is valley land, with high ridges in the western and northern part. It is not as thickly settled as the country farther south, and the soil is much more sandy. The height of the dividing ridges in this town is about 530 ft., above the Mississippi, and they are well timbered with white oak. The formations are Potsdam, covering two-thirds of the town, and Lower Magnesian the rest. Population of Modena, 811.

Town 24, Canton. There is a high, narrow dividing ridge of Lower Magnesian in the southern part of the town. The rest of the town is covered with a sandy soil, and slopes to Bear creek, which has a very wide and swampy valley, consisting chiefly of meadow land and some tamarack. There is some very good farming land. Population of Canton, 738.

RANGE THIRTEEN WEST.

Town 22, Nelson (in part.) The southern and western parts are occupied by the wide sandy valleys of Beef river and Beef slough, in which the soil is very poor except at the foot of the bluffs. Trout creek, which runs through the northeast part of the town has a long and well cultivated valley, from a quarter to a half mile in width. There are some high limestone ridges in sections 2, 4, 10, 11, 12, 13, 15 and 22, which are timbered with white oak; the rest of the town has the Potsdam for the surface rock. Population of Nelson, 1,651.

Town 23, Nelson (in part). This town consists of high limestone ridges in the central and southern parts; the northern part is occupied by Little Bear creek and its tributaries. The soil is very sandy in the valleys but clay on the ridges. The formations are Potsdam and Lower Magnesian in nearly equal parts.

RANGE FOURTEEN WEST.

Town 23, Pepin (in part). The eastern half of the town is occupied by the valley of the Chippewa river, which is quite swampy near the river and heavily timbered with elm. Near the bluffs the soil is sandy and gravely, and somewhat cultivated. The valley of Roaring river has a fine clay soil, and is well settled. There are numerous broken limestone ridges in the northern and central parts, which lie about 450 feet above the river, are timbered with white oak, and have a good soil. The formation over most of the town is Potsdam. Population of Pepin, 1,515.

Town 24, Frankfort. The eastern part of the town contains part of the Chippewa valley, and Plum and Porcupine creeks occupy the central part. The valley of Plum creek is about a mile wide, with very good soil in most parts. The town is heavily timbered in the valleys with elm, maple, basswood, etc., and on the ridges with white and black oak. The principal formation is Potsdam. Population, 639.

Town 25, Waterville. This township is very rough and hilly, the general elevation of the ridges being about 450 feet above the Mississippi. The timber is very large and dense, and consists of elm, maple, basswood, ash, etc. The soil is rich and black. The formation is Potsdam, with the exception of a limestone ridge in the southwestern part. The population is American and French, and numbers 1,197.

RANGE FIFTEEN WEST.

Town 23, Pepin (in part). This town is rendered fractional by Lake Pepin in the southern part, which flows from section 18 to 36. The valley adjacent to the lake is from a mile to a mile and a half wide, very sandy, and cultivated only near the foot of the bluffs. The northern part of the town consists of wide rolling ridges with clay soil, and is fine farming land. It is timbered with white and black oak. The Potsdam and Lower Magnesian occupy about equal areas in this township.

Town 24, Maiden Rock (in part). The town consists of high, rolling, ridge land, much intersected with ravines. The general elevation of the ridge is about 450 feet above Lake Pepin. There is a great deal of fine agricultural land in this township. The soil is clay, and the surface rock chiefly Lower Magnesian. Population of Maiden Rock, 1,375.

Town 25, Union. This town is well watered by Plum creek and its branches, and heavily timbered with elm, maple, oak, basswood, etc. The soil is clay derived from the Lower Magnesian, which covers about two-thirds of the town, the Potsdam occupying the remainder. The population of Union is 734.

RANGE SIXTEEN WEST.

Town 24, Maiden Rock (in part). This is a fractional town of about twenty-four sections, lying along Lake Pepin. The most of the town consists of high, rolling ridge land, with fine soil. The bluffs lie very near the lake, and the Lower Magnesian covers nearly all of the town.

Town 25, Salem. This town is well watered by Rush river and its tributaries, which occupies the central part of the town. Its valley is about one-third of a mile wide, and has a rich soil. It supports a heavy growth of maple, elm, basswood, butternut, etc., and considerable oak on the ridges. The Potsdam is the surface rock in the valleys, and the limestone over the rest of the town. Population, 478.

RANGE SEVENTEEN WEST

Town 24, Isabelle. This is a small fractional town of nine sections, lying at the head of Lake Pepin. The western half consists of sandy flats, the eastern half of high limestone bluffs. Population, 250.

Town 25, Hartland. This town is well watered by the branches of the Isabelle river. The eastern and western parts consist of ridges about 400 feet higher than Lake Pepin. The southern portion is timbered with white oak, the remainder with elm and maple. The soil is in most parts very good. The formation is chiefly Lower Magnesian. Population, 1,250.

RANGE EIGHTEEN WEST.

Town 25, Trenton and Diamond Bluff. The town is well watered by the Trimbelle river and its branches, and consists chiefly of high, rolling ridge land, lying about 400 feet above the Mississippi. The town is heavily timbered, and the soil clay. The formation is chiefly Lower Magnesian. The population of Trenton is 737; the population of Diamond Bluff, 534.

Town 26, Trimbelle. The town is divided north and south nearly in the center by the Trimbelle river. East of the river, the country is heavily timbered with hard wood; west of the river, the country is rolling and sparsely timbered with poplar and black oak, and has more of a prairie nature. The soil is clay and well suited to farming. The formation is chiefly Lower Magnesian, with some St. Peters in the northwestern and southeastern parts. Population, 1,148.

RANGE NINETEEN WEST.

Town 26, Oak Grove (in part). This township is mostly prairie, with occasional groves of white and burr oak. The soil is good and the greater part under cultivation. It is not very well watered, the streams being infrequent. The principal surface rock is Lower Magnesian, and some St. Peters in the northern part. Population of Oak Grove, 937.

Town 27, Clifton. The land is quite hilly and rolling, and rather sparsely timbered. The soil is good, and fine farms are numerous. It is well watered by branches of the Kinnikinnick river. The formations are Lower Magnesian and St. Peters, in nearly equal parts. Population, 703.

RANGE TWENTY WEST.

Town 27. This is a fractional town of about ten sections, lying in the valley of the St. Croix. The land is slightly rolling and the soil well adapted to agriculture.

GENERALIZATIONS.

From the preceding descriptions we recognize three natural subdivisions of the country, which exhibit well marked differences in topography, timber and soil. The territory lies entirely within the great driftless area of the state, with a few slight exceptions hereafter to be described, and its surface contour has never been modified by glacial action.

The first of these natural subdivisions is the most important, and consists of high rolling ridge land intersected in all directions with deep ravines and valleys, often bordered with precipitous cliffs, the elevation of the ridges above the valleys being from 300 to 500 feet. The valleys in their length and breadth are the effect of erosion only, but it seems probable that the streams were formerly much larger and acted with greater rapidity and force. When we mentally reconstruct the country as it must once have been, by filling up the valleys with the formations now found on their sides, and then add the formations whose outlines still remain, we appreciate the immense denudation which the country has undergone. It should be remembered, however, that this portion of the continent has never again been submerged since its first emergence from the Paleozoic ocean at the close of the Lower Silurian age, and that since then all the subsequent ages of geological time have elapsed, a length of time commensurate with the results.

Country of the above description is found wherever the Lower Magnesian limestone has not yet been entirely denuded, and is characterized by a clay soil derived from the disintegration of the limestone. It supports usually a heavy growth of hard wood timber, in which maple, elm, basswood, oak and ash predominate. It includes the counties of Richland, Crawford, Vernon, the south half of La Crosse and Monroe, and such parts of Buffalo, Pepin and Pierce as are mentioned in this report.

The second natural subdivision of the territory includes the country in which the Potsdam sandstone is the underlying formation. The denudation having proceeded with greater rapidity in the soft sandstone, the ridges are not so steep and high, and the intervening valleys much wider. The soil is more sandy and not as well adapted to agriculture, and it is usually covered with a growth of small black oak. This includes the northern parts of Monroe, La Crosse and Trempealeau counties.

The third natural subdivision includes the alluvial bottom lands found in the valleys of all the larger streams, as the Mississippi, Trempealeau, Black, La Crosse, Kickapoo and Wisconsin rivers. In all of these streams except the Kickapoo and the upper part of the La Crosse, the materials from which the soil is derived are largely glacial in their origin, and the result is in some cases a barren and sandy soil, and in others a rich and fertile one. In the former is found a growth of small black oak, and in the latter the elm and maple predominate.

CHAPTER 11.

GEOLOGICAL FORMATIONS.

The formations of the territory described in this report are confined to the Lower Silurian age, with the exception of the Quaternary. The following general section, taken from Prof. Dana's Manual, embraces the present received order of geological periods and epochs in North America, and to it is added another column, showing the order of the epochs in the territory under consideration:

Periods.		Epochs.	Epochs in Western Wisconsin.
Quaternary.		Recent	Recent.
		Champlain	Champlain.
		Glacial	Glacial.
Lower Silurian.	*Trenton.*	Cincinnati	Wanting.
		Utica	Wanting.
		Trenton	Galena, and Blue and Buff limestones.
	Canadian.	Chazy	St. Peters sandstone.
		Quebec	Wanting.
		Calciferous	Lower Magnesian limestone.
	Primordial or Cambrian.	Potsdam	Potsdam sandstone.
		Acadian	Wanting.
Archæan.		Archæan	Not exposed.

From the above table it will be seen that there are but seven epochs to be considered, the remainder being either denuded, never deposited, or unexposed. They will be considered in the natural order of their deposition, beginning with the oldest and lowest, which is the Potsdam sandstone.

POTSDAM SANDSTONE.

The territory covered by the Potsdam forms a large part of the district examined, as has been noticed in the previous chapter, or may be seen by reference to areas H and I of the geological atlas, accompanying the report. It is found in the valleys of all the streams, and in the northern part it becomes the surface rock of the entire country.

The strata of the Potsdam emerge from the valley of the Mississippi a short distance above Prairie du Chien, and rise gradually in ascending the river until they attain their maximum elevation of 470 feet above the river, between La Crosse and Trempealeau. From this point, continuing to ascend the river, the elevation diminishes irregularly; being 350 feet at Fountain City, 270 feet at Alma, 320 feet at Buffalo City, 200 feet at Maiden Rock, 80 feet at Bay City, 120 feet at Diamond Bluff, and sinking below the level of the Mississippi a few miles below Prescott.

Lithological Characteristics. The Potsdam formation in the southern and western part of Wisconsin consists almost entirely of sandstone. The only exception to this is the stratum of magnesian limestone and shales found in the upper part of the formation, which will be more particularly described hereafter. Another peculiar feature of the formation is the great uniformity of the various strata. Prof. Owen made six principal subdivisions of the Potsdam; and wherever exposed they can be traced through the entire region, preserving with but little variation the same relative order and thickness.

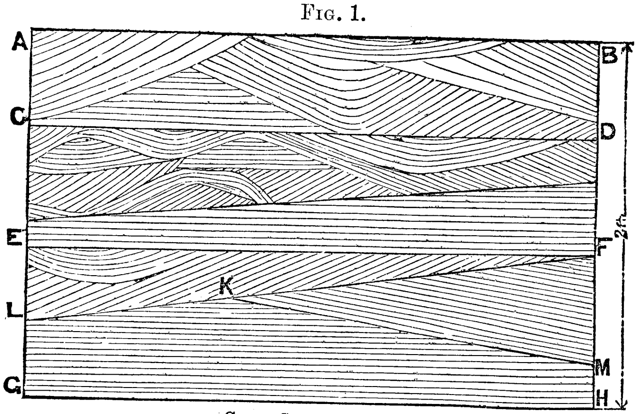
The strata of the formation are usually composed of fine siliceous sand; generally in small, rounded, waterworn grains of almost every color, the most frequent being the various shades of yellow and red, sometimes green, and often snow white. The strata vary greatly in consistency; and in different localities the same stratum may present different degrees of hardness. Some of the layers, and especially the white ones, are frequently almost as compact as quartzite, and from this all degrees are found, to a loose, friable sand that crumbles in the hand. In general, the softer and more crumbling sand contains the least admixture of foreign matter: as when lime or iron are present, they frequently cement the sand into a very hard and compact sandstone, which is sometimes concretionary. An instance of this was observed at Decora Peak, a short distance east of Galesville, in Trempealeau county. The upper layers contain numerous concretionary and stalactitic masses of ferruginous matter, some of them as much as a foot in diameter; they are usually hollow in the interior.

Concretions of sand were also seen in the upper strata of the Potsdam in the road cutting in the N. half of sec. 9, T. 19, R. 11 W. Their color is nearly the same as the adjacent sandstone, and they are seldom more than three or four inches in diameter.

The Stratification of the Potsdam is very regular and even, and the beds usually lie in a nearly horizontal position over large tracts of country. Indeed, so little do they deviate from an apparent level, that the dip cannot be distinguised by the eye, but only by a careful measurement. The dip is usually to the northwest, and seldom exceeds eight or ten feet to the mile, but more frequently it is less.

"**Cross-Stratification**" is of very common occurrence in all the beds of sandstone, and might sometimes be mistaken for the true stratification if its origin was not known and understood. The annexed sketch (Fig. 1), taken from the face of a cliff on Sand creek, in the south-east quarter of section 25, T. 10, R. 4 W., illustrates both the true and the cross-stratification.

Fig. 1.



Cross-Stratification.

In this sketch, the lines A B, C D, E F, G H, show the planes of true stratification, which are nearly horizontal; and in each of the beds are numerous subordinate layers, in which the lines are horizontal, oblique and curved, frequently dipping in different and even opposite directions The lines of stratification of the subordinate beds are as fine and regular on the face of the cliff as in the drawing; from six to twelve being contained in the space of an inch.

This structure is due to the irregular deposition of the sand by the sea, and the cutting away of partially formed beds by irregular and shifting currents and the ebb and flow of tides. In Fig. 1, for instance, the bed G, L, K, M, H, is the remaining part of a horizontal bed which was first cut down to the line K, M, and the bed, of which F, K, M, is a part, was formed. Both of these beds were then cut down to the line F, L. In like manner may be explained the oblique lamination of the constituent parts of all the beds, the waves cutting away and pushing before them the loose sand, and heaping it up in oblique and divergently laminated layers.

Ripple Marks. These are not of common occurrence, and were only seen in the northern part of La Crosse county, and in the southern part of Trempealeau county. The ripple mark is an indication of a sea beach, or of shallow water, and it is possible that the depths of the water over the greater part of the country precluded their formation. Some very good beds of ripple-marked sandstone were seen near Halfway creek, and at Stevenstown, in La Crosse county; on the Black river and at Galesville, in Trempealeau county. At the latter place the specimen was very large and perfect, the ridges being from two to three inches apart, and covered with small *Lingula shells and fucoids*.

Thickness. The greatest exposed thickness of Potsdam was found in the northern part of the territory, in the vicinity of Black river, where the lower beds are exposed. Here, however, the upper beds of the Potsdam have been greatly denuded, or are not exposed, making it difficult to obtain a good general section of the formation at any one place. The two following sections have therefore been prepared, of which section No. 2 is from the southern part of the territory, where the upper beds are most frequently exposed, and exhibit great uniformity. Section No. 1 has been obtained from an examination of the strata of Trempealeau mountain. By placing the beds numbered 2, 3, 4, of section No. 2 above bed No. 3 of section No. 1, a very good ideal section of the Potsdam formation may be constructed.

Section No. 1. Trempealeau Mountain.

		Feet.
1.	Heavy-bedded, unfossiliferous sandstone	40
2.	Intercalations of magnesian limestone and sandstone	20
3.	Sandstone layers, with lines of cross-stratification	19
4.	Layers of yellowish concretionary sandstone	3
5.	Heavy-bedded, yellow sandstone. Layers 2 to 6 feet thick	45
6.	Thin-bedded, brown, yellow, and white sandstone	11
7.	Thin, yellow, argillaceous shales, with traces of *Dicellocephalus*	10
8.	Soft and friable green sandstone	12
9.	Heavy-bedded, red and yellow sandstones	20
10.	Hard and compact sandstone, containing considerable lime	9
11.	Concretionary sandstone, containing greensand	3
12.	Thin-bedded, yellow sandstone, with frequent green layers	33
13.	Band of green clay	1
14.	Alternations of green and red sandstone	6
15.	Compact green sandstone	5
16.	Soft and friable greensand	9
17.	Sandstone containing scales of mica, and indistinct fossils	3
18.	Ferruginous sandstone	20
19.	Thin-bedded, soft, green sandstone, with intercalations of green clay from two to four inches thick	30
20.	Heavy-bedded, brown, calcareous sandstone	10
21.	Soft and friable sandstone, with mica and greensand	12
22.	Friable sandstone, with indistinct trilobites	6
23.	Loose greensand	2
24.	Heavy-bedded, yellow and gray sandstones, containing large quantities of finely comminuted, white *Lingula* shells	80
25.	Slope of hill, sandstone, to water in the Mississippi	25
	Total thickness of section	434

Section No. 2.

On the farm of Mr. Obright, on Hall's branch, Section 6, T. 9, R. 4 W.

	Feet.
1. Gentle slope of hill with exposures of hard and compact, yellow, Lower Magnesian limestone containing no flints	30
2. Steep slope, formed of transition beds of limestone and sandstone, in which the sand is cemented by lime. Very hard	30
3. Perpendicular cliff of yellow sandstone, very irregularly bedded, with lines of cross-stratification	40
4. Thin layers of arenaceous and dolomitic shales	30
5. Heavy-bedded, yellow and brown sandstone, generally loose and friable, but indurated on the surface	20
6. Thin-bedded sandstone, alternating with calcareous and magnesian layers	40
7. Slope of hill covering sandstone, to the water in the creek	20
Total thickness	210

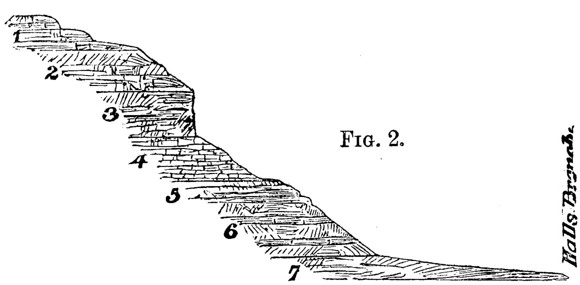


FIG. 2.

SECTION OF HILL OF POTSDAM ON HALL'S BRANCH.

The following sections are also inserted to show the changes which the strata sometimes undergo in different localities:

Section No. 3.

Section of a cliff on Sand creek, in the southeast quarter of Sec. 25, T. 10, R. 4 W.

	Feet.	Inches.
1. Heavy-bedded Lower Magnesian limestone, regularly stratified, and containing but little flint, weathers irregularly on the surface, exposed in a vertical cliff	30	
2. Regularly stratified, thin-bedded limestone layers	3	
3. Transition beds, consisting of loose, angular pieces of magnesian limestone, containing considerable sand. In this stratum there are numerous cavities lined with brown spar and pyrites	3	
4. Very hard, white Potsdam sandstone, like quartzite	1	6
5. Soft, friable, white sandstone	1	6
6. Very hard, close grained, yellow sandstone, containing numerous irregular cavities	2	..
7. Hard and compact white sandstone	2	..
8. Hard and compact yellow sandstone	1	..
9. Soft and friable white sandstone, with fine lines of cross-stratification	20	..
Total thickness	64	00

Section No. 4.

Section of a bluff on the west side of the Kickapoo, in the southwest quarter of section 18, T. 11, R. 3 W. The elevation of the top of the bluff above Lake Michigan is about 430 feet.

	Feet.	*Inches.*
1. Slope of hill to first outcrop of rock	10	..
2. Thin-bedded yellow limestone, containing no flints, stratification regular, beds 6 to 7 feet thick	10	..
3. Hard and compact limestone, beds 2 feet thick	15	..
4. Two beds of light colored limestone, 7 and 8 feet thick, containing no flints. Good building stone	15	..
5. Thin-bedded, gray limestone, much broken into irregular rectangular blocks; contains numerous small cavities, but no chert or flints	10	..
6. Thin, yellow, oölitic limestone, made up of small concretionary particles like fish spawn	3	..
7. Bed of irregularly broken limestone, similar to No. 5	2	..
8. White sandstone (Potsdam)	..	6
9. Layer of irregularly broken limestone, similar to No. 5	1	6
10. Hard and compact white sandstone	1	..
11. Very thin, and regularly bedded limestone; layers 1 inch thick	2	..
12. Hard and compact magnesian limestone	3	..
13. White sandstone	..	3
14. Hard and compact yellow sandstone	1	..
15. Friable white sand	..	6
16. Layer of limestone containing distinct grains of sand	1	6
17. Compact white sandstone	..	6
18. Hard and compact yellow sandstone	2	3
19. Soft, friable, white sandstone	6	..
20. Yellow sandstone	8	..
21. Soft and friable white sandstone	5	..
22. Soft, straw yellow sandstone	6	..
23. Soft, white sandstone	1	..
24. Hard, yellow sandstone, cropping out at intervals in the steep slope of the hill	75	..
25. Gentle slope of hill, covering sandstone, to water in the Kickapoo river	110	..
Total thickness	290	..

The foregoing section is one of the finest exposures of Potsdam sandstone observed, and the remarkable alternations of thin beds of sandstone and magnesian limestone, near the top of the Potsdam, have not their counterpart in any other section of the country. The usual transition beds of calciferous sandstone, and arenaceous limestone, appear here to be replaced by thin and numerous alternating beds of limestone and sand.

Section No. 5.

Section of a bluff in the Mississippi valley, S. E.quarter Sec. 25, T. 18, R. 8 W.

		Feet.
1.	Lower Magnesian limestone, heavy-bedded, light colored, containing numerous flints, in layers and irregular masses, exposed in a vertical cliff	90
2.	Thick magnesian layers, alternating with sandstone	50
3.	Thin-bedded, yellow shales, alternating with layers of white and yellow sandstone	30
4.	Regularly stratified yellow sandstone	50
5.	Steep slope of the hill, covering sandstone	20
6.	Gentle slope of the hill, forming a bench	130
7.	Steep slope of the hill, with small outcrop of sandstone	40
8.	Green sandstone and shales	10
9.	Hard and compact yellow sandstone	40
10.	Heavy-bedded, regularly stratified, hard, white sandstone	30
11.	Yellow sandstone	10
12.	Slope of hill from the last outcrop down to the valley	70
13.	Elevation of the valley above the water in the Mississippi	30
	Total thickness	600

From the preceding sections, Nos. 1 and 2, it will be seen that the total exposed thickness of Potsdam is about 470 feet. Beginning at the bottom and proceeding upward, the formation is composed as follows: First, 100 feet of heavy-bedded sandstone, containing principally *Lingula*. Second, 200 feet of thin-bedded sandstones, in which greensand layers are very frequent. Third, 75 feet of heavy-bedded sandstones, sometimes containing fossiliferous argillaceous layers in the lower parts. Fourth, 100 feet of alternating sandstone and dolomite, with dolomitic shales near the bottom, and transition beds at the top.

Of the thickness of the unexplored portions of the Potsdam, we have derived some knowledge from artesian wells that have penetrated the formation to obtain water, of which detailed descriptions are given on a subsequent page.

At Oil City, on the Kickapoo, near the center of the N. W. quarter of Sec. 26, T. 15, R. 2 W., an artesian well reaches the bottom of the Potsdam at a depth of 490 feet from the surface of the ground. From the surface at the well to the top of the Potsdam, is 354 feet, making the total thickness of the formation at this point, 844 feet.

In the village of Tomah, in Sec. 4, T. 17, R. 1 W., an artesian well has penetrated to the bottom of the Potsdam at a depth of 460 feet. The nearest exposure of the top of the formation is about five miles south of Tomah, where it is about 420 feet higher than the town. Allowing 30 feet for the northerly rise of the strata, it is not too much to assume that the entire thickness of the Potsdam formation in this vicinity is about 900 feet.

In the city of La Crosse, a well has been sunk through 537 feet of

Potsdam, reaching the granite. Above this, to the top of the formation, is 400 feet, making the thickness of the Potsdam formation near La Crosse, 937 feet.

In the town of Prairie du Chien, a well has been sunk through 960 feet of the Potsdam without reaching the bottom of the formation.

In general, the thickness of the Potsdam may be estimated at 800 to 1,000 feet, in the Mississippi valley, the inequalities in the surface of the underlying Archæan rocks being the principal source of its variation.

Local Sections. The following local sections illustrate the structure of several parts of the formation. The following was taken at the road cutting opposite the mill in the village of Boaz in Richland county, section 19, town 10, range 1 west. The top of the section is probably about 100 feet below the upper surface of the Potsdam formation.

Section No. 6.

	Feet.	*Inches.*
1. Thin bedded yellow sandstone, containing *Scolithus*, layers 9 inches thick, separated from each other by a thin, laminated, sandy shale, one inch thick	6	..
2. Bed of very soft calcareous and arenceous clay	1	6
3. Sandstone with interlaminated shales	1	6
4. Hard and compact sandstone consisting largely of greensand	1	2
5. Conglomerate, consisting of small rounded pieces of light colored sandstone, imbedded in greensand; very hard and compact, contains irregular cavities lined with drusy crystals	1	4
6. Friable white sandstone	..	6
7. Soft yellow limestone	2	..
8. Bed of very loose calcareous matter	4	..
9. Very friable greensand	..	1
10. Loose crumbling magnesian limestone	2	4
11. Friable greensand	4	..
12. Greensand alternating with calcareous shales 1 inch thick	5	..
13. Heavy bed of green sandstone, more compact than the preceding	3	..
14. Hard and compact yellow sandstone	..	6
15. Greensand to bed of the creek	1	6
Total thickness exposed	34	5

A fine exposure of the upper beds of the Potsdam was seen in the S. W. quarter of Sec. 32, T. 14, R. 2 W., of which the following section was made:

	Feet.
1. Heavy-bedded, hard and compact yellow sandstone, weathers irregularly on the surface	9
2. White sandstone	3
3. Hard and compact yellow sandstone	8
4. Thin-bedded sandstone layers one inch thick, containing numerous *Scolithus*	1
5. Two beds of yellow sandstone, containing *Lingulæ*	4

		Feet,
6.	Hard and compact white sandstone (this is the bed which appears so continuously throughout the valley)	5
7.	Very soft and crumbling sandstone (yellow)	6
	Total thickness exposed	36

Good exposures of the various beds are seen in the cuts of the Chicago and Northwestern Railroad, and especially at the tunnels.

In Sec. 24, T. 16, R. 2 W., are two cuts, made through the shale beds, in which numerous fucoids were found in a blue clay, together with some remains of *Lingula* in the shales, also one bed of hard sandstone, in which were occasional ripple marks. At tunnel No. 2, in the S. E. quarter of Sec. 25, T. 16, R. 2 W., is a fine exposure of the various beds of Potsdam contained in the shales, of which the following section was taken:

		Feet.
1.	Slope of the hill from the top of the Potsdam sandstone to the top of the cut at the tunnel (probably covers sandstone)	72
2.	Yellow argillaceous shales, containing numerous fucoids and some *Lingulæ*, probably the same as those at Lone Rock and other points on the Wisconsin river	10
3.	Heavy-bedded sandstone	12
4.	Arenaceous shales	4
5.	Bed of magnesian limestone, containing geodes of calcite	2
6.	Arenaceous shales	8
7.	Layer of sandstone	1
8.	Very thin-bedded arenaceous shales	10
9.	Bed of friable greensand	1
10.	Conglomerate of greensand and irregular pieces of shale	2
11.	Heavy-bedded sandstone containing *Scolithus* to track	8
	Total thickness	130

Proceeding west from tunnel No. 2, the shales were found in all the cuts at Cook's creek, and east in all the cuts to Wilton on the Kickapoo; from this it appears that the thickness of alternating shales and sandstone is not less than 200 feet, of which the greater part is shale.

Tunnel No. 3 is situated in the N. W. quarter of Sec. 18, T 16, almost six miles from and nearly due west of tunnel No. 2. The top of the Potsdam was here found to be 20 feet lower than at No. 2. The following section was made of the hill and cut at tunnel No. 3:

		Feet.
1.	Bed of ferruginous sandstone, containing pieces of hematite in considerable quantity	25
2.	Soft yellow sandstone to top of cut at tunnel	14
3.	Thin-bedded yellow and white sandstone layers 2 inches thick, crumbles to sand on exposure, contains seams of iron ore	3
4.	Thick-bedded yellow sandstone, layers 2 feet thick	10

		Feet.
5.	Thin arenaceous, calcareous shales, contain fucoids	6
6.	Soft, yellow, friable sandstone, beds 2 feet thick	8
7.	Hard, calcareous sandstone, beds 3 feet thick	9
8.	Thin-bedded sandstone, containing some lime	2
9.	Hard, concretionary blue sandstone, contains *Dicellocephalus Minnesotensis* and fucoids	3
	Total thickness	80

Water is very abundant at this tunnel, and comes out entirely on top of bed No. 7. The calcareous sandstone seems to be impervious to water, or nearly so. The beds dip to the south, and the flow of water appears to be from the north, and being cut off by the tunnel, issues chiefly from the north side, but very little flowing from the south side.

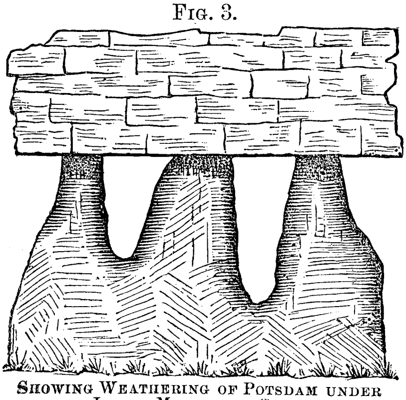
Exposures of the Potsdam. From the observations made during the field work, the following list has been selected, which contains some of the finest exposures of Potsdam sandstone in the state.

(1) On Melancthon creek, in sections 22 and 27, T. 12, R. 1 E., where it joins Pine river, are vertical cliffs about 30 feet high, covered with pines. Continuing down the stream, in section 3, T. 11, R. 1 E., is a very fine exposure of vertical cliffs 50 feet high, forming an unbroken wall in the valley more than a mile and a half long. The rock is white sandstone, with cross-stratification, and large vertical joints at very even distances, usually about fifty feet apart. This formation continues to the village of Rockbridge, in section 10. At this point the west branch of Pine river joins the main stream. On going around the point of the long narrow bluff, which terminates here, it appears that the two streams ran side by side for a short distance, until the west branch, at one of the large vertical joints above mentioned, cut for itself a low arched channel, directly through the bluff, and joined the main stream.

(2) There is a fine Potsdam exposure in the northwest quarter of section 11, T. 10, R. 4 W., where a small creek enters the Kickapoo.

(3) On the Kickapoo, in the S. W. quarter of Sec. 27, T. 9, R. 4 W. The top of the Potsdam is here distinctly marked by a bed of white sandstone fifteen feet thick; above it are the transition beds, and the lower beds of the Lower Magnesian. The Potsdam is also exposed for fifty feet below its junction with the Lower Magnesian, and consists of heavy-bedded white and yellow sandstones. The bluffs in this vicinity present this appearance for a distance of about a mile.

FIG. 3.



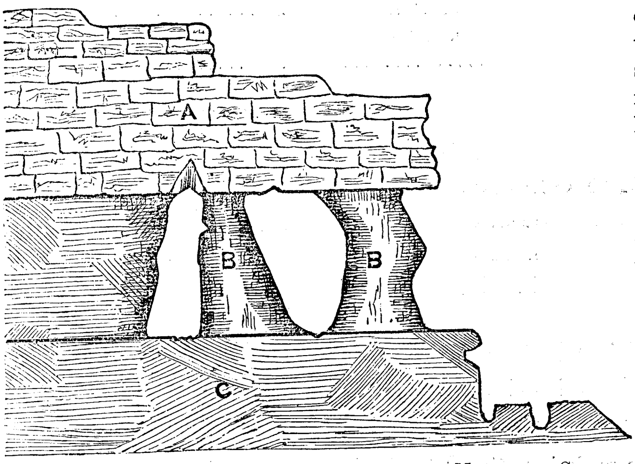
SHOWING WEATHERING OF POTSDAM UNDER LOWER MAGNESIAN CAPS.

(4) The Little Kickapoo, in the north part of T. 12, R. 3 W., exhibits many good exposures of the Potsdam.

(5) There are some remarkable exposures near Readstown, which show the effect of the weather on exposed cliffs. Fig. 3 represents an outlier of Lower Magnesian, supported by rounded columns of sandstone formed by the action of the elements.

Fig. 4 represents another of these exposures situated at the fork of the creek near the center of sec. 7, T. 11, R. 3 W. A is a cap of Lower Magnesian limestone, running out to a sharp point, and supported by the columns B. B., of white Potsdam sandstone. Below them is the bed c., of yellow sandstone.

Fig. 4.



Showing Weathering of Potsdam under Lower Magnesian Cap.

(6) There is a very fine exposure of Potsdam at Peavy's Mill, on the west fork of the Kickapoo, on the S. E. quarter of Sec. 19, T. 13, R. 3 W. It is in a vertical cliff about one hundred feet high, and one thousand feet long, and shows the alternating white and yellow beds very distinctly.

(7) There are fine exposures along the creek in sections 31, 32, 33, 34, of T. 15, R. 4 W.

(8) There are good exposures along the creek near Dorset, in the N. W. quarter of section 27, T. 16, R. 1 W.

(9) On the N. W. quarter of section 5, T. 17, R. 1 E., is a high, isolated bluff, which is an outlier of Potsdam.

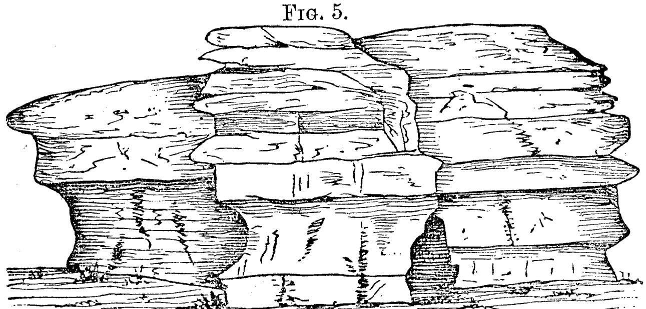
(10) Castle Rock, on the S. E. quarter of section 33, T. 18, R. 4 W., is a high outlier of Potsdam, and forms a very conspicuous object on the crest of the ridge.

(11) A short distance below the mill, on the N. W. quarter of section 26, T. 15, R. 7 W., is a fine exposure of sandstone.

(12) There are good exposures of Potsdam in the S. E. quarter of section 33, T. 17, R. 7 W.

(13) On the N. W. quarter of Section 19, T. 10, R. 2 W., on Knapp creek, the Potsdam is well exposed in a prominent cliff about 160 feet high near the side of the road.

Fig. 5.

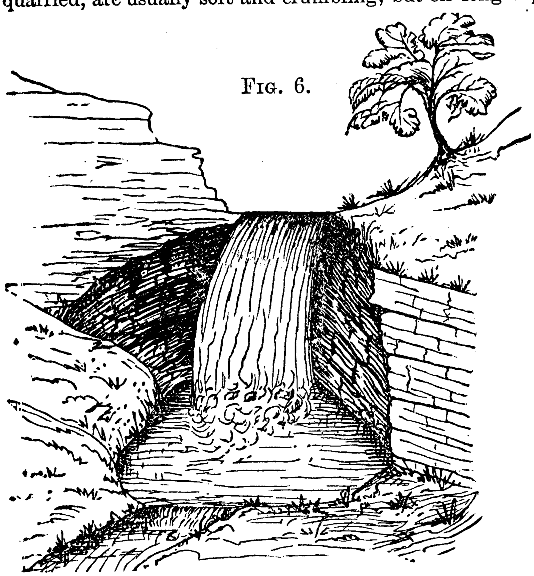


(14) T. 12, R. 2 W. There are very fine and picturesque exposures of the upper portion of the formation on Camp creek in this town, and also on the Kickapoo; one of them, Mt. Nebo, situated a short distance north of Viola, is a very conspicuous object.

(15) Towns 13, 14, 15, R. 2 W. In these townships, in the vicinity of the Kickapoo, two sets of cliffs may be seen: one situated close to the river, and the other consisting of

the upper beds of the Potsdam, near the summits of the hills. The latter, when freshly quarried, are usually soft and crumbling, but on long exposure to the air, the surface becomes much indurated, and the stone is used for foundations. The sandstone forming the lower set of cliffs often rises directly out of the river, and is frequently worn in curious and fantastic shapes by the action of the water. Fig. 5 shows one of these cliffs situated on the Kickapoo river, a short distance below the village of Rockton.

Fig. 6.



Cascade on the N. E. ¼ Sec. 7, T. 23, R. 13 W.

(16) There is a fine exposure of the middle beds of the Potsdam in a deep gorge and small waterfall on the N. E. quarter of Sec. 7, T. 23, R. 13 W. The water falls over a ledge of sandstone about 18 feet high. Fig. 6 is a sketch of the locality.

(17) At Stockholm, on Lake Pepin, there is a fine exposure of yellow, unfossiliferous sandstone on the shore of the lake.

ECONOMICAL PRODUCTS.

The productions of the Potsdam, which are of importance in an economical point of view, are iron, building stone and mineral waters, which will be considered in the order given.

Iron. This mineral is quite abundant in many parts of the territory examined, and especially so in the counties of Richland, Crawford and Vernon. It usually occurs as hematite. The following are the localities where the indications were most favorable for obtaining ore. The material for the analyses was selected with great care, by taking a large number of small pieces from numerous points in the outcrop or ore bed, in order to find the average value of the deposit. The analyses are by Dr. Gustavus Bode, of Milwaukee, and Prof. W. W. Daniells, of Madison.

N. W. quarter, Sec. 12, T. 10, R. 1 W. This is one of the most promising localities examined during the season. It lies near the top of the ridge which divides Horse creek from Brush creek. Commencing where the road crosses the line between sections 11 and 12, ferruginous sandstone is found, of no value except as an indication. Proceeding westward, the ore is found in outcroppings, in a belt from 150 to 200 feet wide, running parallel to the top of the ridge for a distance of a thousand feet. Going east from the aforesaid line, the same belt of ore can be traced nearly a quarter of a mile; thence proceeding south, the same belt and outcroppings are not found for a quarter of a mile, when they again appear, conforming to the curvature of the ridge. At the southern exposure, the bed affords some fine crystallized specimens. The ore seems to be derived from a deposit in one of the upper beds of the Potsdam, and the outcroppings, probably indicate with considerable accuracy the linear extent of the bed. Its thickness and width can only be ascertained by exploration with trenches and pits. There is a large quantity of ore exposed on the surface, in pieces of all sizes, up to thirty pounds in weight, but none were observed in place. The ore is a dark colored and compact hematite. An analysis selected from the southern exposure gave $45\frac{33}{100}$ per cent of metallic iron. An analysis from the middle exposure gave $45\frac{83}{100}$ per cent of metallic iron. These results, although not large, seem to indicate considerable uniformity in the quality of the ore. The deposit is about three miles northwest of Richland Center.

S. W. quarter Sec. 7, T. 10, R. 1 E. The ore at this place is a bright red hematite, found near the point of a ridge, and derived from one of the upper beds of the Potsdam sandstone. Considerable prospecting has been done here by sinking pits through the bed to the sandstone below, which indicate that the amount of stripping would be from two to three feet, and the thickness of the bed of ore about the same. The bed appears to be continuous so far as traced. The facilities are good for removing the stripping, by dumping it over the side of the bluff. The ore could be carried to the valley below in the same manner, or in a slide. I am informed that 10,000 lbs. of this ore were sent to a furnace in 1870, and manufactured into a soft malleable iron. The indications are that this is not a very extensive deposit, but from its softness and bright red color, it appears to be valuable for a mineral paint; indeed some specimens of work were exhibited, on which the ore had been used as a pigment, which showed a very handsome and durable color. An analysis of this ore gives metallic iron $42\frac{16}{100}$ per cent.

A short distance farther up the ridge above mentioned, several holes have been sunk, the principal one being sixteen feet deep. This passed through eight feet of soil and clay, and eight feet of clay and loose masses of ore, which appeared to be more compact toward the bottom; but as the shaft did not reach the lowest portion of the bed, its full thickness was not ascertained. The ore is of a dark brown or black color, and very hard and compact. It is derived from the decomposition or alteration of iron pyrites, as on breaking open some pieces, the pyrites was in an unchanged state in the center, and surrounded by a shell of the ore.

An analysis of the ore gave $45\frac{49}{100}$ per cent. of metallic iron. The land is situated about two miles west of Richland Center. It is leased by Dr. Burnham of that place, but owned by some parties in the eastern states.

S. E. quarter Sec. 30, T. 10, R. 1 E. The ore is found here in small pieces on the surface, near the upper part of the hill. It can be traced along the side of the hill, near the top of the Potsdam sandstone, for a distance of about 600 feet. No prospecting has been done here, consequently there are no means of ascertaining the thickness or width of the bed. The ore nowhere appears in place. It is dark colored, hard and compact, and is the product of the alteration of pyrites. An analysis of the ore gives 44 per cent. of metallic iron. The land is owned by Mr. Pease, of Richland Center.

N. W. quarter Sec. 31, T. 10, R. 1 E. This ore is an earthy red hematite, and is probably more valuable for paint than for iron. It is considerably mixed with clay and sand, and does not appear to be very abundant. It is found near the top of the Potsdam, on the farm of Mr. Lewis. An analysis of the ore gave $42\frac{18}{100}$ per cent of metallic iron.

N. E. quarter Sec. 19, T. 9, R. 1 E. Outcroppings of iron ore are quite abundant here, and consist of small pieces of ore which may be traced from the road in the valley to the upper beds of the Potsdam, from which they are probably derived, near the top of the hill on either side. The pieces are found only on a narrow belt, about fifty feet wide, running across the valley. It seems probable that these pieces, on account of their weight and hardness, have remained from the denudation, and now mark the original course of the bed. No ore was seen in place; it is all imbedded in the soil. The ore is the usual altered pyrites, hard and dark colored, and gives on analysis $38\frac{41}{100}$ per cent. of metallic iron. This land is owned by Mr. A. C. Eastland, of Richland Center.

N. E. quarter Sec. 10, T. 11, R. 3 W. This is the ground operated by the Kickapoo Mining Company, of Readstown. This is a chartered company, and consists of Messrs. Bliss, president; C. Morley, treasurer; Carter, secretary. Other members are Messrs. Purdy, Waters, Nichols, Gott, and General Rusk, of Viroqua.

The first work was done in the winter of 1872; and in the winter of 1873 and 1874 a drift was run into the bluff a distance of fifty feet. The drift was run on a level, according to contract, and, in its course, passed obliquely through the ore bed, which dipped toward the hill.

The ore lies on the surface of the ground, scattered over a considerable area, and near the top of the Potsdam sandstone; some of the pieces weigh as much as twenty or thirty pounds. The ore was not seen in place, as the drift was caved in, and there is nothing on the surface to indicate the dimensions of the deposit. The ore is dark colored, hard and compact, much mixed with red clay, and is produced by the alteration of pyrites. An analysis of the ore gives $52\frac{21}{100}$ per cent. of metallic iron.

N. W. quarter Sec. 8, T. 14, R. 3 W. This is a large surface deposit, consisting of clay, pieces of sandstone, magnesian limestone, chert, sand, red white and yellow clays, ferruginous clay (paint), red hematite, and the dark-colored ore resulting from the decomposition of pyrites. All the foregoing materials are mixed together in the bed, without much regularity, and are in no way connected with the stratified rock beneath and beyond them.

Mr. Philo Taylor, the gentleman who owns the land, has excavated an open cut fifty feet long, and sunk a shaft fifteen feet deep, as represented in Fig. 7. The shaft has passed through the deposit, which is about twenty feet thick, and reached the bed-rock below, which is Potsdam sandstone. Considerable ore of very good quality has been taken out, but it seems necessary to remove so much waste material, that it would not pay to work the deposit as iron ore. In addition to the bright red, soft hematite, there is also found here a plastic red clay, which is very ferruginous. It seems probable that this clay, in connection with the hematite, could be obtained in sufficient quantities to be valuable for the manufacture of mineral paint. An analysis of the red clay gives $53\frac{0}{100}$ of metallic iron; an analysis of the red hematite gives $49\frac{73}{100}$ per cent. of metallic iron; an analysis of the ore produced from pyrites gives $58\frac{24}{100}$ per cent. of metallic iron.

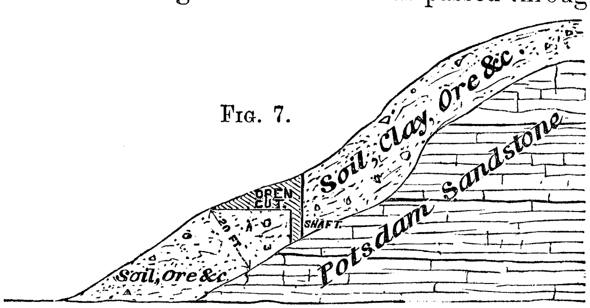


Fig. 7.

N. E. quarter Sec. 20, T. 14, R. 3 W. This locality is on the farm of Mr. C. W. Dyson. In one place a cutting of the road has exposed a surface deposit containing considerable red clay and some fragments of hematite. In examining a small ravine in the vicinity, numerous pieces of ore were found. The ore is of good quality, but does not appear to be very abundant; the clay is quite abundant, but contains only a small percentage of iron. An analysis of the ore gave 50.82 per cent. of metallic iron; an analysis of the clay gave 9 per cent. of metallic iron.

S. E. quarter Sec. 17, T. 14, R. 3 W. At this locality, and in numerous others in the township, the variety of hematite known as red chalk or reddle is found in small pieces, in a ravine which forms the bed of a stream during rains, but nowhere in sufficient quantity to be of much value. Usually the pieces are too hard to work freely. It is known in this section of the country as "keel." An analysis of the red chalk from this locality gave 50.24 per cent. of metallic iron.

In the above mentioned ravine, a number of pieces of iron ore were found, which had evidently washed down from the adjacent hills not far distant, they were nowhere in sufficient quantity to form a workable deposit, but serve to show the general character of ore in this vicinity. The pieces consisted of the soft red hematite, and the hard, compact ore produced from pyrites. An average analysis of the whole gave 56.53 per per cent. of metallic iron.

N. W. quarter Sec. 21, T. 13, R. 3 W. Red clay, ferruginous sandstone, and other indications of iron were found here near the top of the Potsdam sandstone, but no ore bed was found.

Corner of sections 15, 16, 21, 22, T. 14, R. 3 W. On the farm of Mr. Kimar, at this place, considerable ore of good quality is said to have been found.

S. W. quarter Sec. 3, T. 14, R. 3 W. Some very good specimens of hematite have been obtained from this locality.

N. W. quarter Sec. 18, T. 13, R. 2 E. Considerable iron ore of fair quality has been found on this land, which is the property of Mr. Frederick Frieze. The same kind of ore has also been found on the N. E. quarter of section 18 of the same town and range, on land belonging to the River Improvement Company.

The ore is hard, compact, and dark colored, somewhat similar to the ore obtained at Ironton in Sauk county. It is a surface deposit, found on the top of the hill, and near the top of the Potsdam sandstone, but exactly how near, could not be ascertained, as the Lower Magnesian has been denuded. The ore appears to be confined to a place about a thousand feet square, and is found in pieces of all sizes, up to fifty pounds in weight, lying loose in the soil. No shafts have been sunk to determine the thickness of the deposit, but in several places holes have been sunk two or three feet deep, without going through it. Appearances indicate that considerable stripping and removal of waste earth would have to be done to obtain the ore.

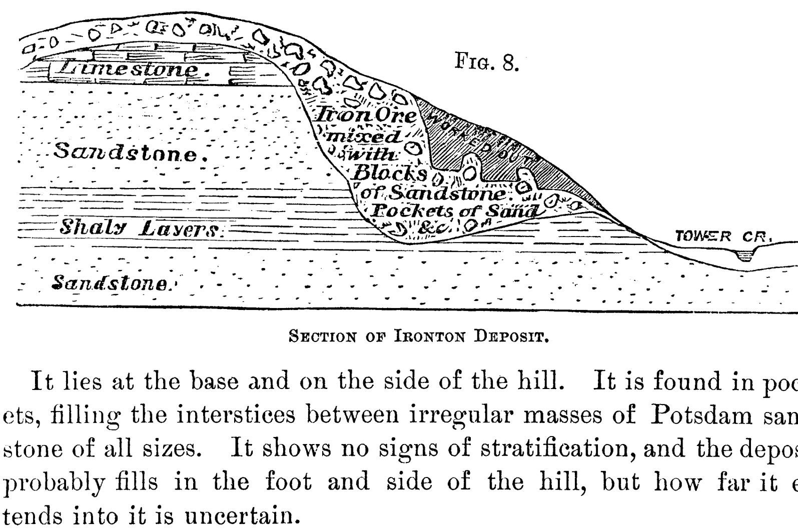
An analysis gives $56\frac{3}{100}$ per cent. of metallic iron.

Ironton Mine. The most valuable and extensive deposit of iron ore observed is at Ironton, situated on the S. W. quarter of Sec. 10, T. 12, R. 3 E.

This deposit, which produces all the ore consumed at Ironton, was discovered previously to 1850, but was not worked until that year. A furnace was then erected and iron has been made every year since with but one or two exceptions to the year 1873, at which time the locality was visited. About 25,000 tons of ore had been mined here, producing 11,000 tons of iron. The metal produced is of a neutral quality, being neither very hard nor very soft. It is mostly consumed in the interior. It is reduced in a hot air blast furnace with charcoal. One seventh of the charge is limestone flux; and 130 bushels of charcoal are required to a gross ton of metal. The charcoal costs eight cents per bushel.

The manner of occurrence of the ore here is shown in Fig. 8.

FIG. 8.



SECTION OF IRONTON DEPOSIT.

It lies at the base and on the side of the hill. It is found in pockets, filling the interstices between irregular masses of Potsdam sandstone of all sizes. It shows no signs of stratification, and the deposit probably fills in the foot and side of the hill, but how far it extends into it is uncertain.

N. E. quarter Sec. 3, T. 12, R. 2 E. Iron ore occurs here in masses of a botryoidal and stalactitic shape similar to the Ironton deposit. The ore is a brown hematite, and does not have much ocher accompanying it. When visited, in August, 1873, the deposit had been worked but a few days. A shaft thirty-six feet deep had been sunk, and considerable ore of good quality taken out. The ore appears to be deposited over about forty acres of ground. It is situated about eight miles from Lavalle, the nearest railroad station.

N. W. quarter of Sec. 10, T. 13, R. 3 E. This was also a recent discovery, and but little ore had been taken out. This seems to be a surface deposit similar to the Ironton bed, and the ore is also a hematite. It does not occur in the stalactitic shape, but has a more crystalline structure. Casts of long, hexagonal crystals are found in some pieces. No limestone was found in the immediate vicinity, which is disadvantageous in view of reduction near the bed. An analysis of the ore gave 59.21 per cent. of metallic iron.

Indications of ore are frequent in outcrops and fragmentary pieces which may be found on nearly all the hills in this vicinity, and many undiscovered deposits similar to those already described probably exist.

On the S. E. quarter of Sec. 13, T. 11, R. 4 E., is also a recent discovery. An excavation has been made about 8 feet deep, 6 feet wide and 25 feet long, from which considerable ore has been taken. Some pieces were observed of good quality, but most of the ore seemed to be a ferruginous sandstone. It is probable, from the lay of the ground, that no large body of ore exists here. Analysis of this ore gave 58.59 per cent. iron.

Center of Sec. 15, T. 12, R. 3 E. An analysis of the ore gave 24.48 per cent. of iron. The locality is on the road from Ironton to Sandusky. Quite numerous fragments were seen at this place. It is probable that the formation of the deposit is similar to that at Ironton.

N. W. quarter Sec. 28, T. 11, R. 3 E. A short distance north of the village of Sandusky, quite a number of spherical concretions of ferruginous sandstone were found. They are not valuable as iron ore, but rather as geological curiosities. An analysis of one of them gave iron 23.26 per cent.

S. E. quarter Sec. 22, T. 10, R. 3 E. Quite a number of fragments of hematite were observed at this place, which is situated on the ridge, and in the Lower Magnesian limestone, which would be found convenient as a flux, if it were found profitable to manufacture it. The ore appeared to be of good quality; the extent of the deposit could not be ascertained. An analysis of the ore gave 59.02 per cent. of iron.

Center of Sec. 23, T. 10, R. 2 E. This locality is situated on the ridge dividing Bear and Willow creeks. There appeared to be a well defined bed, from three to six feet thick. It was observed cropping out in several places, and traced in a southwesterly direction along the crest of the ridge for nearly a mile and a half. It is possible that so much stripping of superincumbent rock would have to be done that it could not be profitably mined. An analysis of the ore gave 31.90 per cent of iron.

Quarter post, Secs. 20 and 29, T. 9, R. 3 E. Considerable ore was seen scattered about the surface of the ground at this place. The larger part of it seemed to be near the junction of the Potsdam sandstone and Lower Magnesian. The ore is a hematite, as is the case in all these localities. It is situated about four miles northeast of Lone Rock. Several varieties of ore were found, of which the following are analyses:

	Per cent.
Analysis No. 1 gave iron	15.24
Analysis No. 2 gave iron	37.95
Analysis No. 3 gave iron	42.06

In general it may be said of the iron ore beds of the Potsdam, that they are surface deposits derived from the upper beds of the formation, which are often very ferruginous. The ore is often of good quality, and tolerably abundant, but usually, in mining, the removal of much rock and useless material would be involved. They are in most cases so far distant from railroads that they cannot now be mined and shipped with profit, especially when so many iron furnaces throughout the United States, favorably situated, and furnished with as good or better ore, find it impossible to work except at a pecuniary loss.

Copper. Ores of this metal are of very rare occurrence in the Potsdam sandstone, no workable deposits having as yet been discovered. A small horizontal sheet of copper pyrites, somewhat mixed with iron pyrites, about an inch thick, was discovered in the bank of the Wisconsin river in the S. E. quarter of Sec. 35, T. 9, R. 1 E. An analysis of it gave 13.78 per cent. of metallic copper.

Building Stone. A very good article of building stone is obtained from the dolomitic layers of the Potsdam, which are usually found about one hundred feet below the upper surface of the formation. The stone is usually of a uniform light yellow color, quite hard, and free from cavities and irregularities; dresses easily, and, when finished, makes a handsome building, and withstands the action of the weather. It usually occurs in thick beds, from two to four feet, and blocks can be obtained of almost any size desired. As these magnesian layers are a very persistent feature of the formation, they are found and used in almost all parts of the country where building stone is required. There are several large quarries of it in the vicinity of La Crosse, on Lake Pepin, and at other points on the Mississippi.

The sandstones of the Postsdam do not usually make a good stone for architectural purposes, as they are so soft and friable that they cannot be obtained in large blocks, and seldom present planes and joints suitable for quarrying. After being exposed to the air, the sandstone loses some of its water and becomes harder. The sandstones are seldom used for anything but foundations, and in structures where regular blocks are not necessary.

Sand suitable for mortar, plastering, etc., can be obtained readily from any part of the Potsdam formation. The only objection to it is, that it is sometimes of too fine a grain for some kinds of mortar. Much of the sand is perfectly white and very pure, frequently containing as little as two per cent. of foreign matter, usually lime and alumina, and there seems to be no reason why it should not be used successfully in the manufacture of glass. It can be obtained in many places of uniform purity and in inexhaustible quantity.

ARTESIAN WELLS AND MINERAL WATERS.

Sparta Mineral Wells. At Sparta there are twelve artesian wells, all situated within a distance of two miles of the central part of the city. They all derive their water from the same stratum, and as the country is very level in the immediate vicinity of Sparta, their depth is uniformly about three hundred feet, and their height of flow from six to ten feet above the surface.

It is claimed that these mineral waters will cure a large and varied list of diseases; but of this we have no personal knowledge. The following is an analysis of the water, made by Prof. J. M. Hirsh, of Chicago.

Solids.	*Grains in one gallon*
Carbonate of iron	14.33501
Carbonate of magnesia	4.03101
Carbonate of lime	0.40202
Carbonate of strontia	0.01402
Carbonate of baryta	0.00600
Carbonate of manganese	0.00072
Carbonate of soda	0.21030
Carbonate of lithia	0.02400
Carbonate of ammonia	0.00210
Sulphate of soda	2.21430
Sulphate of potassa	0.64130
Sulphate of lime	0.18020
Chloride of calcium	0.60502
Chloride of sodium	0.14301
Iodide of sodium	0.00014
Phosphate of soda	0.06400
Phosphate of alumina	0.06080
Silica	0.28000
Hydric sulphide	0.00340
Total	23.21735

In this analysis the Bicarbonates are reduced to Carbonates.

It was found to be impossible to make a descriptive section of the strata penetrated in sinking these wells, no such record having been kept. General information on the subject, obtained from the parties who sunk the wells, leads to the conclusion that the strata consisted entirely of sandstone; that the wells passed entirely through the sandstone, and stopped on encountering the Archæan rocks; and finally, that in all the wells the flow of water originates at or near the junction of the Potsdam and Archæan.

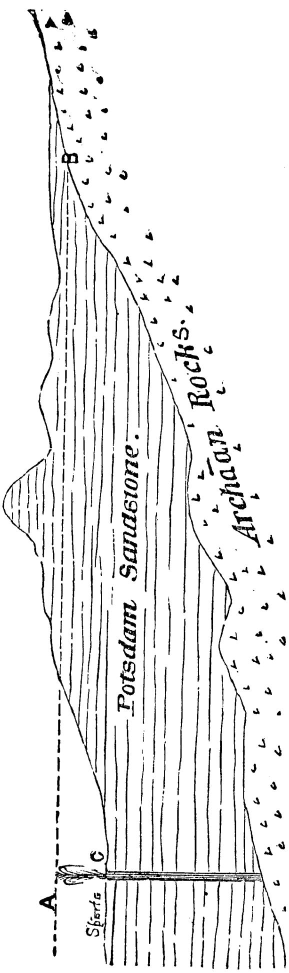


Fig. 9.

Artesian Well at Sparta.

The origin of the water in these wells, and the cause of their flow, may perhaps be explained on the following grounds. North and northeast of Sparta there is a vast tract of country, rising to the north and sloping to the south and southwest, in which the surface rocks are Archæan, and the Potsdam is not found. The drainage being as stated, water would flow over the surface of the Archæan, and on reaching the outcrop of the Potsdam, a part of the water would flow over the surface of the ground, and a part, sinking through the sandstone, (which is porous and easily admits of such action,) would flow down over the surface of the Archæan, below which it could not go. If a well is sunk from any point on the surface, as at C (Fig. 9.) to the Archæan rocks, it is evident that hydrostatic pressure will cause the water to rise in it to a height corresponding in level with the point where the pressure of water is first exerted on the surface of the Archæan, which is represented in Fig. 9 by the dotted line A B. Such is the theory, but in point of fact the water will not rise quite as high, on account of friction, resistance of the air, etc. Finally, if the surface of the ground where the well is sunk is lower than the line of pressure, the water will *flow* to a height approximating it; but if the ground is higher, the water will rise in the well until the level of pressure is reached, and the well will not flow.

The first of these wells was sunk as an experiment in October, 1867.

Since then eleven have been sunk, in and about Sparta, and one in the valley of the Leon, about six miles south of Sparta. They are comparatively inexpensive, the average cost being $250.

Oil City Well. Near the center of the N. W. quarter of Sec. 26, (T. 15), is situated the village of Oil City, otherwise known as Sheldon and Graham's Mill. The locality derives its interest from the flowing artesian well there, situated on the east side of the road. The surface of the ground at the well lies only about four feet above the surface of the Kickapoo. The water rises about twelve feet above the surface, in an iron pipe, and, being confined at the top, spouts out on all sides with considerable violence; it is then conducted away in troughs. It is said that it will rise to a height of twenty-five feet above the surface, if unconfined. Seasons appear to have no influence on the flow, although slight variations in the quantity, of a few hours' duration, have been occasionally noticed. The water produces a red color on the ground, the wooden troughs, and everything with which it comes in contact for a long time.

This well is the result of the oil excitement, which broke out in this section of the country in 1866, which caused the formation of several companies to bore for oil, and the leasing of nearly all the land in the vicinity. The company which sunk this well was composed of seven persons, most of them residents of Sparta. Evidences of mineral oil were supposed to have been seen on the surface of the water in the vicinity; it was probably only the oily scum that frequently appears on the surface of stagnant water, which owes its origin to the decay of organic substances.

The following section of the strata, penetrated in boring this well, was obtained from Mr. M. Graham, one of the owners of the land on which the well is located.

	Feet.
1. Sand and clay	10
2. Gravel	12
3. Quicksand	20
4. Soft sandstone (the well is tubed to this point)	30
5. Hard and compact sandstone	228
6. Opening from which the main body of water flows	4
7. Hard and compact sandstone	186
8. Granite	20
Total depth of well	510

Several veins of water were penetrated in boring the well. The first of any consequence was 90 feet below the surface, at which point the well first flowed to a height of five feet above the ground. The main body of water was found at a depth of 300 feet, at which point the drill dropped four feet, and the water rushed out with great violence.

The water is very pure and clear, and has no perceptible taste, although many persons think it is slightly chalybeate; on being bottled for a few days, and allowed to stand, it gives off sulphuretted hydrogen gas quite freely, and has a singularly disagreeable taste. A qualitative analysis was made of the water by Dr. Gustavus Bode, of Milwaukee, with the following result. He says:

"The water is strongly impregnated with sulphuretted hydrogen, and contains sulphuric acid, chlorine, carbonic acid, soda, lime, magnesia, silica, iron, and alumina, the latter two in very small quantities. The total quantity of salts contained seems not to have been very large; most of the salts are probably contained therein as bicarbonates and sulphates."

Norwalk Mineral Well. In the village of Norwalk, situated in T. 16, R. 2 W., there is a well 19 feet deep, near the store of Mr. George Siebott, which has a chalybeate taste, forms a red deposit on everything with which it comes in contact, and on being bottled and allowed to stand a few days, it gives off sulphuretted hydrogen.

Tomah Artesian Well. In the village of Tomah, situated on Sec. 4, T. 17, R. 1 W., is an artesian well, of which the following section was obtained from information furnished by Mr. George Lea and others:

	Feet.
1. Soil and clay	25
2. White and yellow sandstone	375
3. Gray rock	17
4. Red rock	35
5. Soft, green chloritic rock	10
6. Very hard micaceous rock	30
Total depth	492

Nos. 5 and 6, and perhaps Nos. 3 and 4, of this section are probably in the Archæan rock, but no fragments sufficiently large could be obtained to determine the formation. The well failed to flow, the elevation of the ground, 390 feet above Lake Michigan, probably being too great to admit of subterranean water rising to the surface.

La Crosse Artesian Well. During the year 1876, an artesian well was sunk at La Crosse, of which the following section has been obtained.[1]

	Feet.
1. Loose materials	170
2. Shale	11
3. Calcareous sandstone	145
4. Very coarse white sandstone	201

		Feet.
5.	Red marly rock	5
6.	Fine sandstone	5
7.	White granular granite	36
	Total	573

The thickness of Potsdam in the vicinity above the well is about 400 feet.

Prairie du Chien Artesian Well. During the winter of1875–76 an artesian well was sunk at Prairie du Chien, of which the following account has been obtained from information furnished by Mr. Horace Beach of that place. The strata penetrated in sinking the well are as follows:

		Feet.	Inches.
1.	Sand and gravel	147	..
2.	Fine light blue clay	..	2
3.	Hard arenaceous limestone	2	..
4.	Blue grit	6	..
5.	Bluish-green, argillaceous shale	107	..
6.	White friable sandstone, alternating with hard streaks	118	..
7.	Blue grit	35	..
8.	Slate rock	65	..
9.	Reddish and yellow-ochery sandstone	6	..
10.	Shaly rock	24	..
11.	White sandstone	4	..
12.	Slaty rock	75	..
13.	Sandstone	310	..
14.	Red sandstone	45	..
15.	Conglomerate of white, waterworn, quartz pebbles	5	..
16.	Coarse sandstone	10	..
	Total thickness	959	2

The diameter of the well is $5\frac{5}{8}$ inches, and it is tubed with wrought iron pipe through the first and second numbers of the above section, and 18 inches into bed No. 3.

The water rises in the tubing 60 feet above the hill where the well is situated, and about 100 feet above the level of the Mississippi river at low water, and discharges, by measurement, 869,916 gallons in 24 hours. The water is clear and sparkling, a little brackish to the taste, and has a temperature of 56° Fah. at the surface.

In bed No. 6 of the above section, at a depth of 268 feet from the surface, the water flowed to the top of the tubing, continuing to increase through the stratum.

In bed No. 9 the water increased, and in bed No. 11 a vein of brine was struck; from bed No. 13 to the bottom of the well the amount of water was greatly increased.

[1] I am indebted to Prof. Chamberlin for the above section.

With regard to the source of the water in the well at Prairie du Chien, it may be remarked that the strata rise gradually to the north, and very rapidly to the east for a few miles; so that it is not impossible that the flow of the water is in this case from the east or northeast, although it cannot be regarded as certain.

The surface of the river valley at Prairie du Chien is but a few feet below the upper surface of the Potsdam, and from the shallowness at which flowing water is obtained, we must infer that the water is not exclusively derived from the upper surface of the Archæan rocks — as is the case with the wells at Sparta — but from several different layers of the sandstone.

The elevation of the ground at Sparta, on which the wells are situated, is 215 feet above Lake Michigan. At La Crosse the elevation is 75 feet, and at the Prairie du Chien well, 64 feet. There is therefore an antecedent probability that flowing wells could be obtained in the valley of the La Crosse river from Sparta to its mouth; in the valley of the Mississippi from La Crosse to Dubuque; in the valley of the Wisconsin from its mouth to Arena; and perhaps in the lower parts of the Grant, Platte and Pecatonica rivers. There are, however, liable to be exceptions to this, of which the failure to obtain a flowing well at La Crosse is an instance.

Jordan Mineral Well. A well, said to possess medicinal qualities, is situated in the village of Galesville, in Trempealeau county, at the residence of Dr. Wm. M. Young. The well is situated on the upper table or flat on which the village is built, and lies in the valley of Beaver creek. The well is sixty-five feet deep; it was sunk for household purposes, and does not flow. The following analysis of the water was made by Dr. Bode.

	Grains.
Chloride of sodium	0.1792
Sulphate of soda	1.9744
Bicarbonate of soda	0.8904
Bicarbonate of lime	6.5000
Bicarbonate of magnesia	8.1632
Bicarbonate of protoxide of iron	2.6632
Silica	0.2880
Alumina	0.6832
Organic matter	0.4816
Total solid salts in one gallon	21.8232

Fine springs are very common in the Potsdam formation. They usually escape from the surface of some clay layer, or some close-grained sandstone. Their water is usually much softer than that of the springs in a limestone region. A number of them were tried

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ARTESIAN WELL AT PRAIRIE DU CHIEN.

with a thermometer, and their temperature was always between forty-six and forty-nine degrees Fahrenheit, or about the average temperature of the earth near the surface.

PALEONTOLOGY.

It is not the intention in this portion of the report to do anything more than to indicate briefly the species found, and to describe the localities where they may be obtained, for the benefit of collectors and others who are interested in this branch of the science. For full descriptions and lists of fossils, the reader is referred to the paleontological section of the report.

List of Localities.

Section 6, T. 13, R. 3 W. In this section, and at many other places on the west fork of the Kickapoo, there are beds of greensand and friable sandstone, containing numerous fucoids and fucoidal impressions.

Sections 20 and 29, T. 14, R. 3 W. The sandstone about the creek contains fragments of *Dicellocephalus*, *Lingula* and *Fucoids*.

T. 14, R. 1 E. In the vicinity of Hillsboro in this town, *Scolithus* are quite numerous in the Potsdam sandstone ledges about the river.

N. W. quarter Sec. 15, T. 18, R. 6 W. Specimens of *Dicellocephalus* were obtained from some thin bedded sandstone, by the side of the road, near the summit of the ridge.

N. W. quarter Sec. 27, T. 18, R. 9 W. Trempealeau Mountain. This is an excellent locality from which to obtain several species of *Lingula*, and at the height of 110 feet above the river is a layer containing numerous good specimens of small *trilobites*, and fragments of large ones.

S. E. quarter Sec. 4, T. 18, R. 8 W. On Beaver creek. A small white *Lingula* is quite abundant at this locality.

N. E. quarter Sec. 29, T. 18, R. 7 W. Fine specimens of *Lingula* and small *trilobites* were obtained from an exposure of thin-bedded sandstone, in a small hill by the side of the road.

S. E. quarter Sec. 3, T. 18, R. 8 W. At Gales Ferry on Black river. At the ferry used in low water, on the north side of the river, some strata of Potsdam crop out near the surface of the water, which are full of fragments of *Obolella polita* and *trilobites*. The sandstone is rather soft and friable, and contains only casts of the fossils, the shell in most cases being removed. Fine specimens were obtained here of several varieties of *Lingula*, and some small *trilobites*. Some of the sandstone higher up in the bluff is full of small white *Obolella* shells, about one eighth of an inch in diameter.

N. W. quarter Sec. 25, T. 19, R. 9 W. This is in the valley of the Trempealeau river. There are numerous exposures of sandstone containing *Obolella polita*, by the side of the road in this quarter section.

N. W. quarter Sec. 33, T. 19, R. 8 W. At the mill in the village of Galesville, and in the bluffs which border the stream to the bridge below. This is an excellent locality from which to obtain *Obolella polita*, *fucoids*, and small *trilobites*. The sandstone here belongs to the lower members of the Potsdam.

Quarter post Secs. 33 and 34, T. 20, R. 8 W. Fine specimens of large and small *Lingula* shells and casts, and a few *trilobites* were found here. The sandstone is so soft that it is somewhat difficult to procure specimens, but it becomes harder on exposure.

S. W. quarter Sec. 23, T. 19, R. 7 W. *Obolella* shells are found in nearly all the sandstone exposures about Hardy creek, in this vicinity.

N. W. quarter Sec. 29, T. 20, R. 10 W. Small but good specimens of *Obolella* are found in the red sandstone in this vicinity.

S. W. quarter Sec. 23, T. 25, R. 13 W. By the side of the main road are exposures of dark colored sandstone containing several species of *trilobites* in great abundance.

The foregoing are some of the best of the localities discovered during the field operations. They are all convenient of access, and will repay examination. The northern part of La Crosse, and the southern part of Trempealeau counties have been much more prolific of organic remains than any other part of the territory examined. In Crawford, Richland and Vernon counties, the occurrence of fossils in the Potsdam is comparatively rare. This leads to the inference either that the conditions under which the strata were deposited were unfavorable to organic life; or that after the shells were deposited, their calcareous matter was removed by water percolating through the sandstone, so that no further trace or memorial of the shell remains. The latter of the two suppositions appears to be the more probable, as casts are occasionally found in nearly all the members of the formation.

LOWER MAGNESIAN LIMESTONE.

The country in which the Lower Magnesian is the surface work, constitutes the greater part of the ridges and valleys about the heads of the small streams and ravines. Its geographical area is about equal to that of the Potsdam. It is an important formation, not only on account of the large territory it covers, but also because by its decomposition it produces a rich and fertile soil on the ridges, and being washed down into the valleys it fertilizes the otherwise barren sand derived from the Potsdam.

In the valley of the Mississippi there is no formation which presents finer or more frequent exposures. Its hardness, and the frequent joints it contains, predispose it to form the lofty cliffs and precipices which form such an impressive feature in the scenery of the river.

At Prairie du Chien the upper and middle portions are exposed, but the entire thickness is not seen until about six miles above the town, when the lower layers are exposed. Proceeding up the river, the formation constantly occupies a higher position in the bluffs until in the vicinity of Black river it is found only in thin outliers, covering the most elevated points.

The northern outcrop of the Lower Magnesian forms an extremely irregular line. Beginning with T. 16, R. 1 E., it may be traced westward nearly to the mouth of the La Crosse river. From here to the

Trempealeau river is a wide tract of country from which the formation has been nearly eroded, and remains only in thin and widely separated outliers.

On entering Buffalo county in its southeastern part, on account of the increased height of the country and the gradual slope of the strata to the northwest, the Lower Magnesian limestone appears in a thickness of from 100 to 200 feet, forming high cliffs and escarpments along the Mississippi from the Trempealeau to the Chippewa river.

The northern outcrop of the formation in Buffalo county lies parallel to the Mississippi and about 18 miles distant from it. On approaching this line a marked change is seen in the topography of the country. The valleys are much wider, and the hills not so high or so steep as near the Mississippi. Probably this appearance results from the original thin deposit of the limestone near its line of outcrop; which being worn away sooner than in the south part of the county, the subsequent erosive action took effect on the softer Potsdam; thus in the same period of time making wide valleys in the northern part of the county and narrow ones near the Mississippi where the thickness of the Lower Magnesian limestone was greater.

In Pepin county the bluffs are somewhat lower and more retreating, and do not afford so many fine exposures of the formation. In Pierce county, from Maiden Rock to Diamond Bluff, the exposures are unexcelled, both on the Mississippi and its tributary streams, and a few miles below Prescott it becomes the surface formation of the greater part of the country.

Lithological characteristics. This limestone is always light colored, embracing all shades of yellow and gray, and is sometimes perfectly white.

In texture the Lower Magnesian is always very hard and compact, the separate grains of which it is composed being seldom distinguishable. It usually presents an indistinct crystalline appearance, but the crystals are never large enough to present distinct faces or a cleavage. The only exception to this is the occasional occurrence of small cavities in the limestone, which are sometimes lined with small crystals of calcite or bitter spar, and very rarely contain iron pyrites.

Exposed surfaces of this formation always weather very irregularly by the removal of the lime through the usual atmospheric agencies; small irregular cavities and hollows are thus formed in all parts, and in cliff exposures small holes and caves are sometimes seen, usually penetrating but a short distance.

Chert. Another characteristic feature of the Lower Magnesian limestone is the occurrence of beds of chert, interstratified with the rock, appearing in large isolated masses, and in separate nodules disseminated through it. The chert is not confined to any particular part of the formation, but is most common in the middle beds, and less frequent in the upper and lower beds. Its surface is often covered with the points of small but distinct crystals of quartz, and when cavities occur in it, they are often lined in the same way. Such cavities sometimes occur which were formerly occupied by shells, that have been removed and replaced by the drusy quartz, and still exhibit the general features of the shell. Prof. Dana, in his Manual, thus explains the formation of flint nodules or chert (pp. 474, 698): "The silica was distributed through the calcareous mud of the sea bottom in the form of *Diatoms*, *Polycystines*, and the silicious spicules of sponges, and therefore was in the soluble state; and the solution of this silica took place within the mass of the deposit. The tendency of matter of one kind to concrete together led to the forming of flint-nodules; and the tendency to aggregation around some foreign body as a nucleus, especially when such a body is undergoing chemical change or decomposition, explains the frequent occurrence of fossils within flints."

In the country bordering the Mississippi, above the Trempealeau river, the Lower Magnesian does not contain nearly so much chert and other silicious material as in the southern part of the state. Calcite is, however, of more frequent occurrence. In the bluffs near Fountain City, in Buffalo county, it exists in small irregular layers and masses of a few inches in diameter, quite transparent and cleavable, filling cavities of the rock and sometimes giving it a brecciated appearance.

The composition of the Lower Magnesian is somewhat liable to variation in different parts of the formation. Usually, however, it is a highly magnesian limestone, and its average composition is as follows:

Carbonate of lime	51
Carbonate of magnesia	41
Water, insoluble matter, oxide of iron and alumina	8
Total	100

The formation of magnesian limestone is attributed by Dana[1] and others "to the reaction of the magnesian salts of the ocean's waters, in evaporating basins, on the calcareous material of the bottom. The magnesia can have come only very sparingly from corals, shells, or other calcareous relics, animal or vegetable, and must therefore, have been introduced from outside. As the dolomites are of all ages, in-

[1] Dana, Manual of Geology, p. 696.

clude the majority of the earth's limestones, and have often a wide continental extent, no magnesian mineral springs can be adequate for their production, excepting the great ocean itself."

The lower beds are much more arenaceous than any others of the formation, as they contain considerable silicious sand, apparently derived from the Potsdam. These sandy beds, however, seldom extend more than a few feet above the upper surface of the Potsdam.

The Lower Magnesian always overlies the Potsdam conformably; that is, no denudation of the latter appears to have taken place before the former was deposited. The line of demarcation between the two formations is sometimes very distinctly defined by beds of limestone devoid of sand, overlying the white *sandstone of the Potsdam*. The transition beds are, however, usually present, and the Lower Magnesian sometimes graduates almost insensibly into the Potsdam.

The stratification of the Lower Magnesian is very regular and uniform; in some of the exposures, as in the cliffs along the Mississippi river, the same beds can be traced continuously for long distances.

As a general guide to the formation in the country examined, the following section is inserted. The section is designed to show only the general composition of the formation, and it is not to be inferred that each individual layer or its equivalent can be found in any part of the country. For instance, the flints in layer No. 16 must be regarded as local, as it is not usual to find them in such large quantities so low down in the formation.

Section No. 6.

Section of a bluff in the Mississippi valley, S. E. quarter Sec. 6, T. 7, R. 6 W.:

		Feet.
1.	Slope of hill covering Lower Magnesian limestone	45
2.	Hard, flinty, light-colored limestone	15
3.	Heavy-bedded limestone, with disseminated flints	10
4.	Beds of yellow limestone from one to two feet thick containing no flint.	8
5.	Limestone containing numerous flints	5
6.	Beds of limestone without flint. Layers from one and a half to two feet thick. Good building stone	7
7.	Heavy-bedded limestone with irregularly dissiminated flints. Hard and compact	14
8.	Limestone containing regular layers of flint	24
9.	Alternating beds of limestone and flint	15
10.	Fine-grained, light-colored limestone	3
11.	Slope of hill covering limestone	16
12.	Quarry-rock, consisting of thin beds of limestone, each one foot thick, containing no flints	3
13.	Heavy beds of limestone, streaked with light-colored bands	7
14.	Alternating beds of limestone and flint, the latter being in layers sometimes three feet thick	22

	Feet.
15. Hard, light-colored limestone....................................	3
16. Beds of flint, from six inches to two feet thick, alternating with thin layers of limestone to the bottom of the hill......................	10
Total..	207

The bottom of this section is not far from the top of the Potsdam, although it is not exposed in the immediate vicinty.

Thickness. The greatest thickness which the Lower Magnesian is found to attain anywhere north of the Wisconsin river is in the northern part of town 12, range 6 west, where it is two hundred and fifty feet thick. The least thickness observed was one hundred feet; this occurred in the N. W. quarter of Sec. 5, T. 9, R. 5 W. Its average thickness may be stated at about one hundred and seventy-five feet These measures of thickness refer to localities where the formation is overlaid by the St. Peters.

Unconformability. From the foregoing measurements it will be seen that the Lower Magnesian is subject to great variation in its thickness, which can only be satisfactorily explained on the theory that the St. Peters sandstone is not conformable to the Lower Magnesian, as has been discovered by Prof. Chamberlin in the eastern part of the state. No single outcrop has been seen in the western part of the state which satisfactorily exhibits this unconformability, yet the great differences in elevation of the upper surface within short distances, combined with the regular and undisturbed stratification, can only be explained by the above supposition.

Exposures. The following is a list of localities, where the exposures at the Lower Magnesian limestone offer facilities for the study of the formation, or where some local peculiarities exist.

In Sections 16 and 17 of T. 15, R. 3 W., in the valley of a small stream. The Lower Magnesian crops out in a series of ledges from ten to thirty feet high. The entire thickness in this vicinity is one hundred and fifty feet, and nearly all parts of the formation are exposed in the various outcrops. Numerous handsome isolated pillars exist in the sides of the valley.

S. E. quarter Sec. 14, T. 11, R. 3 W. At this locality the junction of the St. Peters and Lower Magnesian is clearly marked by a bed of soft, yellowish-white clay, about four feet thick. This clay resembles the pipe clay of the Trenton limestone, found in the Lead region.

At De Soto, on the Mississippi river, the Lower Magnesian limestone affords a fine, close-grained and durable building stone. It is of a very light color, and often nearly white.

N. E. quarter Sec. 26, T. 13, R. 5 W. In the village of Springville, and along the banks of the stream a short distance below the village, the Lower Magnesian presents good outcrops and is extensively quarried. It occurs in beds from one to four feet thick, of a light yellow color, free from flints, and makes a very handsome building stone. It is much used for foundations.

T. 14, R. 6 W. Along the Raccoon creek are numerous good exposures of the lower beds of the formation.

Section 6, T. 7, R. 6 W. There are many fine cliff exposures of Lower Magnesian, overlaid with bluffs of St. Peters.

N. W. quarter Sec. 18, T. 8, R. 6 W. Along the Mississippi river there are long, continuous cliff exposures of the formation, overlying the upper beds of the Potsdam, and affording good opportunities to examine the transition beds.

At River Falls, in Pierce county, the river flows through a deep and narrow gorge in the Lower Magnesian, making several small falls with fine and extensive exposures of the formation.

The foregoing are a few of the finest of the many exposures with which the country abounds; in general they may be found on all streams, and particularly along the valley of the Mississippi. There is, however, much sameness about these exposures, and they are not as interesting as if search in them was awarded with fossil remains.

ECONOMICAL PRODUCTS.

No very extensive or valuable deposits of metallic ore are found in the Lower Magnesian formation in the southwestern part of the state. A few localities of copper and lead exist, which show that the formation is not entirely destitute of metallic contents. Economically considered, this formation is most useful in affording good building stone and lime, both of which articles are abundant in all parts of the country where the Lower Magnesian limestone becomes the surface rock.

Copper. Traces of this valuable metal are found in many places in the Lower Magnesian, and it does not seem to be confined to any particular stratum of the formation. Small pieces have been picked up on the side hills, and in the dry beds of small streams, which on analysis have yielded very fair results. Copper is also occasionally seen in small seams in some of the cliff exposures of the formation; but it is not present in large and inexhaustible quantity. It sometimes occurs combined with sulphur, but never in its native state. The principal localities where ores of this metal are found are the following:

Plum Creek Copper Mine. The lands in which copper has been found in this vicinity are the N. E. quarter of the S. W. quarter and the N. W. quarter of the S. E. quarter of section 26, T. 8, R. 5 W., in the valley of Plum creek, a small tributary of the Kickapoo, and about two miles above its junction with that stream.

The existence of copper ore at this place has been known for the last twenty-five years, and small quantities have been from time to time extracted; but it was not until the year 1860 that any systematic attempt at mining was begun. The following items of ownership and operation were obtained from Mr. John Coil, a gentleman residing on the land. The land was bought in the year 1858 or 1859, by a company of five gentlemen, residents of New York city, who commenced work in 1860, and abandoned it in 1861, on account of the civil war. The time of their operations extended over a period of nearly two years; since which time no work has been done. The operations of this company seem to have been only preliminary steps, and consisted in sinking a great number of prospecting holes, from ten to thirty feet deep, in nearly all of which small quantities of ore were obtained. The holes are still to be seen at various places on the side of the hill, from the top to the bottom. After doing this prospecting, the company concentrated their efforts at a point on the side hill about one hundred and fifty feet above the upper surface of the Potsdam, and excavated a horizontal drift for a distance of two hundred feet into the hill, the course of which was nearly southeast.

During the progress of this drift considerable ore was obtained, some of which was found lying about the entrance, at the time the mine was examined. The ore was found in small veins crossing the drift, and in pockets; it is of a dark brown color, and is much mixed with iron, containing also considerable malachite or green carbonate of copper disseminated through it in small grains and nodules. The malachite has frequently a radiate structure and sometimes affords good cabinet specimens. In its present condition there is not much to be seen at the mine. The drift and shafts have all fallen in and only serve as evidence of former work.

It is not known how much ore has been obtained here; but I am informed that two car loads were shipped, and that it was customary to burn it before shipping.

An analysis of this ore from specimens selected at the mouth of the drift gives $10\frac{71}{100}$ per cent. of metallic copper. This is a very small result, and Dr. Owen in his report of 1851, states that analyses made by him of copper ore from this locality gave from 17 to 23 per cent. of metallic copper.

Copper Creek Mine. N. E. quarter Sec. 34, T. 10, R. 5 W. The diggings of this locality are situated about three-quarters of a mile southwest of the village of Mount Sterling, and on the side of a hill sloping toward one of the branches of Copper creek. The deposit was discovered in 1843, by Mr. William T. Sterling, a resident of the village, from whom most of the following information was obtained.

The deposit was first worked by Mr. Sterling and Mr. George Messersmith, paying a tribute of one-sixteenth to the government. During this time a specimen was sent to the patent office weighing three hundred pounds. In the course of these operations twenty thousand pounds of ore were taken out; the best part of the deposit appeared to be exhausted, and work was suspended for two years. Some of the ore obtained by them was taken to Mineral Point and reduced in the furnaces at that place.

In 1846 the ground was leased to a German company, who worked it about a year, their work being chiefly drifting and prospecting, after which time they abandoned it as unprofitable.

The property remained idle until 1856, when it was leased to a New York company, who worked from May to September, producing twenty thousand pounds of ore, at a cost of about four thousand dollars; since which time the land has never been worked, and is now held under a tax title by the heirs of A. W. Pelton.

Such, in brief, is the history of running operations at this place. At present, there is nothing to be seen here except a few deep shafts and numerous prospecting holes. The shafts and underground workings are caved in and impassable. The mining appears to have been confined to the Lower Magnesian formation, and most of the ore was found high up on the hill, lying on the west side of the divide which separates the Kickapoo river from the Mississippi.

Of the manner of occurrence of the ore but little could be learned, except that it was found in loose ground, lying between a nearly vertical wall-rock of limestone, having a north and south course, and the western side of the hill. It does not seem to have formed a well defined vein, but rather an irregular bed conforming to the surface of the ground. Considerable ore in detached pieces, or float, was also found in the immediate vicinity.

Satisfactory specimens for analysis could not be obtained from this locality; a single specimen was presented, which gave 17.09 per cent. of metallic copper. As this cannot be regarded as a fair average, the following analysis is inserted from Owen's Report of 1852:[1]

Water	11.2
Carbon acid	5.0
Insoluble silicates, with a trace of oxide of iron	8.3
Protoxide of copper	25.0[2]
Protoxide of iron	48.7
Protoxide of manganese	.2
Alumina	.6
Carbonate of lime	.8
Loss	.2
Total	100.0

[1] Owen's Geological Survey of Wisconsin, Iowa and Minnesota, p. 54. [2] 19.87 of metallic copper.

N. E. quarter Sec. 35, T. 12, R. 4 W. On the side of one of the hills near the center of this tract there are a great number of shallow holes, said to have been sunk about twelve years since in search of copper. Whether any was found or not is uncertain. At the time they were visited in 1875, nothing could be found except some small fragments of iron ore of no value. These diggings were in the inferior beds of the Lower Magnesian. On the opposite side of the valley, in the S. E. quarter of sec. 34, T. 12, R. 4 W., near the town line, there are similar vestiges of old diggings; and I am informed, on good authority, that some copper was found here, but the precise amount is not known.

S. E. quarter Sec. 17, T. 14, R. 3 W. A piece of copper ore weighing about fifty pounds was found in one of the ravines in this vicinity. It was evidently washed down from the adjacent bluffs of Lower Magnesian limestone. It consisted of copper pyrites mixed with malachite, and yielded on analysis 23.25 per cent. of metallic copper. A large deposit of ore of this quality would be very valuable.

A specimen of copper ore was presented to the survey from Mr. Brown's farm in the town of Webster (T. 13, R. 3 W), which yielded on analysis 15.07 per cent. of metallic copper.

The foregoing are the only localities, so far as could be ascertained, where copper has been found. The ore always presents the same characteristics, -being hard, dark-colored, and brittle, mixed with oxide of iron, and malachite in small quantities. In general, the deposits do not seem to be sufficiently extensive to be of much economic value.

Lead. The existence of lead in the Lower Magnesian formation in this state has long been a subject of much controversy; many denying its existence altogether, while others are ready to believe in its presence in large quantities.

It is well known that the lead mines of Missouri are situated in this formation, and the question very naturally arises: if it exists there in large quantities, so as to be profitably mined, may not the same be true of our own state?

Inasmuch as there are only certain portions of the lead region which are productive of lead, and as it has been found to be a useless waste of time and money to mine in those parts which experience has proven to be unproductive, attention is now directed to the Lower Magnesian formation, in the hope that its mineral deposits will prove to be such that the lead mines will regain their former flourishing condition.

In view of these important considerations, every fact connected with the occurrence of lead in this formation is important, and it is advisable to record everything which can be elicited relative to this question.

Small pieces of galenite or sulphuret of lead are occasionally found on the sides of the bluffs and in the dry beds of the small ravines. Their seams and particles of the same ore are sometimes found in the cliff exposures of the Lower Magnesian, but the ore is never very abundant. The following list embraces, so far as could be ascertained, all the localities where this ore has been found. It will be noticed that they are all in the vicinity of the lower part of the Kickapoo valley, except the localities near Orion.

Orion Lead Mine is situated on the N. E. quarter of the S. W. quarter of sec. 28, T. 9, R. 1 E., about three miles northeast of the village of Orion, in Richland county, on the summit of the ridge dividing Ash and Indian creeks.

It is owned and operated by Messrs. Levi Houts and E. B. Andrews, of Orion, who were engaged during portions of the years 1871–72–73, chiefly in the winter season, in developing this mine. Their attention was first directed to this place by finding small pieces of lead ore, known as float mineral, on the surface of the ground in several of the adjoining ravines. Several small shallow shafts were then sunk, and considerable prospecting was done with varying success.

They then decided to sink a shaft from the top of the ridge through the Lower Magnesian formation, with a view of proving the ground with respect to the existence of flat openings. This shaft was sunk to the depth of 86 feet. The greatest thickness of Lower Magnesian limestone on this ridge is 155 feet, consequently there remained from the bottom of the shaft to the top of the Potsdam sandstone an unexplored thickness of 69 feet of limestone.

At the time the mine was visited, August, 1873, work had been suspended for the summer, the windlass and other mining appliances removed, and water was standing in the shaft so that it was impossible to go into it.

The following very accurate description of the strata penetrated in sinking the shaft was furnished by Mr. Houts, who kindly accompanied us, and explained all the interesting features of the ground.

The first lead ore which was discovered was lying on the surface of the rock, at a depth of forty feet below the surface. This was in all respects similar to the float-mineral of the lead region; it was crystallized in small cubes about an inch square, many of the surfaces and edges presenting the appearance of having been worn away by the action of some dissolvent. The original faces of many of the crystals were marked by a shell of white carbonate of lead, while the interior had been partially dissolved out. All of these characteristics are also common to the "float-mineral" of the lead region.[1]

Passing through six feet of gray limestone, a cave five feet high was found, filled with a very fine, bright red clay, and some lead ore. The ground here was quite loose and easily worked, and this appears to have been the first regular and well defined opening. The shaft was then sunk through twenty feet of very hard and compact dolomite, in which were found occasional pockets containing galenite coated with small crystals of quartz; a mode of occurrence never found in the lead region, yet one which might reasonably be looked for in the Lower Magnesian, where quartz crystals are so frequently found. A second well defined opening was then found, about two and a half feet high, from which considerable ore was taken. The ore is described as occurring in this opening in small pillars, the rest of the opening being filled with loose rock and earthy material, known in the mines as sand. It is a noticeable feature of this opening that the ore occurred in small cubes resting on the loose rock immediately under the cap rock.

After passing through eighteen inches of rock, a third opening about eight inches thick was found, filled with sand, and containing no ore. On examination of the rock, it seemed probable that these two beds were constituent parts of what has been termed the second opening.

Below this was found a very hard, close-grained rock, two feet thick, of a bluish color, containing small pockets, and irregular masses of white flints; corresponding nearly in color, texture, and irregular distribution, to the flint beds of the Galena limestone. From here the remainder of the shaft was sunk through a fine-grained dolomite, and little or no ore was discovered.

The total product of this mine has been 6,300 lbs. of lead ore, mostly taken from the shaft, during the process of excavation; and, al-

[1] A specimen of this ore gave an analysis:

	Per cent.
Lead sulphide	68.93
Lead carbonate	15.17
Sesquioxide of iron and alumina	5.45
Insoluble siliceous residue	9,75
	99.30
Metallic lead	71.46

though no large body of ore has been discovered, yet sufficient has been found to establish beyond a doubt its occurrence in flat openings in this formation. A remarkable feature of this shaft is that it was not sunk on any crevice, and that the several openings are not connected by any seam or vein.

Akan Mine. Some mining has also been done on this ridge, about two miles northeast of the preceding locality. The shaft is situated on the N. E. quarter of the N. W. quarter of Sec. 22, T. 9, R. 1 E. The ground is the property of Mr. Robert Akan, of Richland Center, who, with his son, devoted most of the summer and fall of 1873, and a part of 1874, to sinking shafts and general prospecting. Considerable work has been done and a small amount of lead ore, galenite, found in the shape of float mineral.

The thickness of Lower Magnesian on this part of the ridge is 110 feet. A shaft has been sunk on the summit to a depth of 60 feet. The first forty feet was through clay, in which was a large quantity of chert, called quartz at the mine. This chert or quartz was analyzed, and found not to contain anything of any value.

On reaching the solid rock the flint disappeared, and the shaft was sunk the rest of the way through the limestone, without finding anything of any economic value.

Various places on this ridge afford evidences of the existence of lead in this formation. Several pieces have also been found at various places on the ridge dividing Bear and Willow creeks from Pine river. Among such localities may be mentioned the S. E. quarter of Sec. 14, T. 10, R. 2 E., and the S. E. quarter of Sec. 4, T. 9, R. 2 E.

At the first of these two localities some prospecting has been done in past years. A vein of lead ore was discovered about half an inch in thickness running in a northwest course. It was abandoned because nothing very remunerative was found, and on account of the excessive amount of water.

Little Kickapoo Lead Mine. N. W. quarter Sec. 10, T. 7, R. 5 W. The diggings at this place are situated in the upper part of a bluff on the north side of the Little Kickapoo, a small tributary of the Wisconsin river. Lead ore was first discovered here about the year 1840, and was worked at intervals until the year 1850. The greater part of the ore was found near a ledge of limestone which forms the point of the bluff, and not far from the upper surface of the Lower Magnesian. The ore occurred usually as float, in pieces from an ounce to several pounds weight, sometimes quite near the surface, but usually at a depth of about twenty feet; and in one instance as deep as eighty feet. Small cubes or dice-mineral, mixed with flint was the prevailing form. In some instances it was found in small flat openings, the crystallized ore being mixed with ochre and clay. Small sheets of iron pyrites were also occasionally found. The ore sometimes occurs in vertical crevices having a general northeast and southwest direction; on one of these crevices a shaft was sunk to a depth of eighty feet, but without obtaining much ore.

There are also several caves and irregular openings in the vicinity, which have the same general course as the crevices. One of them is now open, and I explored the first chamber, which is about fifty feet in length and ten feet high. I am informed that there are several branches to the cave, and that it extends into the hill a distance of three hundred and fifty feet. It does not present any metalliferous indications, and was probably formed at a much later period than the deposition of the ore. A short distance from this is a second cave, which enters the hill on a steep incline, and is now filled up with clay and rubbish washed down from the side of the hill. Its location is indicated by a large sinkhole. A shaft was sunk in it seventy feet deep. About one hundred prospecting holes have been sunk about this bluff, all within a short distance of each other, and from three to five feet deep, from which the greater part of the ore was obtained. Mr. Lathrop, a gentleman who lives on the land, informs me that four or five men worked here during the whole of one winter and "made wages;" and he estimates that from twenty-five to fifty thousand pounds of ore have been obtained from the ground, as the product of all mining operations. The Lower Magnesian limestone is here about two hundred feet thick, very regularly stratified, and in the upper and middle portions, very full of flint. The fossil *Receptaculites*, or lead coral of the Lead region, also occurs here.

An average analysis from specimens collected on the ground gave 82.35 per cent. of metallic lead; from which it will be seen that the ore is of a very fine quality, and equal to any found in the lead region.

A small body of ore was also found on the opposite side of the valley, on the S. E. quarter of Sec. 9, at a depth varying from five to twenty-two feet.

About a quarter of a mile northeast of the principal locality, and also on the N. W. quarter of Sec. 10, another small body of ore was found, consisting entirely of float. Ten prospecting holes were sunk here, averaging twenty feet in depth.

Near the quarter post of sections 3 and 10, a third small body of ore was discovered, as float near the surface.

S. half Sec. 15, T. 7, R. 5 W. About one hundred pounds of ore were obtained from some locality in this half section, but the precise spot is not definitely known.

South part of Secs. 33, 34, 35, T. 8, R. 5 W. There are some diggings in the south part of these sections, near the town line, on the upper part of the hill sloping to Plum creek. They were found when the country was surveyed by the government, and it is not definitely known by whom they were made.

Small quantities of galenite are said to have been found on the N. E. quarter of Sec. 35, T. 25, R. 16 W., in Pierce county, in opening a quarry in the limestone.

While on the subject of lead, we desire to mention a specimen of lead, or galenite, which was plowed up on the farm of Mr. L. Thomas, near Reedsburg, in Sauk county. It was found on the S. E. quarter of Sec. 26, T. 12, R. 4 E., and was in the form of a solid mass, weighing eleven pounds, and in all respects resembling the ore of the Lead region. An analysis of it gave this result:

	Per cent.
Lead sulphide	98.01 [1]
Insoluble silicious matter	.12

The above specimen, occurring isolated as it did, and not "in place," can hardly be supposed to have originated in the vicinity, but was probably dropped there in the course of transportation.

An examination of the above described deposits of lead ore, lead us to conclude that it is not extensively or generally distributed through the Lower Magnesian limestone in the country north of the Wisconsin river. If it were present in large bodies, as is the case in the Galena limestone of the Lead region, it could not fail to have been long since discovered and utilized, as the country is everywhere intersected with valleys and ravines, which expose all parts of the formation, and there is no covering of drift to conceal it.

The occurrence of lead ore in this formation so closely resembles that of the Galena limestone, that it seems more than probable that the ore is the result of agencies which are similar in their action and effects, if not identical. Assuming that the agencies are similar, it follows that a similar distribution of ore would be the result; which is true to this extent, that the deposits in each are local and comprise but a comparatively small part of the entire formation. If we assume that the agencies were identical, we might fairly expect that the deposits of lead in the Lower Magnesian would be most extensive in the vicinity of the deposits in the Galena limestone; and the barrenness of the Lower Magnesian in the country in which it is so largely ex-

[1] Equivalent to metallic lead, 84.88 per cent.

posed would be no argument against its productiveness in certain localities, any more than the absence of lead ore in the greater part of the Galena limestone, in the lead region, is an argument against its productiveness in certain districts. There are, however, many reasons why we cannot fully accept or reject the latter alternative, chief among which are the intervention of a non-metalliferous formation — the St. Peters — and the unconformability of the Lower Magnesian with it.

In view of the scarcity of facts bearing on this question, it seems as if no satisfactory conclusion can be reached unless it is experimentally, as by drilling in the vicinity of the mines.

Building stone. Wherever the Lower Magnesian is exposed, there is always an abundance of good building stone. This is more especially true of the inferior members, which contain less flint, are more uniform in texture, and have a hardness and compactness which enable them to withstand the disintegrating effects of exposure to the elements. The lower beds of the formation are usually found in heavy regular beds, very suitable for quarrying.

Among the best and most extensive quarries observed are those at Prairie du Chien, and at Springville in Vernon county. On Trempealeau mountain, Hale's quarry furnishes two varieties of white limestone. The stone is very hard and seems somewhat silicious; it is quite crystalline, and takes a handsome finish.

On the S. E. quarter Sec. 31, T. 19, R. 10 W., is a fine quarry where a white crystalline limestone is obtained. It is conveniently loaded on the cars which run to the foot of the hill.

Flemming's quarry, between Pepin and Durand, also furnishes a handsome stone, somewhat similar to that from Hale's quarry.

There are also a great many small quarries throughout the country, which it is not necessary to particularize; their location may be seen on the map.

Lime. The Lower Magnesian formation affords lime with as much facility as building stone. All parts of the formation which are free from flint will produce lime on burning. The best lime is that obtained from some of the upper beds, and from the inferior strata. It is, however, necessary to use care in selecting from the upper beds such parts as are free from the cavities which sometimes contain quartz, and in the lower strata to avoid the transition beds which frequently contain considerable sand. There are numerous lime-kilns in the country examined, and in nearly every instance lime is obtained from some member of the Lower Magnesian. Owing to the large percentage of magnesia contained in the Lower Magnesian, the lime obtained from it is somewhat hydraulic and slakes slowly. This quality may be regarded as rather advantageous than otherwise.

The best quality of lime is that obtained from the stalagmitic deposits which are occasionally found. They are recent deposits of carbonate of lime in a nearly pure state, usually of a pure white color, and found in irregular beds, having filled up preëxisting caves in the rock, as more particularly described on page 96 of this report.

The following is a list of the principal localities where lime is burned; in addition to these there are perhaps some others so situated that they escaped the observation of the survey. The stone used is always some stratum of the Lower Magnesian, and the fuel used is wood, which the country furnishes abundantly. The kilns are of the simplest form and construction, and are sometimes nothing more than a rude excavation in the side of a steep bank.

Crawford County.

N. W. quarter Sec. 35, T. 9, R. 3 W. The kiln is situated on the west side of one of the small branches of Knapp creek, and supplies the surrounding country.

N. W. quarter Sec. 19, T. 11, R. 4 W. and **S. W. quarter Sec. 21, T. 11, R. 4 W.** These two kilns are situated on Horse creek, a tributary of the Kickapoo, and about a mile from the village of Towerville. They supply the small towns on the Kickapoo and vicinity.

S. W. quarter Sec. 9, T. 9, R. 5 W. This kiln is situated about a mile west of the village of Seneca, at the head of a small ravine emptying into Copper creek.

Richland County.

N. W. quarter Sec. 19, T. 9, R. 1 W. This kiln is situated near the Eagle cave hereinafter described. It is owned and operated by Mr. Orrin Henry, and furnishes considerable lime.

N. E. quarter Sec. 30, T. 12, R. 1 E. This kiln is situated about a mile and a half north of Woodstock, and supplies that place, together with Spring Valley and the adjacent country.

N. E. quarter Sec. 19, T. 9, R. 1 E. Two kilns have been operated here, and an excellent quality of white lime is made from a stalagmitic deposit. It is free from the grayish tint usual in lime produced from the Lower Magnesian. The deposit is worked by Mr. A. C. Eastland, of Richland Center.

There are also several kilns in the vicinity of Richland Center, which supply most of the lime used in that part of the country.

Vernon County.

N. E. quarter Sec. 12, T. 12, R. 7 W. This kiln is situated near the forks of the Bad Axe river, and supplies the lime used in that valley.

S. W. quarter Sec. 11, T. 11, R. 7 W. The kiln is about one mile and a half north of the village of De Soto; most of the lime is consumed at that place.

N. E. quarter Sec. 24, T. 14, R. 5 W. This kiln is near the head of a small branch of Raccoon creek. Only a small amount of lime is produced here.

S. E. quarter Sec. 27, T. 12, R. 5 W. The kiln lies about two and a half miles southwest of the village of Liberty Pole. The lime produced here supplies the adjacent region.

S. W. quarter Sec. 15, T. 13, R. 4 W., and **N. E. quarter Sec. 23, T. 13, R. 4 W.** These two kilns are on the heads of small tributaries of the Kickapoo, and are distant about three and a half miles northeast of Viroqua. They supply the lime used at this place, and in the country for several miles around them. The first one is known as Wallace's kiln.

Monroe County.

S. W. quarter Sec. 31, T. 17, R. 1 E. This kiln is situated on the northern line of outcrop of the Lower Magnesian, and about seven miles southeast of Tomah. It supplies a large extent of country.

S. W. quarter Sec. 22, T. 17, R. 2 W. This kiln is situated on an isolated outlier of limestone, about six miles southwest of Tomah.

N. W. quarter Sec. 12, T. 16, R. 3 W. There are two kilns at this locality which produce considerable lime.

S. W. quarter Sec. 28, T. 18, R. 4 W. The kiln at this place is situated at the foot of a high bluff capped with limestone; it being an isolated outlier. Considerable lime is produced here, most of which is consumed in Sparta and the vicinity.

La Crosse County.

S. E. quarter Sec. 26, T. 15, R. 6 W. This kiln is situated at the head of the Morman coolie, and supplies the adjacent country.

The greater part of the lime used in La Crosse county is imported, either on one of the railroads, or brought down the river; but little is manufactured in the county.

Trempealeau County.

S. E. quarter Sec. 25, T. 19, R. 9 W. This kiln is situated about two miles west of the village of Galesville. Lime is produced from small outliers of Lower Magnesian capping the bluff.

On the south side of Trempealeau Mountain, a short distance above the village, is a kiln producing lime from the limestone on the upper part of the hill.

Buffalo County.

N. half Sec. 9, T. 19, R. 11 W. Lime is manufactured here from the Lower Magnesian, supplying Fountain City and the neighboring country. There are also two kilns on the S. W. quarter of Sec. 5 of the same township.

W. half Sec. 35, T. 22, R. 13 W. There are two lime kilns situated about a mile, and a mile and a quarter above the village of Alma. They supply this part of the country.

In the counties of Crawford, Richland, Vernon, Monroe and La Crosse, there are but few kilns where lime burning is regularly and continuously carried on. This is in consequence of the limited demand for lime, caused by the infrequency of stone and brick buildings. The inhabitants live usually in log houses, and occasionally in frame houses; stone and brick buildings are confined to the railroad towns, and the lime is usually brought by rail. It is also a common practice among settlers, when about to build, when only a small quantity is required, as for a cellar or a foundation, to make a rude kiln and burn for themselves the quantity desired. This is the more easily done because limestone and timber are so abundant; and at the same time, by lessening the demand, it tends to discourage lime burning as a business.

Paleontology. In the department of paleontology but little has been or can be done, owing to the great scarcity of organic remains, and the unsatisfactory condition in which they are found. The total number of specimens obtained is only eight, and are as follows:

No. 1. A specimen of *Receptaculites*, found at the lead mines on the Little Kickapoo, previously mentioned, page 76.

No. 2. A specimen of the same, found on the S. W. quarter of Sec. 25, T. 19, R. 9 W., near the top of a high ridge capped with outliers of Lower Magnesian.

No. 3. Silicified specimens of *Euomphalus Strongi* of Whitfield, found on the S. E. quarter Sec. 32, T. 9, R. 1 E.

No. 4. Silicified specimen of the same as No. 3, from the N. E. quarter Sec. 35, T. 11, R. 3 E.

No. 5. A silicified specimen of *Streptelasma*, found on the S. W. quarter of Sec. 6, T. 9, R. 4 W., on Hall's branch.

No. 6. A small, fragmentary specimen of an *Orthoceras*, in which the several chambers are only one-sixteenth of an inch wide. It is possible that it is a piece of an *Cyrtoceras;* the specimen is so broken and imperfect that it is difficult to decide.

No. 7. A fragment of cast of some variety of *Cyrtolites*, found at the same locality as No. 1.

No. 8. A cast of the inside of a *Holopea turgida,* found on the N. W. quarter Sec. 18, T. 13, R. 2 E., in the course of explorations for iron ore.

The fossils, so far as observed, are not confined to any particular stratum or part of the formation, but appear to have been best preserved where the carbonate of lime has been replaced by silica. The original shell does not appear in any instance to be preserved.

ST. PETERS SANDSTONE.

Owing to the elevation attained by the several formations, through their gradual rise in a northerly direction, and to the great and general denudation to which the country has been subjected, the St. Peters sandstone, north of the Wisconsin river, is only found in isolated areas of comparatively small extent, and confined to the highest parts of the ridges.

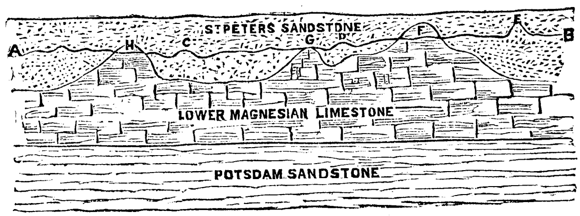
It frequently happens that the St. Peters manifests itself in the shape of prominent mounds and cliffs of sandstone, sometimes visible at a considerable distance, which, owing to some local peculiarity of their composition, usually the presence of iron as a consolidating material, have withstood the wear which has disintegrated the remainder of the formation, and now remain as monuments projecting from the crests of the divides and their adjacent spurs.

There is another phenomenon noticeable in those portions of the country where the St. Peters is found, which may be thus briefly described. It may often be observed in traveling along the crest of one of the principal dividing ridges, as, for instance, the one dividing

Pine and Eagle rivers, that mounds and other surface exposures of the St. Peters sandstone occur, and that in other adjacent parts of the same ridge which are as high, or even higher, the Lower Magnesian is found in place. This apparent irregularity may be easily understood and explained on the theory of unconformability between the two formations previously alluded to in this chapter.

Figure 10, which is an ideal section, explains the unconformability, and shows how the sandstone and limestone may alternate on the same ridge and at the same elevation.

FIG. 10.



It may be supposed that the denudation of the country has advanced until the upper surface is represented in section by the line A B. We may then find points of sandstone as at C, D and E, alternating with exposures of limestone as at F, G and H; and if the limestone is sufficiently hard to resist disintegration, it may even be found relatively higher than the sandstone, as is represented at H.

It also frequently happens that portions of a limestone ridge are covered with loose, irregular boulders of sandstone, and that the sandstone cannot be found in place anywhere in the vicinity. Such boulders are usually quite hard, and appear to be the only remaining relics of the St. Peters.

Lithological Characteristics. The appearance of the St. Peters sandstone is very similar in all parts of the country, and does not differ materially from the exposures south of the Wisconsin river, except that it is not usually found of a pure white color, but generally yellow, or some shade of brown, being more or less colored with iron.

Frequently the ferruginous matter is sufficient to form a very hard and compact sandstone, which may be often seen in the mounds and cliff exposures. Occasionally, the iron forms small, irregular concretionary masses.

Stratification. The stratification is usually very irregular, and the rock does not readily divide by means of planes and joints. The peculiarity of cross-stratification of the subordinate layers, already described as occurring in the Potsdam, is occasionally seen in the St. Peters; it is not, however, such a characteristic feature. No traces of organic remains have been discovered.

Composition. The formation is composed almost entirely of silicious sand, with little admixture of foreign material except the small amount of iron already referred to; the individual grains of sand which compose the stone are always very fine and small.

Thickness. The thickness of the St. Peters is very variable, and depends upon the amount of irregularity of the upper surface of the Lower Magnesian limestone underlying it, and upon the general denudation of the country. Its original thickness is seldom found, and only in those portions where the Trenton still exists. The greatest thickness noted is one hundred and fifty feet; this occurs in the S. W. quarter Sec. 9, T. 9, R. 5 W., about a mile west of the village of Seneca.

Economical Products. No minerals or ores of any metals have been found in this formation. Building stone of fair quality might be obtained from the St. Peters; it is, however, seldom used, on account of the difficulty of quarrying it, and because the Lower Magnesian affords a much better stone, and dresses in better shape, with less trouble.

Exposures of the St. Peters Sandstone. The country in which the St. Peters is the surface rock has been somewhat briefly mentioned in the description of the several townships given in the first chapter. Much has been done to accurately define the limits of the formation, and it has resulted in the discovery of a large number of localities where the existence of the formation was heretofore unknown and unsuspected.

Previous to the present survey, all that was definitely known regarding the occurrence of this sandstone north of the Wisconsin river was delineated on the excellent map published by the late Dr. I. A. Lapham, in 1869. On it, four large areas are shown.

The first embraces a large tract of country in towns 7, 8 and 9, ranges 5 and 6 west. The second is a large area in towns 10 and 11, range 5 west. The third is a small one west of the town of Viroqua. The fourth passes diagonally through T. 14, R. 4 W. They are all situated on the ridge dividing the Mississippi and Kickapoo rivers.

The St. Peters formation, as it is now known, is as follows: The four areas mentioned above are component parts of one large area, extending from T. 6, R. 6 W. to T. 14, R. 4 W., a distance of about fifty miles. On the west it approaches to the Mississippi in T. 10, R. 6 W., and may be traced along the bluffs of that river and all its tributary streams, in a belt varying from a mile in width on the north, to a quarter of a mile wide opposite Prairie du Chien. Thence along the bluffs of the Wisconsin and its tributaries, to the Kickapoo. On the eastern side of the divide it is seldom found more than two or three miles from the principal ridge, but as the country descends more gradually to the Kickapoo than to the Mississippi, it covers relatively a much larger area than on the western slope; and in T. 10, R. 5 W., it is the surface rock over about one-half of the township.

Exposures. The country just described embraces many fine exposures, among which may be mentioned the following:

1. The mounds near Mt. Sterling, which are chiefly composed of sandstone.
2. A ledge 50 feet high near the quarter post of Secs. 15 and 22, T. 8, R. 5 W.
3. A mound on the S. W. quarter of Sec. 34, T. 8, R. 5 W.
4. A ledge 50 feet high, near the quarter post of Secs. 20 and 29, T. 8, R. 5 W.

The following exposures in Crawford county are situated on the ridge between Knapp creek and the Kickapoo; they are also new discoveries:

T. 8, R. 4 W. The St. Peters is the surface rock in parts of the following sections 1, 2, 11, 12, 13, 14, 15, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32, 33, 34. Its total area is a little more than seven square miles. There is one good exposure, where it forms a mound in the S. E. quarter of Sec. 2.

T. 8, R. 3 W. A branch of the same range extends into this town, through Secs. 6, 7, 16, 17, 18, 19, 20, 21, 29, forming an area of about three square miles, with one fine ledge exposure near the center of Sec. 7.

T. 9, R. 3 and 4 W. The same sandstone ridge continues in a northerly direction through Secs. 36, 25, 24, of range 4, and through Secs. 31, 30, 19, 18, 17, 16, 15, 10, 9, 8, 4, 5, 6, of range 3, and runs out in Secs. 31 and 32, of T. 10, R. 3 W., comprising a surface area of six sections. There is also an isolated area in Secs. 13, 14, 23, 24, T. 9, R. 3 W., equal to one section.

T. 10, R. 3 W. In this town there are two large isolated areas: The first is in Secs. 22, 23, 26, 27, 35, 36, having an extent of two square miles: The second is in Secs. 3, 4, 9, 16, 17, 20, having an extent of one and a half square miles. On it are four large and prominent mounds, which afford fine opportunities to study the formation.

Vernon County.

In Vernon county, the country in which the St. Peters sandstone becomes the surface-rock may be thus briefly described. At the village of Coon Prairie, Sec. 5, T. 10, R. 4 W., on the ridge dividing the Kickapoo from the Mississippi, this formation forms the surface-rock. A spur of it also extends in a northwesterly direction as far as Sec. 22, T. 14, R. 5 W., forming a belt averaging a mile and a half in width. Proceeding south from Coon Prairie to Viroqua, the sandstone covers nearly all of the western half of T. 13, R. 4 W., and presents the following fine exposures:

1. A mound in the S. W. quarter of Sec. 5, and one in the N. W. quarter of Sec. 8; all near the south line of Sec. 5.
2. Three mounds in the N. W. quarter of Sec. 21; all near the north line of the section, and about 50 feet high.
3. A ridge consisting of ledges of sandstone 50 feet high, extending from near the center of Sec. 17 nearly to the northwest corner of Sec. 18, presenting good exposures through almost the entire distance.

At Viroqua, a branch of the main ridge extends to the west a distance of twelve miles, between the north and south forks of the Bad Axe river. The sandstone on this ridge averages a mile and a quarter in width, with several small lateral branches.

Continuing along the principal divide from Viroqua to the south line of T. 12, R. 4 W., the St. Peters covers nearly all the western half of that town.

In T. 11, R. 4 W., a spur of the principal divide, covered with sandstone from half a mile to two miles in width, occupies the central part of the town, extending from section 4 to section 34.

In T. 11, R. 5 W., the sandstone on the principal divide covers the greater part of the township, with a fine exposure in two mounds near the center of Sec. 5. From the northeast corner of this township a high and very irregular ridge, with numerous lateral branches, extends west nearly to the Mississippi river, dividing Rush creek from the south fork of the Bad Axe river. This ridge is covered with sandstone, the width of the belt varying from one to three miles. There are two good exposures formed by mounds; one a short distance south of the center of Sec. 16, T. 11, R. 6 W., and the other in the southeast quarter of the same section.

In addition to the foregoing, the following isolated areas were discovered in Vernon county:

In T. 12, R. 5 W. in sections 15, 16, 21, 22, an area equal to a section and a half.

In T. 14, R. 4 W. In sections 20, 21, 28, 29, is a sandstone area equal to a little more than half a square mile.

West of the quarter post of sections 34 and 3, on the south line of T. 14, R. 4, W. is an isolated mound of sandstone forming a good exposure.

In Sec. 3, T. 13, R. 7 W. an area of sandstone extending into Sec. 34, T. 13, R. 7 W., comprising about half a section.

In T. 11, R. 4 W., is a large area of sandstone lying on the ridge west of the Kickapoo river. It is situated in sections 1, 2, 11, 12, 13, 14, 15, 23, 24, 25, 28, 33, 35, 36, comprises an area of about five sections, and extends southward into Crawford county.

In T. 12, R. 3 W. On the ridge between the Kickapoo river and its western branch is a narrow ridge of sandstone, about four miles long and a half a mile wide, running through Secs. 2, 3, 10, 11, 13, 14, and ending in Secs. 34 and 35 of T. 13, R. 3, W.

In T. 14, R. 3 W., on the same ridge previously mentioned, is an area of sandstone lying in sections 15, 16, 21, 22, 27, 28, and covering a surface equal to one section.

Richland County.

The following discoveries of St. Peters sandstone have been made in this county. There are seventeen small areas, entirely separated from each other, and all lying on the high ridges which divide the Eagle river from the Pine river and its tributaries on the east side, and from the Kickapoo on the west:

1. A small area of about half a section, lying in Secs. 26 and 35, of T. 10, R. 1 W.
2. A quarter of a mile north of the preceding is an area equal to one square mile, lying in Secs. 23, 24, 25 and 26.
3. In Secs. 15 and 22 of the same town, an area equal to half a section.
4. An area equal to one and a half square miles lying in Secs. 2, 3, 10, 11, 14, 15, of T. 10, R. 1 W. A good exposure of the formation is seen in a mound near the quarter post of Secs. 3 and 10.
5. An area equal to a quarter section, lying chiefly in Sec. 9, T. 10, R. 1 W.
6. An area equal to a quarter section, lying chiefly in Sec. 3, T. 10, R. 1 W.

7. An area of 80 acres, lying in the S. W. quarter of Sec. 27, T. 11, R. 1 W.

8. A short distance west of the preceding is an area lying in Secs. 28 and 29, equal to one section.

9. A somewhat irregular area of sandstone is found in Secs. 5, 7, 8, 17, 18, of T. 11, R. 1 W., equal to one and a half square miles.

10. This area is situated in Secs. 30 and 31 of T. 12, R. 1 W., and in Sec. 6 of T. 11, R. 1 W., and comprises about one and a quarter square miles.

11. An area equal to one and three-quarter square miles, situated in Secs. 18, 19 and 20, of T. 12, R. 1 W.

12. Traces of the St. Peters are frequently seen in loose blocks of sandstone at many places on the summit of the ridge; this was noticed first in the N. W. quarter of Sec. 35, T. 10, R. 2 W., on the road. On the line between sections 9, 10, 15 and 16, is an area comprising about half a square mile, where the surface rock is St. Peters; it has here a thickness of about 30 feet.

13. Proceeding in a northwesterly direction, along the divide, to section 4, the St. Peters is found covering nearly the entire west half of the section; extending south into section 9; west, nearly to the center of section 5. Crossing the line into T. 11, R. 2 W., it extends as far north as the N. W. corner of section 33, covering a large part of the west half of that section, and a small area in the east half of Sec. 32. The entire area of St. Peters comprised in this outlier, is somewhat more than one square mile. Numerous detached pieces of a concretionary structure were found here; the thickness of the Lower Magnesian appears to be here 200 feet.

14. A short distance north of the preceding, and separated from it only by a small ravine, is a third small outlier, situated near the quarter post of Secs. 28 and 29, T. 11, R. 2 W., comprising about 80 acres, lying chiefly in section 28.

15. A fourth outlier of St. Peters was found in Secs. 17, 18, 19, 20, 21, of T. 11, R. 2 W., near Sylvan Corners, comprising about a mile and a quarter in area.

16. A fifth outlier is situated in the N. W. quarter of Sec. 15, and the E. half of Sec. 16, T. 11, R. 2 W., its area being about one-half a square mile.

17. The last and largest outlier observed, is situated in Secs. 3 and 4, T. 11, R. 2 W., and in Secs. 32, 33, 34, T. 12, R. 2 W., and comprises an area of a little more than one and a half square miles. It is situated on the ridge south of Camp creek, and is the most northern point at which the St. Peters was found in Richland county.

Monroe County.

Three small exposures of the St. Peters sandstone have been found in Monroe county, on the high ridge which divides the Kickapoo from the La Crosse river, and all in the vicinity of the village of Pine Valley.

1. An area situated in the central part of Sec. 29, T. 15, R. 3 W., and comprising a little more than a quarter section.

2. A very small exposure on the line between sections 29 and 30, and a short distance west of Pine Valley.

3. An area equal to a quarter section, situated in the north half of Sec. 30, T. 15, R. 3 W., and a short distance west of the preceding.

Buffalo County.

There are two small outliers of St. Peters in the southern part of the county, on the ridge between Eagle creek and the Trempealeau river.

1. This is a large outlying area, comprising parts of Secs. 2, 3, 10, 11, in T. 19, R. 11 W., equal to one square mile. It only manifests its presence in making the soil more sandy, in occasional bowlders and fragments of sandstone, and in a few outcrops in place.

2. There is a small area, equal to about half a section, on the same ridge, and a short distance north of area No. 1. The greater part of it lies in Sec. 35, T. 20, R. 11 W.

The above are new discoveries, and serve as connecting links between the outcrops south of the La Crosse river and the following in

Pierce County.

A considerable part of Pierce county has the St. Peters sandstone for the surface rock, especially in the western part.

It is found occupying the upper portions of the ridges between the Isabelle river and Lost creek, between the Isabelle and Trimbelle rivers, between the Trimbelle and Big river, and south of the Kinnikinnick river. It occurs in a large connected area, in which the entire thickness of the formation is frequently present.

In the vicinity of Ellsworth, the county seat, there are numerous exposures of the St. Peters, which is generally a reddish or yellowish sandstone which is lithologically similar to the same formation in the south part of the state. On the road from Ellsworth to River Falls, there are occasional exposures of the St. Peters, and in the vicinity of the latter place it is exposed frequently in sloping hills capped with Buff limestone. The sandstone is here usually very white, and has the line of demarkation from the overlying Trenton very plainly marked. The thickness of the St. Peters in this part of the country is about 100 feet.

The situation of the above described outliers of the St. Peters indicates somewhat of the former extent of the formation. The country between the Trempealeau and La Crosse rivers has undergone a much greater amount of denudation than the rest of the territory adjacent to the Mississippi, probably for the reason that the original deposit of Lower Magnesian was thinner, or it may have been exposed to denudation for a longer period before the formation of the St. Peters; consequently there are now no outliers of the St. Peters remaining in it. From the height at which the outliers of sandstone occur in Buffalo county, and south of the La Crosse river, taken in connection with the regularity of the stratification between them, it seems almost certain that this portion of the country was submerged during some portion of the period of the St. Peters, and must have participated in that formation; and it is probably true that there was at one time a continuous belt of St. Peters extending from near Hudson, on the St. Croix, southeastward, and covering all, or nearly all, of La Crosse, Vernon, Crawford and Richland counties. How wide this belt may have once been, or how far it extended from the Mississippi river, northeastward, does not now appear; it is not improbable, however, that it covered all the Lower Magnesian limestone which is now exposed, and it is possible that its surface extent was much greater.

TRENTON, OR BUFF AND BLUE LIMESTONE.

These two formations, which are usually considered collectively, as is most convenient, are occasionally found north of the Wisconsin river. They usually attain their average thickness, which is about twenty-five feet for each.

Lithological Characteristics. These are the same as in the exposures of the formation in the Lead region. The Buff limestone retains its customary yellowish color, and is, as there, somewhat argillaceous and highly magnesian.

The Blue limestone is fine grained, hard and compact, and very fossiliferous, usually thin-bedded, and, on exposure, bleaches out to a bluish-white color. For a more particular description of these two formations, with sections, reference is made to Volume II of this report.

Economical Products. There are no useful ores or minerals found in this formation, north of the Wisconsin river. The Blue limestone would furnish an excellent material for burning to lime; but it is not used for that purpose.

A very singular deposit was found at the village of Seneca, in Crawford county, in the lower part of the Buff limestone. It forms a small eminence a short distance north of the village. The deposit consists of a conglomerate, formed of quartz pebbles of small size, and sand in large rounded grains, firmly united with iron as a cementing material. The pebbles are seldom more than half an inch in the longest dimension, consisting always of white or transparent quartz, and always smoothly rounded, evidently having been rolled by the action of water.

The extent of the deposit is small, covering only about an acre, and not exceeding five or six feet in depth. Several pits have been sunk in it, and numerous large masses of the conglomerate taken out in attempts to utilize it as iron ore; but on account of the large amount of quartz ore material, which constitutes nearly one-half of the entire bulk, it is useless as an ore.

This deposit derives its chief interest from the fact that it is the only ore of the kind found anywhere in the formation. The rounded appearance of the pebbles appears to point to its origin, and suggests this explanation: First, during the deposition of the Buff limestone, currents of the ocean transported the pebbles from the Archæan territory, depositing them here, and probably in many other places. Secondly, there was afterward a deposit of iron, made possibly by some ferruginous spring, or by some cause operating to precipitate iron from the water of the sea; and finally, in the process of the solidification of the formation, the iron became the cementing material of the conglomerate.

It is not safe to conclude that this deposit was an isolated one, although nothing like it was seen in the large area of the formation exposed in Crawford county. The pebbles were doubtless derived from the north, and it is in that direction that a continuation of the deposit would naturally be expected. It should, however, be remembered that only five or six small outliers of the formation now remain north of Seneca; and it is probable that they were not in the course of the transporting current, and consequently not so situated as to receive the deposit. Doubtless this deposit, whatever its extent and direction may have been, has been swept away in the general denudation of the formation.

The present survey has resulted, as in the case of the St. Peters, in discovering new and extensive areas of Trenton limestone, and in delineating with much accuracy the contour lines of the formation.

The areas of the Trenton, as they were formerly known, are represented on Dr. Lapham's map by an elliptical belt about a mile wide, lying in towns 7, 8 and 9, ranges 5 and 6 west; by a small area situated in T. 11, R. 5 W;. and by six areas in Pierce and St. Croix counties.

These formations as they are now known, form the surface rock in the following tracts of country:

1. In T. 9, R. 5 W. The Trenton is found in sections 3, 10, 11, 15, 16, 17, 18, 19, 20, 21, 29, 30, 31 and 32. In section 20, the Galena limestone appears, and the Buff and Blue form a belt surrounding it. This belt, commencing in section 20, runs southwest to the bluffs of the Mississippi; thence south along that stream and all its tributaries; thence east and north, about the upper parts of the Grand Grès, Little Kickapoo, and Plum Creek; thence north to the head of Otter Creek to the point of departure. Compared with this large tract, all the other areas are small.

2. The Blue limestone is found in Secs. 13, 14, 21, 22, 23, 28, T. 8, R. 4 W., lying on the crest of the ridge, in a long strip about half a mile in width, comprising an area of about two sections.

3. There is also a semi-circular strip in sections 1 and 2 of the same town, extending into Sec. 6 of T. 8, R. 3 W., and forming an area equal to one square mile.

4. T. 10, R. 5 W. In this town the two small mounds near the village of Mt. Sterling are capped with Buff limestone.

5. In T. 11, R. 5 W. is an area of about two square miles, surrounding the village of Rising Sun, lying in sections 14, 15, 21, 22, 23, 26, 27, 35 and on the divide between the Mississippi and Kickapoo rivers.

6. On the same divide, and in sections 15, 16 and 21 of T. 12, R. 4 W., is an area equal to about three quarters of a section, situated about three miles south of Viroqua. This is the most northerly point to which the Trenton formation has been traced in this part of the state.

7. In T. 11, R. 6 W., in section one, is an area equal to half a section.

8. In the same town in section 10, is an area equal to a quarter of a section. These last two areas are situated, on the high ridge which separates the Bad Axe river from Rush creek.

9. There is quite a large area of Trenton about the village of Ellsworth in Pierce county, T. 26, R. 17 W. It is situated in sections 7, 18, 19, 20, and comprises about two square miles. The Trenton has here a thickness of at least 50 feet in many places. The Buff limestone is used for building stone, and is characterized here as in the southern part of the state by having a bluish gray color on fresh fractures, and in time, weathering to a buff color which penetrates several inches from the surface towards the interior. The Blue limestone is less compact than in the southern counties and more inclined to straw color. It is thin bedded and weathers in white rounded pieces.

10. There is a large area in the town of Clifton situated in sections 22, 27, 28, 32, 33, 34, T. 27, R. 19, W., comprising about three square miles.

11. In the same town, in sections 24 and 25, is a small area.

12. In the same town, in sections 29 and 30, is a small area.

13. In Secs. 4 and 5, T. 26, R. 19, W., is a small area.

That the above mentioned outliers are the remains of a formation that was at one time much more extensive, cannot be doubted; but it does not now appear how large the area may once have been over which it was the surface rock. The outliers in Pierce county are so distant from those in Crawford county that we are not warranted in asserting that they were once connected, although it is possible that they may have been.

It is, however, probable that the Trenton was deposited over as great an extent of country as is now occupied by the St. Peters formation, and in the same localities.

Paleontology. The Buff limestone is not as fossiliferous as in the country south of the Wisconsin river. The fossils which are characteristic of the formation are generally present, although somewhat indistinct and imperfectly preserved. In Pierce county, it is characterized by a great number of *Strophomena* remains.

In the Blue limestone the usual characteristic forms were found, and as the stone presents the same lithological appearances of color, texture, etc., as in the Lead region, so also it appears to have supported the same forms of life. In Pierce county it does not show the usual profusion of *Brachiopods*, but is characterized by large branching corals.

GALENA LIMESTONE.

This subdivision of the Trenton period was not found in any part of the territory examined, except in Crawford county, and a small outlier at Ellsworth, in Pierce county. In the former county it is found in a strip averaging about a mile in width, occupying the highest part of the ridge between the Kickapoo and Mississippi, extending from Sec. 20, T. 9, R. 5 W., to Sec. 28, T. 7, R. 6 W., a distance of about fourteen miles. From this ridge the formation extends west, towards the Mississippi, in three small, subordinate ridges; and on the east it extends for a short distance on the ridges between the Grand Grès, Little Kickapoo, Plum and Pine creeks. The formation presents its customary lithological appearances. It is usually hard and compact in texture, of a yellow color, and contains numerous flints disseminated through it. It is almost devoid of organic remains, and has not been found to contain any ores or minerals of value.

CHAPTER III.

QUATERNARY FORMATIONS.

I. The Glacial Period.

In the country described in this report, no deposits which are properly referable to the Glacial period have been found in the counties of Crawford, Richland, Vernon, Monroe, La Crosse and Trempealeau. The broad valley of the Trempealeau river seems to have formed a boundary, below which the glacial deposits were not formed.

The most southerly glacial deposit observed is situated in Buffalo county, on the S. W. quarter of Sec. 14, T. 19, R. 11 W., at an elevation of 380 feet above the Mississippi river. It consists of a small, isolated patch — not over 400 feet in its longest dimension — of small gravel, containing the usual drift materials, such as granite, quartz, trap, etc., but no large bowlders. It lies on the side of a small ravine near the summit of the ridge, and is exposed for a short distance by a road excavation.

A similar deposit was seen on the S. W. quarter of Sec. 3, T. 19, R. 11 W., on the ridge sloping towards Eagle creek, at an elevation of 480 feet above the Mississippi. The materials are fine gravel, containing no large bowlders.

From these points northwestward, to the Chippewa river, patches of drift gravel are found at numerous points, but bowlders are rare. Beyond the Chippewa, bowlders and more considerable deposits of drift occur, but the glacial deposits nowhere appear in very great force within the district under consideration.

II. Champlain Period.

Valley Drift of the Mississippi and Wisconsin rivers. There are numerous places in the valley of the Mississippi, on both sides of the river, where heavy deposits are found of materials foreign to the adjacent formations. The deposits consist chiefly of silicious sand, with some clay and a large percentage of small gravel. The gravel is chiefly composed of smooth rounded pebbles of quartz, granite, trap, and fragments of other Archæan rocks. The pebbles seldom exceed a few ounces in weight. The deposits are, for the most part, stratified, although this appearance is seldom visible, because, whenever an exposure is made, as by a stream cutting through the deposit, the sand and gravel, having but little compactness or coherency, soon slide down and cover the exposed face with a sloping bank.

These deposits are not found continuously in the valley, but only in certain localities, where circumstances seem to have precluded their removal. Such localities are high grounds in the valley, which are never reached by floods, and the sides of the hills about the entrances of small valleys adjacent to the river. In places where the bluffs rise directly from the flood grounds of the river, these deposits are not found.

The following is a list of localities where these sand and gravel beds were observed:

1. At the mouth of Sugar Creek, in section 16, T. 10, R. 6 W., and along the valley of the Mississippi for some distance above and below, these beds occur at an elevation of twenty feet above the river.

2. In the village of De Soto there is a very large deposit, which is found as high as fifty feet above the river.

3. On section 4, T. 11, R. 7 W. About the sides of the valley of a small stream, and at an elevation of twenty feet above the Mississippi.

4. Between the villages of Genoa and Coon Slough, for a distance of about four miles, the deposits are continuous, and as high as fifty feet above the Mississippi.

5. In section 27, T. 15, R. 7 W., in the valley of Mormon Coolie, and along the bluffs east of the city of La Crosse, these deposits exist. From La Crosse as far up the valley of the Mississippi as the observations of the survey extended, the deposits were found spread over the valley and along the base of the enclosing hills, seldom attaining an elevation of more than fifty feet above the river.

6. Along the Black river, within a few miles of its mouth, there are numerous good opportunities of examining the structure of the deposits, where the river has excavated its channel through them. A notable instance is on the west bank at McGilvray's ferry.

7. Along the line of the Chicago, Dubuque & Minnesota Railroad, these deposits may be seen; and especially in the vicinity of Guttenburg and Turkey river.

8. Mr. Whitney, in the Geological Report of 1862, mentions some deposits near Dubuque and in the Catfish valley, consisting of clay, mixed with gravelly materials; and in the same report there is a note of a bed of waterworn materials on the Wisconsin river, fifteen or twenty feet above the river, and twenty feet thick, in which bowlders as large as two or three feet in diameter were observed.

9. At Boydstown, on the Wisconsin river, a short distance above Wauzeka, beds of gravel and small bowlders were seen about twenty feet above the river.

10. A short distance northwest of the bridge at Muscoda, a deposit of sand and gravel occurs thirty feet above the river. Several other localities have been observed.

The circumstances under which the deposits are found lead inevitably to the following *conclusions:*

First. The material of which the deposits are composed was brought down by the Mississippi and Wisconsin rivers from the north, and was derived from the drift remaining after the melting of the great glacier.

Second. The valleys of those rivers were occupied by immense streams of water, extending to the bluffs on either side, filling the valleys to a height now indicated by the gravel deposits, which average about fifty feet above the present water level. The slack-water from these rivers extended up the valleys of the tributary streams, in the same manner as is now seen in the seasons of high water, but to a much greater distance; inasmuch as the present size of the Mississippi and Wisconsin, when compared with those rivers during the Champlain Period, must be insignificant.

Third. There was a period of depression, during which time the valley of the Mississippi was depressed from the mouth to its sources; the depression being relatively greater at the sources than at the mouth. This depression, by decreasing the slope of the valley, slackened the flow of the water, and permitted it to spread out over the valley. The same is also true of the Wisconsin river.

Fourth. The period of depression was followed by one of elevation, during which the deposits were raised to their present level. The absence of terraces in the valleys indicates that the elevation was gradual and continuous, rather than interrupted; the evidence, however, is not conclusive, as such terraces may have been formed and afterwards removed. The elevation took place during the Recent Period, or the one following the Champlain.

It is probable that these deposits, and the corresponding depression, took place during the Champlain Period, because this was a period of universal depression of the interior of the continent. Prof. Dana remarks in his Manual: "The facts show that there was a vast and violent flow of waters down the Mississippi valley, bearing an immense amount of coarse detritus; a result commensurate with the width of the glacier that lay over the upper part of the great valley west of the Appalachians."

In regard to the absence of large bowlders, it may be remarked that the deposits which remain are but a small part of what once was deposited; that they are situated on what was then the extreme edge of the river, where the strength of the current may have been insufficient to transport such large masses; that wherever they were dropped, their great weight would cause them to assume a position near the bottom of the deposit, where they would not readily be visible; and finally, in the second or Alluvian epoch of the Champlain Period, to which I am inclined to refer these deposits, the material brought down by the rivers consisted chiefly of sand and gravel, which was deposited over the earlier or Diluvian beds.

The absence of Champlain deposits on such streams as the Kickapoo and Pine rivers is easily explained by the fact that their sources nowhere enter the drift region; and conversely, it might have been argued that because they have no such deposits, they do not anywhere encounter the drift. In the entire country examined, which includes their sources, no evidence of glacial drift has been found.

Swamps. It will be seen, on an inspection of the maps, that the northern portion of Monroe county, especially towns 18 and 19, ranges one east and one west, consists, to a large extent, of swamp lands drained by the Lemonweir river. These low lands, consisting principally of hay meadow and tamarack swamp, extend to the Wisconsin river, and indeed there is a large portion of the central part of the state in which they form a prominent feature. In 1872, while connected with the survey of the Wisconsin Central R. R., I observed these swamps, extending from town 30, range one east, to the Penokee Iron Range.

Exposures are not common in the vicinity of the swamps, but a few instances were observed near their edges, where fresh water formations had been deposited in the form of regularly stratified layers of clay, intermixed with gravel. It requires no great stretch of the imagination to suppose that the depression of the country known to have taken place during the Champlain Period, in connection with the abundance of water at that time, may have sufficed to form shallow lakes where the marshes and swamps now exist; and that the subsequent elevation of the country by increasing their drainage, has left them in the form of swamps and marshes.

It is reported to me as a fact, by farmers who have been for many years residents of Monroe county, that the marsh and swamp lands are much dryer than they formerly were, and some parts of them are under cultivation. This is often due to artificial drainage, but it is also frequently true where there has been no such drainage; and it is probably true that the swamps are generally becoming dryer, independently of artificial drainage.

III. Recent Period.

During this period there was a general elevation of the country, which resulted in bringing up the Champlain deposits of the river valleys to their present elevation, gradually increasing the velocity of the rivers, and removing the greater part of the drift filling of the valleys, which had accumulated during the Champlain Period. In addition to this, fluviatile deposits were in progress on all the streams, and a general distribution of soil such as is at present constantly progressing.

In the valley of Pine river, a short distance above Woodstock, near the quarter-post of Secs. 25 and 36, T. 12, R. 1 W., is a good exposure of Alluvium, which has been cut away to make the road. It serves to show the materials of which the lower parts of the hills adjacent to the valleys are formed; which materials appear to have been derived chiefly from the higher ground above, and in the immediate vicinity:

	Feet.	In.
1. Black clay soil and vegetable mould	1	6
2. Subsoil, light sandy clay	2	..
3. Interstratified and alternating layers of sand and small pebbles	1	6
4. Sand	..	3
5. Loose conglomerate of sand and pieces of chert from 2 to 5 pounds weight, derived from the Lower Magnesian limestone	3	..
6. Sand	..	2
7. Conglomerate of sand and chert, same as No. 5	4	..
8. Light colored, stratified sand	..	3
9. Conglomerate of small pebbles	..	5
10. Sand	..	3
Total thickness exposed	13	4

It must be remembered that this section is merely local, and not of universal application. It only serves to show the structure of the talus of the hill at this particular spot, and the nature of the materials which compose it. It is not probable that the order of the section would be preserved unchanged even through the distance of a quarter of a mile.

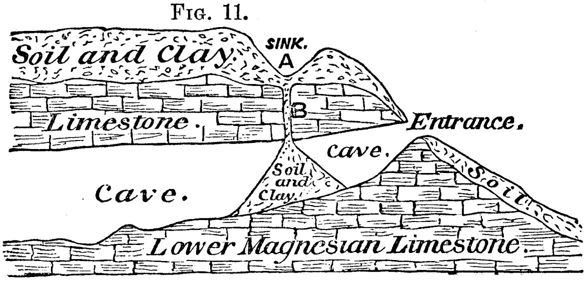
Calcareous Deposits. During the Recent Period, probably, the deposits of carbonate of lime were made in the caves, irregular openings and fissures of the limestone rocks; which we now describe as stalactite, stalagmite and travertine.

One of the finest examples of these cave deposits is that known as the Eagle Cave. It is situated on the farm of Mr. Orrin Henry, on the N. W. quarter of Sec. 19, T. 9, R. 1 W. It lies on the top of the ridge, and in the lower beds of the Lower Magnesian formation; it is nearly horizontal, and counting its various branches and ramifications, it is about a quarter of a mile in length. Its greatest height is about thirty feet, which occurs in one of the chambers. The cave contains several rooms or chambers, connected together by narrow passages somewhat obstructed by large masses of fallen rock. The strata composing the roof are quite level and horizontal, the floor is uneven and irregular, and the width very variable. The roof of the cave is covered with long and glistening stalactites, with long stalagmites rising to meet them from the floor; and over the entire bottom of the cave, encasing the fragments of fallen rock, is a heavy deposit of travertine.

This cave has for many years been a place of resort for visitors, whose vandal hands have to some extent marred its natural beauty. Its present owner, who cheerfully accompanies all visitors through his cave, by preventing the wanton destruction of the stalactites, hopes to restore it, in time, to its pristine beauty. Among other features of the cave, is a spring of cold, clear water, situated in its farthest extremity, and having some undiscovered subterranean outlet.

Sinks. Near the entrance to this cave there is a fine opportunity to observe the surface and subterranean formation of one of the sinks which are so numerous in all parts of the country. On the surface, a short distance from the entrance, is a sink hole presenting the usual appearance of a funnel shaped depression, represented in section, at A, in Fig. 11.

FIG. 11.



CAVE AND SINK.

On entering the cave, we find a large conical mound of earth situated directly under the sink hole on the surface, extending from the floor to the roof of the cave, and almost barring the entrance. The most superficial inspection shows undeniably the origin of the sink. The preëxistence of the cave and the fissure in the roof at B rendered it possible for water percolating the ground to remove a portion of the soil and clay, and form the sink at A, depositing a corresponding amount of clay in the cave.

About seventy such sink holes were noticed, chiefly in Richland, Crawford, and Vernon counties; and it is probable that these are only a small fraction of the entire existing number. They are seldom more than ten or fifteen feet in diameter, and average about five feet in depth. They are seldom visible except in their immediate vicinity. They occur in the Lower Magnesian limestone, and in the St. Peters sandstone, but are more numerous in the limestone. None were observed in the Potsdam sandstone.

The sinks are in all respects similar to the one described as occurring at the Eagle Cave, and are doubtless formed in the same way. They are therefore indications of subterranean caves or fissures.

A study of these caves and sinks, leads to the following conclusions:

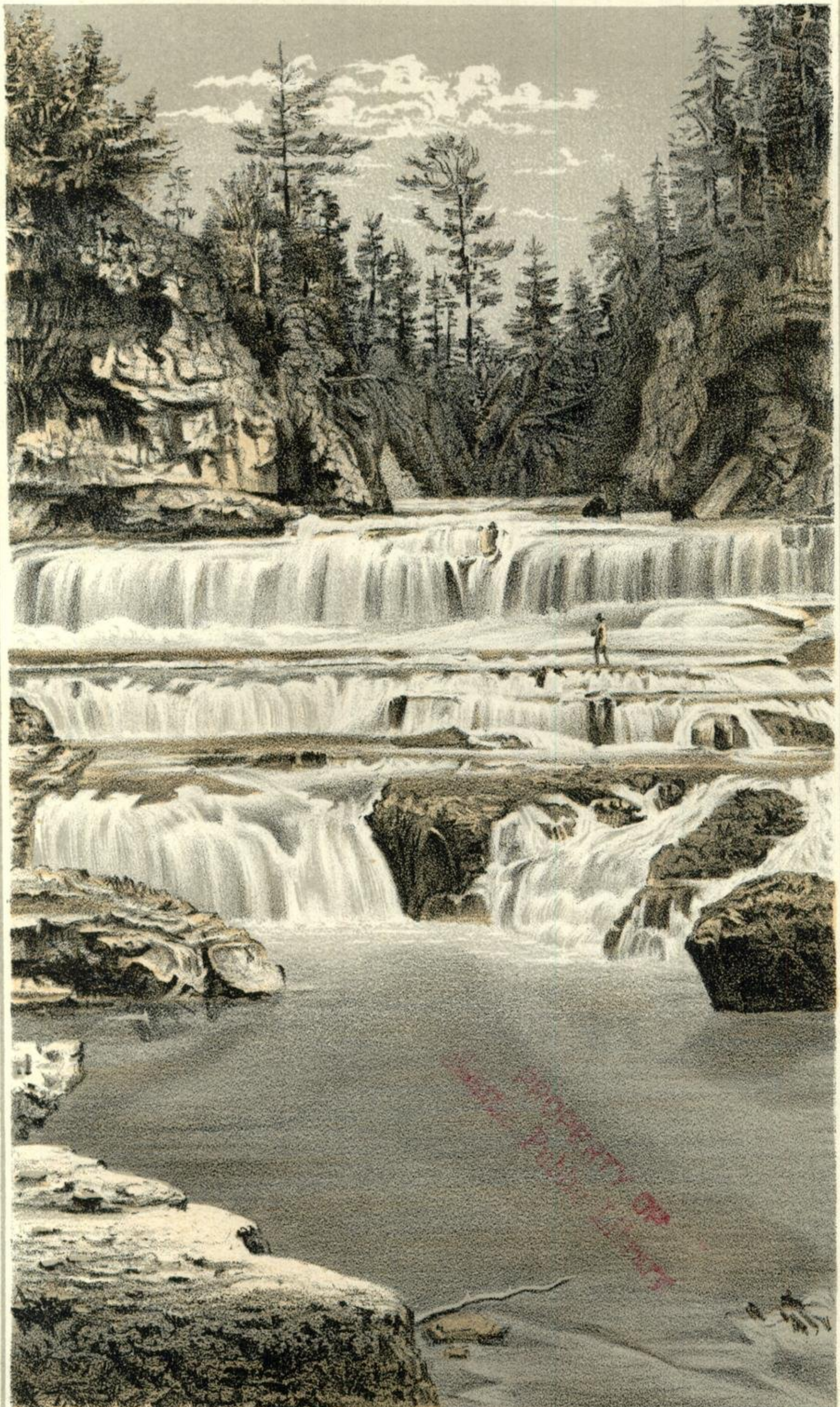
First, there must have been a period in which the materials of the rocks were largely dissolved and carried away by subterranean waters. Springs occurring in limestone districts are invariably "hard water," which is due to the carbonate of lime which they hold in solution. The quantity of lime thus constantly removed must be very great; and as the process has been continuous for a long period of time, it must have resulted in the formation of cavities within the earth, whose size, shape and direction would be influenced and determined by local peculiarities of the formation; such as preëxisting crevices or joints, or the varying hardness and solubility of different stata, or of the same stratum.

In the case of the sandstone, which contains but little soluable material, the cavities are probably due more to an erosion of the sides of preëxisting crevices, and to a mechanical transportation of the eroded particles.

The origin of the stalactitic and travertine deposits, and the process of their formation is thus described by Prof. Liebig: "Upon the surface is a fertile soil in which vegetable matter is constantly decaying. This mold or humus, being acted on by moisture and air, evolves carbonic acid, which is dissolved by rain. The rainwater thus impregnated, permeates the porous limestone, dissolves a portion of it, and afterwards, when the excess of carbonic acid evaporates in the caves, parts with the calcareous matter and forms stalactite; and when they are no longer in the line of drainage, a solid floor of hard stalagmite is formed on the bottom."

In caves and fissures, found where the sandstone is the surface rock such calcareous deposits consequently would not exist.

Before concluding this report, I desire to express my thanks to all those persons who, during the past season, have, in various ways, aided and assisted the corps in the prosecution of their labors; and to the inhabitants who have always received and entertained us with kindness and hospitality.



WILLOW RIVER FALLS,

St. Croix Co.

PART II.

GEOLOGY

OF THE

LOWER

ST. CROIX DISTRICT.

BY L. C. WOOSTER.

T. C. CHAMBERLIN, *Chief Geologist:*

SIR: The accompanying report upon the district assigned to me for investigation during the years 1876-77, is respectfully submitted.

Very truly yours,

L. C. WOOSTER.

GREELEY, *Colorado, June, 1878.*

INTRODUCTION.

The territory described in this report embraces St. Croix and Dunn counties, together with the western range of townships of Chippewa and Eau Claire counties, the northern tier of Pepin, and portions of the two northern tiers of Pierce county.

The limited time at my disposal, and the large area to be examined — over two thousand square miles — obliged me to pass somewhat rapidly over the different portions of the district; but it is believed that sufficient data were obtained to fix with a reasonable degree of certainty all the more important geological features of the above territory.

During the survey of these counties I have had the assistance of Mr. E. M. Hill, who has given especial attention to the vegetation of the district.

Plate IV, giving the distribution of the several groups, is based mainly upon Mr. Hill's field map, and the chapter on vegetation is in part a compilation of his notes upon this subject.

In the construction of sections of rock exposures, I have been obliged to depend largely upon aneroid observations for the elevations of the exposures, so that those given are only approximately correct.

In addition to work in the above area, the northern portions of Buffalo and Trempealeau counties were examined to complete the survey of the same by Mr. Moses Strong.

The data obtained have been sent to Mr. Strong; but one or two sections will be presented with this report, on account of their bearing upon certain important questions discussed in the same.

The formations at Chippewa Falls were also examined, together with the terraces along the Chippewa river south of that point, to complete the survey of the Potsdam sandstone to the Archæan formations, and to gather further data concerning the work of the Champlain period in the northwest.

We found a large proportion of the district lying as nature had fashioned it, though little of it is owned by the United States government, most of the land being in the hands of private parties, lumber companies, and the Fox River Improvement Company. The latter organization has in its possession and offers for sale, some of the finest farming lands this part of the state affords, being situated, in part, in a region where the soil has been built up by wash from the Lower Magnesian limestone, or where the glacial drift still rests upon that formation. There is certainly little need of going to other states or to the territories for cheap *valuable* farming lands so long as our Northwest supports so sparse a population. It is a mistake to suppose that all pine land is poor and unproductive. An exclusively pine region may be nearly valueless for farming purposes, but the best pine seen in this district grows in the midst of oak, maple, etc., trees which indicate the best of soil.

In this forest region, in the central and northeastern portions of the district, outcrops are very rare and wagon roads few and far between, and so it is quite probable that the true northeastern boundary line of the Lower Magnesian limestone may vary somewhat from the one given in the geological map of the district.

Lack of time also forbade an exploration of the northeastern portion of Dunn county, and it is possible that outcrops of granite, etc., exist here in the midst of the area of the Potsdam sandstone shown on the map, though lumbermen, questioned in regard to the nature of the rock, knew of no such exposures.

In submitting this report, I take pleasure in acknowledging the aid of the people of the several counties, who have uniformly given all the assistance in their power, and furnished all the information in their possession to further the objects of this survey.

GEOLOGY OF THE LOWER ST. CROIX DISTRICT.

Outline of Treatment.

- **I. GENERAL FORMATIONS.**
  1. *Names.*
     - A. Archæan,
     - B. Paleozoic,—Silurian.
       - **A.** Potsdam.
       - **B.** Lower Magnesian.
       - **C.** St. Peters.
       - **D.** Trenton.
     - C. Cenozoic—Quaternary.
       - **A.** Glacial.
       - **B.** Champlain.
       - **C.** Recent.
  2. *Distribution. (Map.)*
  3. *Dip and Flexures.*
- **II. DETAILED DESCRIPTIONS.**
  1. *Archæan.*
  2. *Potsdam Sandstone.*
  3. *Lower Magnesian Limestone.*
  4. *St. Peters Sandstone.*
  5. *Trenton Limestone.*
     - **A.** Composition.
     - **B.** Thickness.
     - **C.** Des. of Layers.
     - **D.** Uses.
  6. *Quaternary.*
     - **A.** Glacial.
     - **B.** Champlain.
     - **C.** Recent.
     - Suface Features including the Vegetation.
       - **D.** Topography.
       - **E.** Hydrology.
       - **F.** Vegetation.
       - **G.** Soils.

LOWER ST. CROIX DISTRICT.

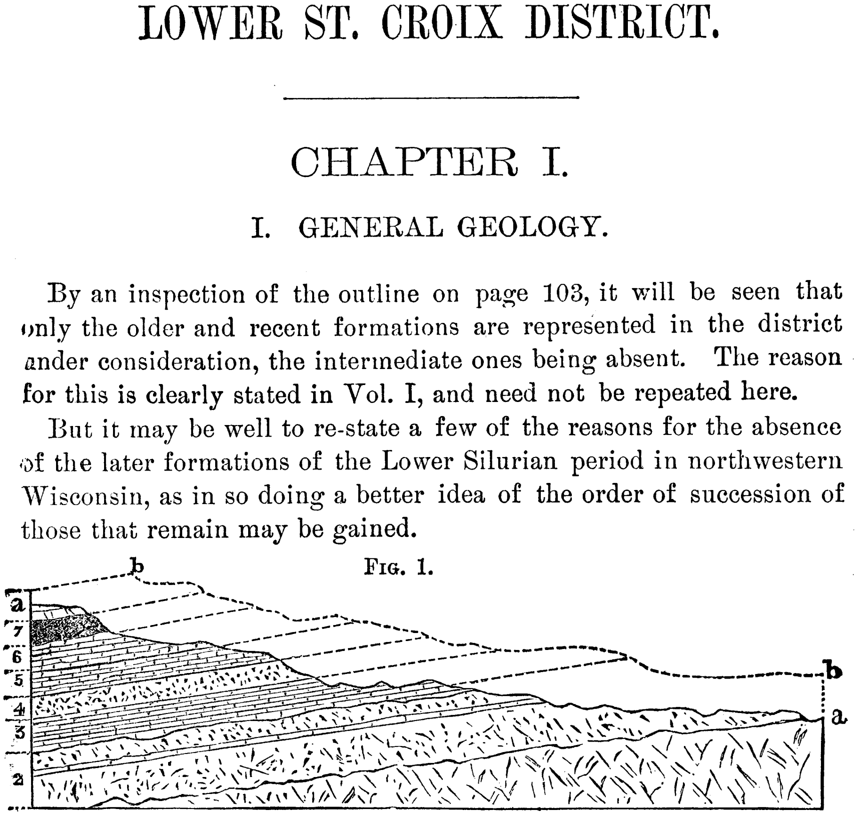
CHAPTER I.

I. GENERAL GEOLOGY.

By an inspection of the outline on page 103, it will be seen that only the older and recent formations are represented in the district under consideration, the intermediate ones being absent. The reason for this is clearly stated in Vol. I, and need not be repeated here.

But it may be well to re-state a few of the reasons for the absence of the later formations of the Lower Silurian period in northwestern Wisconsin, as in so doing a better idea of the order of succession of those that remain may be gained.

FIG. 1.



1. Archæan formation. 2. Potsdam sandstone. 3. Lower Magnesian limestone. 4. St. Peters sandstone. 5. Trenton limestone. 6. Galena limestone; and 7. Cincinnati shale. a a. Present surface. b b. Former surface.

It is quite possible that one or both of the later formations of the Lower Silurian period once rested upon those now represented in the district at the time when the latter had a greater northward extension. The Galena limestone and the Cincinnati shale now rest upon the Trenton limestone, a few miles to the southwest in Minnesota. As the formations dip southwesterly, and as the later were deposited upon the earlier, the only portion of each formation which reaches the surface is its northeastern border or edge. These borders, being exposed to denuding agencies in the subsequent periods, would retreat to the southwest so long as erosion continued.

The accompaning ideal cross-section from Chippewa Falls, S. W., will illustrate this, and show the succession of strata. The dip and relative thickness of the strata are but partially regarded in the figure.

The Trenton and Lower Magnesian limestones are more enduring than the underlying sandstones, and hence are found in isolated areas in St. Croix and Dunn counties capping, and thus protecting, bluffs of sandstone. The main body of these limestones lies in every instance a few miles to the south or west.

Fig. 1 also shows why the older layers of each formation are found to the northeast and at the same level as the more recent layers. For this reason it would have been more systematic to have commenced on the eastern border of the district, and then worked to the west; but as we found it necessary to pursue the opposite course, the sections of rock exposures will be given in the order of the investigation of the latter.

1. Names of the Formations Represented. The term, Archæan, applies to all the metamorphic rocks in place, examined in this district.

Several geologists in the west have divided the sandstone, that lies between the Archæan rocks below, and Lower Magnesian limestone above, into two formations; but no abrupt change in the nature of the sandstone, nor any unconformability in the layers was discovered in my district, and hence the name, Potsdam sandstone, is applied to the entire formation as in Eastern Wisconsin.

The name, Lower Magnesian limestone covers a series of layers more uniformly dolomitic than the same strata at the east, there being no layers of any thickness to which the term, sandstone, may be applied, with the exception of one horizon. It is possible that the upper layers in Northwestern Wisconsin are not represented by limestone at the east, having been laid down after the deposition of the St. Peters sandstone commenced in those regions. In this report, these layers of limestone will be termed Willow River Beds, and the sandstone between these layers and the Lower Magnesian proper, the New Richmond Beds, from the localities in which these strata are best exposed and most fully developed.

The formation next above, to which the name, St. Peters sandstone has been applied in the Northwest, is more nearly like the sandstone at its typical localities in Minnesota than in Eastern Wisconsin, being quite uniform in thickness and composition.

The only layers of Trenton limestone which remain in my district are those that belong to the Lower Buff Beds and a few of the lower layers of the Lower Blue.

THE MILWAUKEE LITHO.& ENGR. CO.

H-I-K ILLUSTRATES THE POSITION OF THE LINE OF JUNCTION BETWEEN

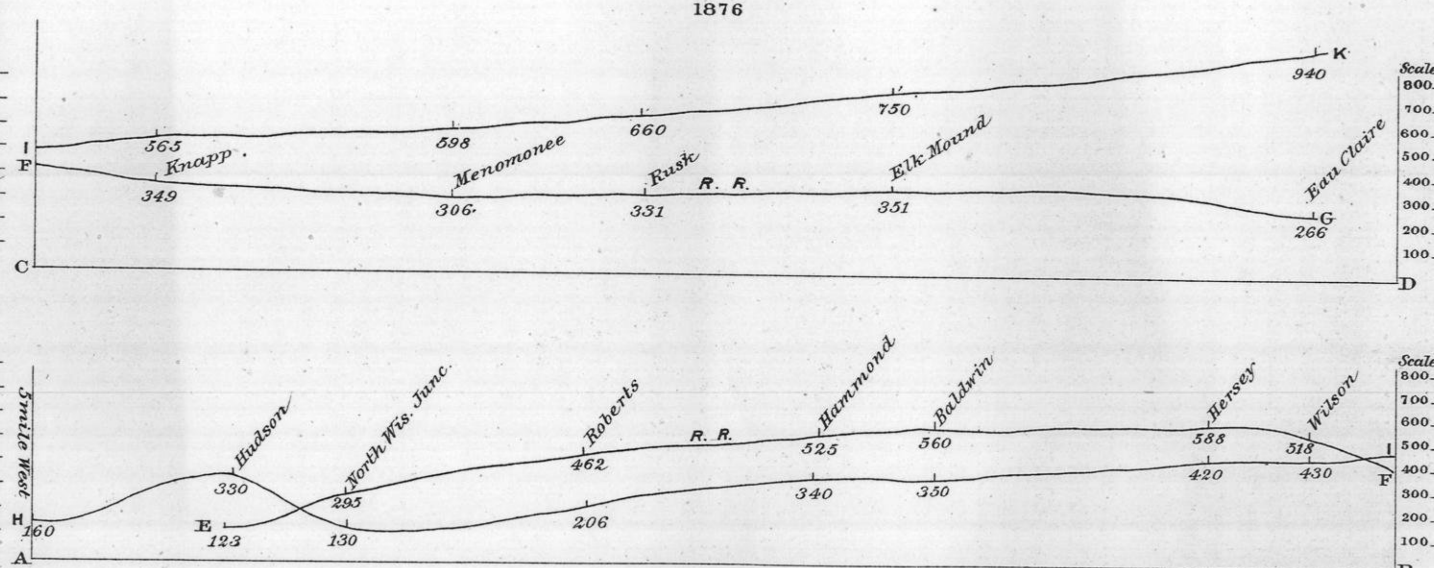
THE POTSDAM AND LOWER MAGNESIAN FORMATIONS

as it exists now and may have existed before denudation,

—BY—

L. C. Wooster

1876



A-B-C-D — *Level of Lake Michigan*

E-F-G - *Line of West Wis. R.R.*

Vertical scale, 1 in. = 800 ft.

Horizontal scale, 1 in = 5 mi.

PLATE V.

The loose uncompacted material deposited, distributed, and modified during the Glacial, Champlain, and Recent periods, rests unconformably upon the granite, sandstones, and limestones of Archæan and Paleozoic times, as in other localities.

The work of these three periods will be considered in connection with the topography, soils, and hydrology of the district.

2. Distribution. Of these formations, viz.: Archæan, Potsdam sandstone, Lower Magnesian limestone, St. Peters sandstone, and Trenton limestone, the second, third, and fourth cover large areas; the fifth is limited to the highlands of southern St. Croix, and Pierce counties; while the first is exposed, so far as known, only at Chippewa Falls.

3. Dip and Flexures. The line of dip of the formations is from S., 20° W., to S., 25° W. The angle is very small. An angle of one degree gives a dip of over ninety feet to the mile. In the Potsdam and Lower Magnesian formations, the change is twelve and one-half feet per mile, or less than one-eighth of a degree.

But, while the formations as a whole dip S., 20 or 25° W., the local dip varies considerably in direction and amount. The cause of this will be seen in the undulations represented in part by Plate II. This section, viewed in connection with one across the state of Minnesota, shows that the formations of my district lie on the eastern side of a broad but very shallow trough or synclinal, trending south-southwest, having its lowest line in Eastern Minnesota. The eastern slope of the synclinal is not continuous, but is interrupted by several anticlinals and synclinals of limited extent. The flexure at Hudson is the most marked. This, however, possesses a dip of less than one degree; and, were there no evidence to the contrary, so slight a dip could hardly afford sufficient reason for supposing a fault to account for it, as was presumed by the earlier geologists.

The layers of Lower Magnesian limestone on the east side of the anticlinal were found to dip as above; but exposures to the west in Wisconsin are rare, and the method used in obtaining the dip in this direction consisted in comparing the elevation of layers exposed at Stillwater and north along the St. Croix, with the elevation of tho same layers at Hudson and Somersett.

If a fault exists, a careful exploration of Apple river from Somersett to the mouth would reveal it. This, unfortunately, we had not the time to make, and so that view will be entertained as correct which is supported by the facts in our possession.

How far the Lower Magnesian participated with the Potsdam in the movement which produced the fold, is not shown by the rock exposed in western St. Croix county, and so it is impossible to state the time of the movement. If the folding commenced near the close of the Potsdam period, the ridge of sandstone may have been partially denuded, and thus the Lower Magnesian limestone would be slightly unconformable. This supposition would account for the greater thickness of the upper portion of the Potsdam sandstone in eastern St. Croix county.

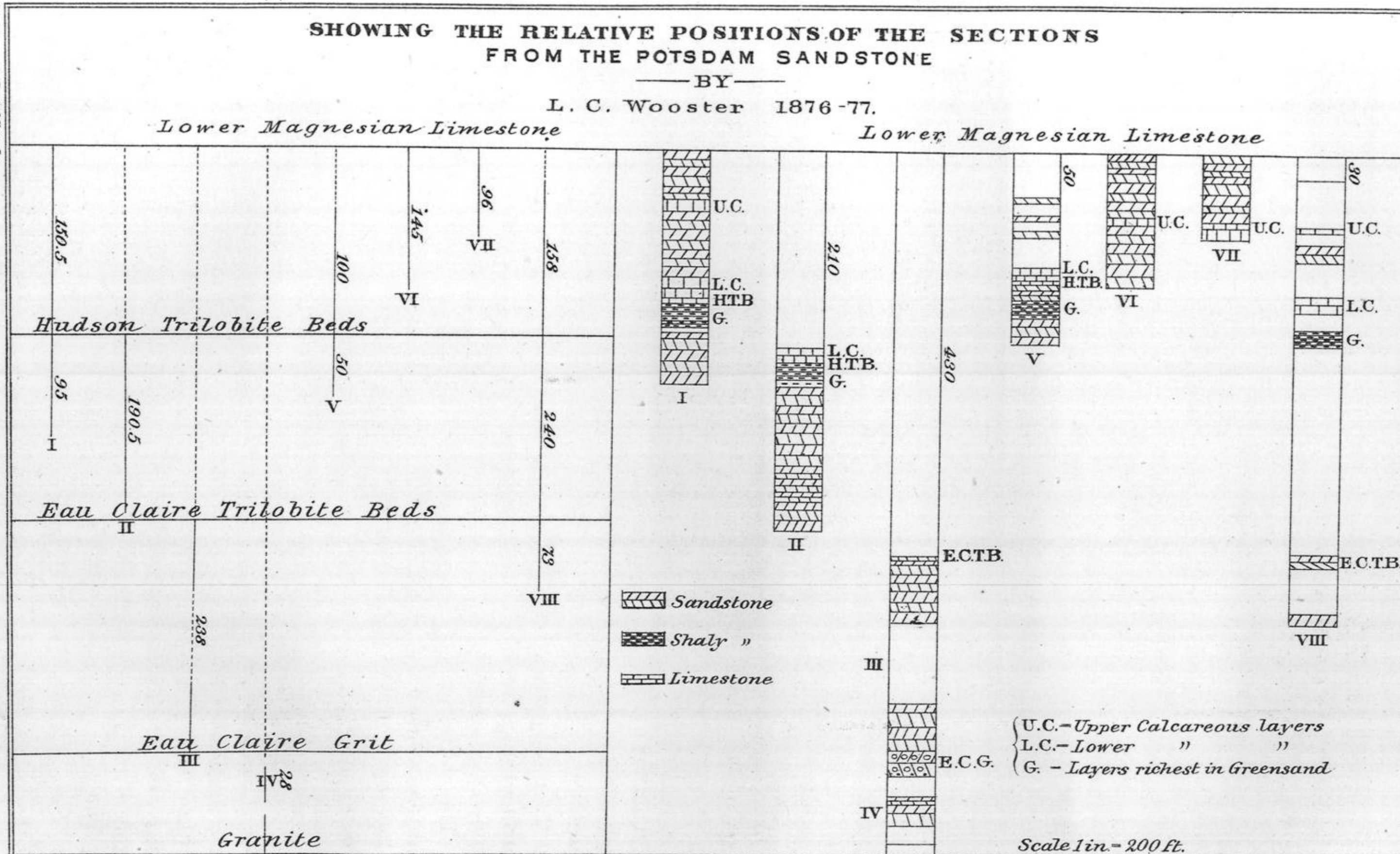
The following are the elevations above Lake Michigan of the base of the Lower Magnesian in the vicinity and along the anticlinal axis. Though the line of junction is not shown at all these points, the figures approximate very closely to the true elevation.

	Feet above Lake Michigan.
At Stillwater, Minn	190
At Hudson	330
At three and one-half miles east of Hudson	140
At Marine on Lake St. Croix	290
At Somersett	400
At New Richmond	231
At Sec. 24, T. 28, R. 20 W., on Lake St. Croix, five miles south of Hudson	280
At Star Prairie, Sec. 1, T. 31, R. 18 W	366

From these figures, it is probable that the anticlinal axis passes to the west of Star Prairie four or five miles, bears a little to the west of Somersett Postoffice, continues south southwest, to the crest of Hudson Bluff, and passes out of the state, leaving Catfish Point (five miles south of Hudson) one or two miles to the east.

By an inspection of Plate II, it will be seen that the synclinal in these formations, east of the anticlinal, is quite marked. The bearing of this upon other questions will be discussed hereafter.

The existence of other folds in the Potsdam and Lower Magnesian is suspected in the valleys of Rush and Red Cedar rivers, and from the direction of dip still further to the east, it is probable that these flexures are not peculiar to Northwestern Wisconsin.



PLATE, VI.

The Milwaukee Litho. & Engr. Co.

CHAPTER II.

DETAILED GEOLOGY.

I. The Archæan Formation.

The granite at Chippewa Falls is the only exposure seen in my district, the formation being hidden by the fragmental rocks at all other points. The rock is a coarse granite, composed of quartz, orthoclase feldspar, and greenish black mica.

The surface is much cut by fissures trending north, N. 22° W., N. 10° W., and N. 67° E. The coarseness of the rock and the broken nature of its surface exposes it to air and frost, and a rapid decomposition is the result. For this reason the neighboring sandstone, it is believed, is equally enduring as a building stone.

As Chippewa Falls is on the boundary line of Archæan rocks, other exposures probably exist a few miles north and east.

II. Potsdam Sandstone.

This formation possesses a much greater thickness than all the other sedimentary rocks of the district combined, and is exposed over a larger area. Bordering upon the metamorphic and igneous rocks to the north and east, this sandstone stretches south and west, at the surface, till it passes from view beneath the Lower Magnesian limestone. (Fig. 1.)

The character of the sandstone varies somewhat in the different localities, apparently being dependent upon the nature of the metamorphic rocks to the north, and the abundance and kind of life. The sandstone seems to vary also with the vertical and horizontal distance at which it was deposited from the metamorphic rocks, changing from very coarse to fine, and from being quite purely silicious to a rock that is freighted with impurities. At equal distances from the granite below, the character of these impurities and the size of the component grains seem to be quite constant throughout the district, and thus they afford valuable horizons for reference in determining the position in the formation of any outcrop of the sandstone.

The most important of these horizons are: 1. *Eau Claire Grit;* 2. *Eau Claire Trilobite Beds;* 3. *Hudson Trilobite Beds;* and 4. *Line of junction with the Lower Magnesian limestone.*

The *Eau Claire Grit*, exposed at the mouth of Eau Claire river, is a very coarse sandstone, with Scolithus tubes in one or two of the layers. The rock is so coarse that it has been termed a conglomerate, not without reason.

The *Eau Claire Trilobite Beds* are characterized by several species of trilobites not found at any other horizon, and also by being the lower limit at which brachiopods were found in the sandstone. These beds likewise mark the lower limit of calcareous matter in the formation.

The Hudson Trilobite Beds lie at the best defined horizon in the sandstone. These beds lie in close relationship to and between the *Lower Calcareous Band* and the layers which are richest in greensand, and thus cannot well be mistaken. The calcareous layers, about ten feet in thickness, everywhere show a brisk effervescence when treated with acid, and frequently possess the jointed structure and weathering of limestone. For a list of the trilobites found in the layers below the *Calcareous Band*, see section I. 1. The shaly layers below the Trilobite Beds are intensely green from the presence of greensand (a variety of glauconite), which, so far as known, is true of no other horizon.

The Line of Junction with the Lower Magnesian limestone may, in nearly every instance, be recognized by the heavy brecciated beds of limestone just above. But this character may fail in the extreme southeastern border of the district where it is possible that beds of sandstone are interstratified with the lower layers of the Lower Magnesian limestone as in Eastern Wisconsin. Though no instance of the kind has come to our notice, the character of the upper portion of the Potsdam sandstone, resembling quite closely, except in thickness, the same layers in the eastern part of the state, seems to warrant this conclusion.

There is one other horizon, in which lies the *Upper Calcareous Band* (Plate III) that has been omitted in forming this list, on account of its variable position and thickness, but which is very interesting, as it possibly marks the horizon of the Mendota limestone of Central Wisconsin. In the western portion of the district, about sixty feet below the line of junction, are three or four feet of calcareous sandstone. Forty miles east-southeast, at the same horizon, are at least twelve feet of silicious (?) limestone, gray in color, with reddish blotches. Near Madison, Dane county, thirty-five feet below the Lower Magnesian, is a limestone which possesses a somewhat similar character.[1] On the western line of Sauk county, the distance of this limestone below the line of junction is stated to be sixty feet.

[1] See Vol. II, p. 543.

On Lake St. Croix and at Madison the greensand has its upper limit at these calcareous layers. The sandstone above them is quite friable in St. Croix county, but eighty miles to the southeast it caps numerous bluffs, standing forth in vertical ledges, as in the eastern part of the state. This change in its character is due to the increased percentage of calcareous matter present.

But it may be stated in this connection, that the propriety of making the upper calcareous layers, as defined above, the exact equivalent of the Mendota limestone, is questionable. It is evidently a closer approximation to state that the series of layers extending three hundred feet below the Madison sandstone in Central Wisconsin is equivalent to three hundred feet in St. Croix county, of alternating ing calcareous, silicious and argillaceous layers extending downward from and including the Upper Calcareous layers.

The nature of the rocks between the above characteristic horizons is indicated subsequently (Topic **A.**).

In nearly every layer of the Potsdam sandstone one finds evidences by which he may gain a partial knowledge of the previous history of its component grains.

The pebbles of quartz and feldspar in the coarse sandstones, in the vicinity of Chippewa Falls, together with the layers of clay containing mica scales, show as unmistakable a relationship to the granite, as the pebbles and sand upon a modern beach to the cliffs at whose base they lie.

The scales of mica, the quartzose sand and the clay are found associated hundreds of miles to the southwest in this formation, and as these minerals are only given to sedimentary rocks through the decomposition of granite, quartzite, etc., and as the metamorphic rocks do not exist, except as small islands in those regions, the component minerals of the sandstone, except those derived from shells of animals and tissues of plants, must have been derived from the main body of the Archæan rock, lying at the northern borders of the area of deposition.

A. Composition. The chief components of the Potsdam sandstone are silica, carbonate of lime and magnesia, approaching dolomite, greensand *(Glauconite)*, and oxide of iron, together with a varying quantity of clay.

The formation is most purely silicious in the lower and upper portions, viz., from the granite to the Eau Claire trilobite beds and from the Upper Calcareous band (see Plate III) to the Lower Magnesian limestone. Many layers in the intermediate portion likewise contain a very large percentage of quartzose sand, but most of them are quite impure. Most of the calcareous material was distributed between one and three hundred feet of the top, many of the layers being more properly limestone. Above this, in St. Croix and Dunn counties, are but one or two dolomitic bands, but in the extreme southeastern portion of the district much of the sandstone effervesces freely, showing a considerable proportion of lime.

The quantity of greensand varies greatly in different localities, but it is nearly all comprised in the upper three hundred feet of the formation, having about the same range as the calcareous matter. Its presence in a neighboring sandstone outcrop is nearly always indicated by the green color of the soil. This is especially true where the Hudson trilobite beds are exposed, and thus one is enabled to readily find this horizon.

Iron oxide is found in nearly every layer, but it is most abundant and most uniformly distributed in the lower beds, where it performs the office of cement, giving these layers much of their value as a building stone. It occurs also quite abundantly in some of the upper layers in the form of thin laminæ, often very much curved and angulated.

Clay occurs in layers of considerable thickness in the lower half of the formation. In the upper half, it is found in the form of thin laminæ between the layers of sandstone; and is evenly distributed through the same, forming, between the Hudson and Eau Claire Tribolite beds, a bluish and reddish argillaceous sandstone.

B. Thickness. At no one point in the district is the entire formation exposed, and so, to obtain the entire thickness from the Lower Magnesian limestone to the granite below, the sum of the thicknesses of the subdivisions is taken:

	Feet.
From the Lower Magnesian to the Hudson Trilobite bed	200
From the Hudson Trilobite bed to the Eau Claire Trilobite bed	200
From the Eau Claire Trilobite bed to the Eau Claire grit	240
From the Eau Claire grit to the granite (at Eau Claire), estimated	100
Total	740

The last division is probably much thicker to the south and west, making the thickness of the formation range to eight hundred and one thousand feet.

C. Description of Layers. In order to present the formation as a whole, sections from Hudson, Menomonie, Eau Claire, and Chippewa Falls, will be presented first. The remaining sections will be given in the same order, and the relationship of all may be seen by an examination of Plate III.

The exposures at Hudson do not show the upper fifteen or twenty feet of the formation, and, that the record may be complete, the missing link is supplied from an exposure a few miles distant, where these layers are shown beneath the heavy, brecciated beds of the Lower Magnesian limestone. In the section they are marked **Z.**[2]

Section I, Hudson. In descending order, the beds are as follows:

		Feet.	*In.*
z.[2]	The upper layers are composed of coarse, incoherent, red to white quartzose sand. The layers below are yellow to buff in color, composed of nearly pure quartz-sand, and are for the most part quite fine in texture. *Scolithus* tubes are abundant	20	..
z.[1]	A buff, calcareous layer above and a few shaly layers of greensand below	3	..
z.	Somewhat compact, brown, calcareous sandstone. One layer	2	..
y.	Brownish white sandstone, with wormhole fillings projecting. Effervesces briskly	2	..
x.	Where long exposed, an uncompact, white sandstone, containing a small percentage of greensand	8	..
w.	Same as **y**	2	..
v.	Same as **x**	8	..
u.	Partially turfed, but shows a few layers of white to buff sandstone, somewhat heavy bedded and quite friable	12	6
t.	Similar to **u**, but much stained by iron, which forms thick incrustations in places	8	..
s.	Heavy bedded, mottled layers. The sandstone is yellowish brown, with numerous light colored blotches, irregular in shape	12	6
r.	A buff colored, friable sandstone, giving a slight effervescence. Near the bottom is about one foot rich in greensand	3	6
q.	Heavy bedded, incoherent sandstone, with much green material distributed through it. A few fragments of trilobites were found	10	..
p.	Shaly sandstone, effervescing slightly with acid, and holding much green material. At the base the layers become thicker quite abruptly	27	..
o.	Compact, heavy bedded, light buff sandstone, with reddish laminæ. Portions effervesce briskly	9	..
n.	Dark brown on fresh exposure. Many fragments of trilobites, but the sandstone is so friable that but few could be identified. Among these were the *Conocephalites* (sp. undet.) and *Ptychaspis granulosa*. A fossil plant, *Cruziana sp?*, was also found	5	..
m.	Thin bedded buff colored rock, containing much calcareous material,—shown by the limestone weathering, jointed structure, and brisk effervescence. In the lower portion a fragment of *Paleophycus*, sp. undet., was obtained	10	..
l.	Shades into **m** above and **k** below. In the upper portion were found: *Conocephalites anatimus*, *C. diadematus*, *C. Eryon*, two new species of *Conocephalites* (one minute), and *Ptychaspis granulosa*. In the middle portion, *Obolellæ* were found with the trilobites. The lower layers are quite dark from greensand and iron stain, and contain many fragments of crinoid columns	8	..
k.	Turfed over except the lower four or five feet, where the rock is a dark green shale	17	

	Feet.	In.
j. Dark buff sandstone with three or four layers containing greensand interstratified	10	..
i. Buff calcareous sandstone varying to brown, with a few thin layers of greensand interstratified. *Obolella polita* is very abundant in the buff layers	5	..
h. Green shale	5	..
g. The upper portion is mottled like s. above. The remaining layers are shaly, with colors varying from buff to brown, red and green	5	..
f. Persistent sandstones, changing to fragmental above. Colors are light brown to white and reddish; the upper four feet are mottled	13	..
e. Very friable shale. The alternating white and slate-colored laminæ vary from one-eighth to three-eights of an inch in thickness	2	..
d. White sandstone, with reddish bands. The rock hardens on exposure. Two thin layers of blue clay are interstratified	10	..
c. Alternating green and white sandstone	3	..
b. Friable, light buff, and yellowish sandstones, shown near the mouth of Willow river	15	..
a. White sandstone, incoherent on long exposure	10	..
	245	6

a. — **f.** were tested and showed no effervescence.

Very little greensand occurs below this horizon, and likewise but a small amount of calcareous material. No line of separation, nor any marked transition, was found in the entire exposure.

Where not otherwise noted in the section, the sandstone is medium to fine grained. Under the microscope, the grains of quartz are white or transparent, and are both angular and rounded. The rounded grains are spherical or irregular, mostly the latter. The calcareous material seems to perform the office of a cement; and when the rock is pulverized it frequently remains as a coating upon the grains of quartz.

In the lower layers glistening scales of mica are abundant, especially in beds **l**, **m** and **i**. The Upper Calcareous band is not well shown at Hudson, but a few miles distant it is clearly defined.

Between Sections II and III there is believed to be a gap of twenty to thirty feet; but upon collating all the data in my possession, it is thought that the exposure at Rock Falls (Sec. 22, T. 26, R. 11 W.) furnishes most of the missing layers.

This exposure shows about twenty feet of thin to heavy bedded buff sandstone. At the top were found numerous specimens of *Lingulepis pinnaformis* and near the base, layers of silicious shale are interstratified.

Section II, Menomonie. Forty miles east of Hudson the following vertical section is found, the topmost layers of which are believed to be equivalent to beds **l** and **m** of section I, above given:

From above downwards:	*Feet.*	*Inches.*
n. Thin bedded sandstone, with greensand and mica scales. The buff layers effervesce briskly. Fossils: *Conocephalites minor*, *C. diadematus*, *C. Shumardi*, and *Agnostis paralis*, together with *Obolella polita* and *Lingulepis pinnaformis*	10	..
Thin bedded, buff to brown, calcareous sandstone. Some layers are more properly called limestone. A few fragments of trilobites were found	12	..
l. Greensand layers above, and mottled buff and green calcareous layers, and dark green layers from the presence of greensand below. The layers are thicker than those at the top	17	..
k. Massive, yellowish to brown sandstone	26	..
j. White sandstone above; then greensand layers; below which succeed thin, bluish, argillaceous layers. Non-calcareous	5	..
i. Massive light buff to yellowish sandstone. Little or no greensand. The lower layers rather coarse. *Lingulepis* abundant near the base. The rock is non-calcareous, except at the bottom, where the thin layers effervesce freely	56	..
h. Yellow, loose, non-calcareous sandstone, much stained with iron. The lower two feet are white in color	8	..
g. Coarse, red, yellow, and buff sandstone. The layers are thin and contain much argillaceous material	4	..
f. Similar to bed **g**, but more heavy-bedded and veined with iron	4	..
e. Coarse, heavy layers, dark red to brown from the presence of iron. Contain *Obolella*, etc.	4	6
d. With the exception of the upper, these layers are compact and heavy-bedded. *Obolella*, etc., abundant. Lighter colors predominate below, though the layers are somewhat stained with iron. Greensand in many layers. No effervescence	8	..
c. Brown, bluish-green, and buff shale. Layers rather compact and non-calcareous. *Obolella*, etc., not so abundant as above	6	..
b. Similar to **c**, but with more iron	15	..
a. Heavy-bedded brown sandstone, used for building purposes. Fossils: *Obolella polita*, *Lingulepis pinnaformis*, *Conocephalites Iowensis*, *C. minor*, and *Hyolithes gregarius*	15	..
	190	6

The layers described in the above section are exposed along the banks of Red Cedar river and Wilson creek, in the western part of the village. The layers of greensand, characteristic of this horizon of the Potsdam sandstone, are exposed at numerous points north and south of Menomonie, coloring the soil a deep green. They are not seen to the east, as these layers have been removed through denudation, nor to the west, being covered by the more recent layers of the sandstone. Twelve miles north of Menomonie, in the town of Sherman (T. 29, R. 13 W., secs. 8, 17 and 18), some of the higher bluffs expose the layers of Section I, with ten to twenty feet of Lower Magnesian limestone at the top. The same is true, for the most part, of the regions south and northwest. In many of the bluffs, possessing but a slight capping of limestone, numerous attempts have been made to burn lime, but as the lowest layers of the Lower Magnesian limestone are quite impure, these efforts are almost uniformly unsuccessful. By an inspection of the section made at Wilson of the Lower Magnesian limestone, it will be seen how far above the line of junction it will be necessary to look for stone that may be successfully burnt. Excellent lime is produced from this horizon in the southern part of the county, but the bluffs in the town of Sherman are the only ones visited at the north, which hold the pure dolomite found at Wilson, though it is probable that many of the bluffs near the northwestern border of the county hold this stone in paying quantities. By an inspection of the Map of Formations in the atlas accompanying this report, it will be seen where the layers of Sections I and II may be expected. In one of the bluffs in the town of Sherman a quarry has been opened and about two thousand bushels of lime burnt per year. The stone is a buff colored, massive, nearly pure dolomite, and burns to a strong, dark colored lime. The owner finds a ready market at various points in Dunn and contiguous counties. About forty feet below the quarry, layers of sandstone are exposed on the slope, the structure of which, so far as observed, is peculiar to the upper layers of the Potsdam formation. The rock at a short distance has the appearance of a pudding stone, but on closer examination it is seen to be made up of balls of light quartz grains, about one-half an inch in diameter, imbedded in a matrix of darker quartzose sand. Frequently scolithus tubes are found in the same connection.

The sandstone immediately below Section II was not observed, except near Rock Falls, in the southeastern portion of Dunn county. In the bank of the creek near that village is an exposure of about twenty feet of sandstone. The rock is thin above to heavy bedded below, where several layers of siliceous shale are interstratified. In the shaly layers above, valves of *Lingulepis pinniformis* were seen in great abundance. From the character of the rock and its fossil contents, and from its position in the formation, it is believed that this exposure lies midway between Sections II and III, not entirely filling the gap between, as the distance between the two sections is probably more than twenty feet (see Section VIII, Arcadia).

Section III, Eau Claire, sixty miles east of Hudson, is composed of several subsections. The lower layers were found exposed near the mouth of Eau Claire river, and at the Dalles, two miles above the city. The upper layers were seen at one mile and at four miles above the Dalles. At the latter point, the Eau Claire Trilobite beds were discovered in the high bank, nearly two hundred feet above the terrace, on the left side of Chippewa river. I have learned since visiting Eau Claire, that fossiliferous beds, possibly the Trilobite beds, are exposed a short distance below the city. The trilobites are quite small, and, with one exception, only the head and tail parts were discovered, the body segments having been destroyed. The exposures of sandstone are quite numerous in the vicinity of Eau Claire, and offer to the geologist one of the finest fields for the study of the lower layers of the Potsdam formation that I have seen in the state. Within a radius of fifteen miles, the first three hundred feet of the sandstone may be studied in detail, hardly a layer being inaccessible. Unfortunately, lack of time forbade a detailed survey of this region, and as a consequence, some of the upper and lower layers were not seen. But the undescribed beds are above and below the point where unconformability would be seen in the layers, if the sandstone below the Lower Magnesian limestone is composed of two formations, as has been suggested by several writers. In descending order:

		Feet.
o.	Buff to brown sandstone. Rather heavy bedded, but becoming thin above and below. Trilobites are very abundant in the heavy beds. The following species have been determined: *Conocephalites calymenoides*, n. sp., C. Sp.? *Agraulos (Bathyurus?) Woosteri*	12
n.	Thin bedded shaly layers	15
m.	Shaly layers becoming samewhat heavy below. The rock is a fine grained, buff to reddish sandstone; some of the layers are much stained with iron. Specimens of *Lingulepis pinniformis* were found in the upper layers	7
l.	Similar to **m.** above. A few fragments of *Lingulepis pinniformis* were seen. The lower layers contain some very peculiar concretions. These are lenticular in shape, with a diameter (greatest) of from one to two feet. The concretions are composed of nearly pure quartz sand, and the grains are transparent to translucent, and closely compacted	13
k.	Light buff sandstone, with layers one to two feet in thickness. Some of the lower layers are traversed vertically by very minute, hair-like tubes, four inches and more in length. The rock is coarser than any of the layers above, and is not quite so compact..	15
j.	Not exposed	95
i.	Loose sandstone, light buff in color	5
h.	Heavy-bedded, coarse grained sandstone, discolored with iron. The grains vary from one-third of an inch to less in diameter, and are quite closely cemented together.	5
g.	Thin bedded, white to reddish, and coarse to fine sandstone. Loose above but more compact below	4
f.	Loose to compact, bluish white, argillaceous sandstone	5
e.	Buff sandstone stained with iron, similar to **f.** in texture	3
d.	The layers are buff to reddish and white in color, and fine to coarse in texture	10
c.	Bluish argillaceous layers	2
b.	Coarse to fine grained sandstone. The rock is somewhat friable, but it presents a hard crust where long exposed. The surface is brown from the presence of iron, but the rock is buff to reddish within	18

		Feet.
a.[1]	These layers contain a much greater percentage of coarse material than **b**. Many of the component grains, or more properly pebbles, show a diameter of one-half an inch. The colors are dark from the presence of iron, and mica scales are abundant..	20
a.	Coarse grit, shown on the Eau Claire river. Numerous worm-holes in several layers..	9
		238

The above layers showed no effervescence when tested with acid. Scales of mica glistened in nearly every layer. As a whole the rock from **a** to **h** is brownish red, and cross lamination is a marked feature. From **k** to **o** lighter colors predominate. Layers containing the peculiar hair-like tubes were found exposed at the Dalles and also in the vicinity of the Eau Claire Trilobite beds. The layers and fossils above these beds are quite similar in the two localities, and hence it is believed that they occupy the same horizon. If this be true, the dip between the two exposures is fourteen feet per mile S. S. W. (This is the average dip of the formation.) If the dip continues the same to Chippewa Falls, the topmost layers of section IV lie ten to twenty feet below the base of section III.

Section IV, Chippewa Falls. The layers of this section were seen in two exposures about one mile apart. From the nearly horizontal position of the layers, and from the comparative elevation of the two outcrops, they are united into one section as below.

From top to base the beds are as follows:

f. Coarse, dark, ferruginous sandstone.
e. Shaly layer with many quartz pebbles and scales of mica.
d. Dark red, ferruginous sandstone. The layer is made up of fine and coarse quartz-grains; and is sufficiently indurated to be used for building purposes.
c. Similar to **d**, but lighter colored.
b. Similar to **d**, but coarser. Many of the pebbles measure one-half an inch in diameter.

The above layers have a total thickness of 8 feet.

a. Exhibits the cross lamination of the lower sandstones. The colors vary from red to buff. The bedding is rather heavy, and the rock is sufficiently persistent and fine grained to be quarried. The exposure measures 20 feet.

The layers marked **a** were found exposed on Duncan creek, north of the city, and **b** to **f** were seen near the depot.

The bottom of the former quarry is fifteen feet above the granite exposed below on the same creek, while the latter outcrop is about fifty feet above the granite at the falls on the Chippewa river.

With a few exceptions, the layers described in these four sections may be regarded as typical of the layers of the Potsdam sandstone occupying the same horizons in Northwestern Wisconsin.

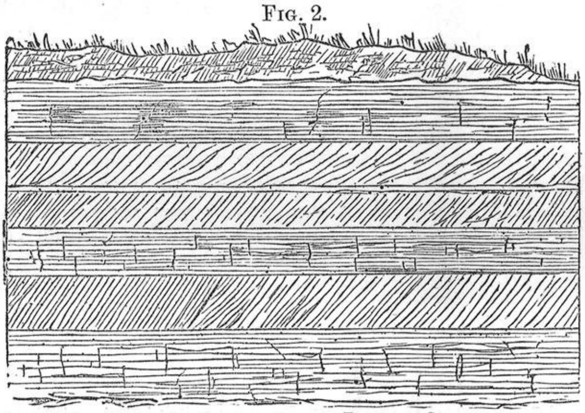
For convenience of reference, the location of each of these sections will be repeated here:

Section I covers the layers exposed at Hudson, seventy miles west southwest of the Archæan areas, and near the western limit of the Potsdam sandstone surface area.

Section II gives the character of the sandstone at Menomonee, on the Red Cedar (or Menomonie) river, forty miles east of Hudson.

Section III was obtained near Eau Claire, on the Chippewa river, within a few miles of the Archæan area, and about twenty miles east southeast of Menomonee.

Fig. 2.



Showing Cross-Lamination in the Potsdam Sandstone on Duncan Creek, Chippewa Falls.

The layers of sandstone described in Section IV are exposed in the banks of the Chippewa river and Duncan creek, where these streams have cut through the Potsdam sandstone to the granite below. This section is located about nine miles north of the exposures covered by Section III.

It is not to be expected that these sections are true for all the localities mentioned below; but it is believed that they give all the more important characteristics.

Nos. III and IV illustrate the layers exposed in Chippewa and Eau Claire counties and eastern Dunn; Nos. II and III, the layers exposed in middle Dunn, Pepin, northern Buffalo and northern Trempealeau counties; and Nos. I and II, the layers in western Dunn, central Buffalo and southern Trempealeau counties, and No. I illustrates the layers in St. Croix and Pierce counties, and those portions in the other counties contiguous to Lower Magnesian limestone areas.

The position of all the exposures from which sections were made, may be seen at a glance by referring to Plate III.

At Somersett (Sec. 3, T. 30, R. 19 W.), ten miles northeast of Hudson, are several exposures which are important from the fact that they are situated upon the summit of the Hudson anticlinal, thus fixing its trend.

The exposures, combined to form

Section V, Somersett, are located near the north line of section 3, one mile below, and in a bluff one-half a mile west of the second outcrop. In the section, **g** and **h** are from the last.

		Feet.
h.	Mostly turfed over, but near the top of the bluff are uniform thin bedded layers of sandstone somewhat ferruginous; midway a highly ferruginous sandstone is exposed; and near the base an outcrop shows numerous concretions, one to four inches in diameter, highly charged with iron	37
g.	Unexposed..........	34
f.	Heavy bedded brown sandstone used for building purposes. Some green material in the lower portions	15
e.	Thin bedded light buff sandstone with limestone weathering. Greensand quite abundant above. Near the base are several layers containing trilobites. *Ptychaspis* (Sp. undet.); *Conocephalites Eryon*	25
d.	Buff rock with layers containing greensand interstratified................	10
c.	Thin bedded sandstone, dark to light green in color, as the greensand is more or less abundant..	10
b.	Partially hidden, but showing in places much green material.............	15
a.	Dark green layers containing greensand..................................	5
		151

The bed **a** is about two hundred and twenty feet above Lake Michigan, and by comparing the layers of Section V with those of Section I, it will be seen that the base of the Lower Magnesian limestone, if present, would have an elevation of nearly four hundred feet.

Between Wilson and Knapp, thirty miles east of Hudson, along the West Wisconsin railway, are several exposures which show the lower two-thirds of the Lower Magnesian limestone, and nearly one hundred and fifty feet of the upper portion of the Potsdam sandstone, illustrating the transition from one formation to the other very finely.

Owing to the distance between the cuts, the absence of marked layers, and a heavy down grade in the opposite direction from the dip, some difficulty was experienced in uniting the exposures of the Potsdam sandstone into one section.

Section VI, Wilson.

From the Lower Magnesian Limestone downward:

		Feet.
f.	Transitional buff layers. Some of the upper are cross laminated, and several are quite fragmental, the angular pieces being light and dark buff in color. Most of the layers show a brisk effervescence....................	15
e.	The layers of sandstone are white and buff, with small quantities of greensand, and are frequently veined with iron	20
d.	Mostly white sandstone veined with iron as in **e**. A few layers of chert and limestone near the middle..	30
c.	Intensely ferruginous, giving the exposure a deep brown appearance. The laminæ are much contorted, and concentric..........................	20
b.	Brown above to white and buff below. The layers, like those above, are quite friable. One or two calcareous bands near the top	30
a.	Quite uniform layers of white sandstone; somewhat more compact than **b**....	30
		145

At Lower Knapp the Lower Magnesian limestone caps the bluffs, but with few exceptions the Potsdam sandstone is unexposed.

A well in the village shows greensand layers with trilobites *(Ptychaspis granulosa)* and brachiopods two hundred and twenty feet below the Lower Magnesian, indicating a greater thickness of the upper portion of the Potsdam than at Hudson.

The remaining exposures of the Potsdam sandstone visited supply no new features, except, perhaps, the outcrops on Gilbert creek and at Arcadia on Trempealeau river.

Along the south fork of Hay river the sandstones of Section I are well exposed, and at Roberts' Store (Sec. 22, T. 31, R. 14 W.) *Dicellocephalus* sp. and *Ptychaspis minuta*, sp. n., were found in greensand layers of the horizon of the Hudson Trilobite beds.

Near the headquarters of Gilbert creek (Secs. 31 and 32, T. 28, R. 14 W.), nine miles southwest of Menomonee, the upper calcareous layers of the Potsdam show unusual thickness. As there is likewise a fine exposure of the Lower Magnesian, the entire section is given.

Section VII, Gilbert Creek.

	Feet.	*Inches.*
i. Heavy bedded, compact, dark gray, brecciated limestone, containing numerous cavities lined with quartz crystals	22	6
h. Turfed	37	6
g. Heavy bedded, brecciated limestone, about	18	..
f. Turfed, except the upper portion, where thin layers of sandstone and limestone alternate	20	..
e. Similar to d below, about	20	..
d. Friable, fine textured, reddish, yellow, buff, and white sandstone	16	..
c. Not exposed, about	20	..
b. Not exposed, but is struck in wells where it is said to be limestone	12	..
a. Exposed in Gilbert creek one-half a mile below. Has the bedding, jointed structure, and weathered appearance of limestone. Effervesces slowly. The colors are buff and red. Some of the lower layers are light buff with numerous red blotches	8	..
	78	L. M.
	96	P.
	174	..

This gives a thickness of about twelve feet for the calcareous layers, and eighty-five feet for the sandstone above (Madison beds). This is about the thickness of the latter at Lower Knapp.

A bluff near Arcadia (S. E. corner of Glencoe, T. 21, R. 10 W.), nearly five hundred feet in height, exposed at intervals on its slope, numerous characteristic layers of the upper half of the Potsdam sandstone, covering Sections I, II, and part of III. The elevations are the heights of the middle of the several exposures above the depot at Arcadia.

Section VIII, Arcadia.

		Feet.	Inches.
i.	At 493 are two layers of white sandstone, two feet apart. Total....	5	6
h.	At 442 are shaly, calcareous layers of sandstone....................	2	..
g.	At 436 is a ferruginous sandstone. A layer at the base is a reddish brown quartzite	6	..
f.	Orange-colored sandstone at 420, with a thickness of	15	..
e.	At 354 are several layers, which have the weathered appearance of limestone: Cream-colored rock, with a slow effervescence, five feet; yellow sandstone, one and one-half feet; conglomerate, three and one-half feet; thin bedded, uniform layers, with a brisk effervescence, three feet. Total.....................................	13	..
d.	At 324: Thin bedded buff sandstone, two feet; one layer of dark green material, one-tenth foot; buff sandstone, with greensand interstratified, two feet; heavy bedded dark buff sandstone, two feet. Total..	6	1
c.	Buff sandstone at 145..	4	.
b.	Exposed at Ettrick (Sec. 30, T. 20, R. 7 W.), thirteen miles southwest of Arcadia. The same, if exposed at Arcadia, would have an elevation of ninety feet above the depot. Buff and brown medium bedded sandstone, with the following trilobites: *Conocephalites calymenoides*, n. sp., *C. Iowensis*, *C. Minor*, *C. (Crepicephalus) Wisconsinensis*, *C.* n. sp., *Crepicephalus onustus*. n. sp., *Ptychaspis granulosa*, and *Agraclos (Bathyurus?) Woosteri*, n. sp	10	..
a.	Heavy dark brown layers of friable sandstone, containing *Obolella polita*, and *Conocephalites Iowensis*. Elevation, 22................	4	..
		65	7

The Lower Magnesian in the vicinity has an elevation of five hundred and twenty feet above the depot at Arcadia. The upper calcareous layers (=**a,** Section VII, Gilbert Creek) are partially exposed at **h,** seventy-eight feet below the Lower Magnesian.

The lower calcareous layers, with the greensand (= Hudson trilobite beds), are exposed at **d,** and **e,** one hundred and eighty feet (av.) below.

The upper layers of Section III (Eau Claire trilobite beds), and the lower of Section II (Menomonie), are evidently comprehended in **b** and **a,** indicating a greater gap between II and III than was supposed.

Had there been a little more time at our disposal, the missing members of the series of layers from the Archæan to the Lower Magnesian limestone might all have been supplied; but it may be questioned whether new or important data would have been obtained, as the sections made in the contiguous districts must cover the undescribed strata.

D. Uses. Everywhere there is sufficient quartzose sand for all the purposes for which it may be used, but good building stone from the Potsdam is not common.

The layers used for that purpose are: those exposed in Section IV; in the lower half of Section III; in the lowest subdivision of Section

II; and in the subdivisions below and above the Hudson Trilobite beds in Sections I and V.

These layers are much used in Chippewa Falls and Menomonee, especially in the former, where buildings constructed of sandstone have stood several years, the stone being harder than when first put into the walls.

In 1876, the sandstone sold readily for nine and one-half and ten dollars per cord, delivered.

At Menomonie, the stone is more uniform in color and seems equally durable, becoming more indurated with age.

Fortunately, in St. Croix county, the presence of good limestone compensates for the absence of the more compact sandstones; though several layers of the latter are used for foundation walls, with good results.

III. The Lower Magnesian Limestone.

Resting upon the Potsdam sandstone and carrying upon its upper surface the St. Peters sandstone, this formation marks at least two more or less abrupt changes in the level of the northwest.

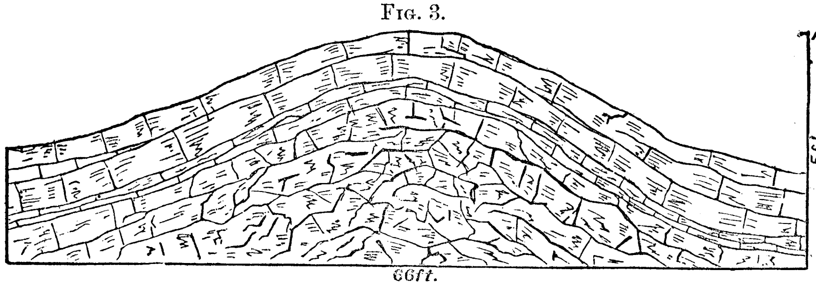
The large amount of lime (carbonate of lime and magnesia, and carbonate of lime) in some portions of the Potsdam, was a prophecy of the nearly pure dolomite that was to follow; but geologists have long been in doubt as to the source of the material and the method of deposition in this succeeding formation.

In most cases where a limestone is believed to be composed of finely comminuted shells and corals, the fact is indicated by fragments of these; but in this formation none were discovered, except in the middle and upper layers. Some have supposed the limestone to be a precipitate from the waters of the ocean, but this hypothesis, it seems to me, has far less support from the formation itself. The great abundance of carbon di-oxide, both in air and water, the fact that the rock is a carbonate and not another salt, the consequent necessity for exposure to the air that the same may remove the excess of carbon di-oxide from the water, all present difficulties more serious than the single one of paucity of animal remains. Limestones of unquestioned organic origin, just as compact and just as free from organic remains are being laid down in modern seas. Evidence of an oscillating bed, unequal deposition, and a stormy ocean are very apparent in this limestone in St. Croix county.

The first layer above the Potsdam sandstone is usually massive, irregular, and brecciated. In the middle and upper portions of the formation numerous "mounds" occur, varying in diameter from two feet to as many rods. (See Fig. 3.) In the upper portion are a few layers that are quite conglomeritic. About one hundred feet from the base are found, in several localities, a few inches of white quartzoze sand. This layer probably represents in Wisconsin the horizon of the Jordan sandstone of Minnesota. There may have been a slow elevation during which sand was deposited, and as the land emerged from the water, the waves and surface waters may have carried the loose sand down the valley and redeposited it in central Minnesota. Then the ocean may have advanced till sufficient depth was attained for the renewal of the deposition of first a thin layer of standstone (except in hollows favorably situated, where several feet were laid down and retained), then numerous horizontal layers of limestone quite uniform in texture and structure.

Lastly, all the fossils obtained, except those from the upper or New Richmond beds, were found imbedded in masses of chert. This would

FIG. 3.



MOUND IN THE LOWER MAGNESIAN LIMESTONE NEAR BURKHARDT'S MILL ON WILLOW RIVER, SIX MILES NORTHEAST OF HUDSON.

indicate that the fossil shells were protected from destroying agencies by the more enduring qualities of chert, given to the fossils and surrounding rock by silicious waters.

The fossil remains of animals now found in the rocks are evidently but a small remnant of the life that existed when the layers were being deposited. Not only were the shells and corals broken and ground by the waves, and thus destroyed, but many that then escaped were afterwards dissolved by water soaking through the calcareous mud before induration, and thus have also left no trace of their existence other than the carbonate of lime of which their skeletons were composed.

A. Composition. The Lower Magnesian limestone is a dolomite with a varying amount of arenaceous and argillaceous material. The proportion of greensand is very small.

In the lower half of the formation the numerous cavities are frequently lined with crystals of quartz; in the upper, lenticular and irregular masses of chert, and a few layers of silicious oölite characterize the formation in many localities; and about eighty feet from the top a varying amount of quartzose sand is interstratified.

Clay, when present, is in the form of thin seams, or is distributed uniformly through the limestone, rarely giving it a schistose structure.

B. Thickness. Few localities in the district expose the entire formation.

At and near Willow River Falls, the thickness is one hundred and eighty-five feet. On Lake St. Croix, near the mouth of Kinnickinnick river, one hundred and fifty-two feet of the formation is shown. This, after allowing for denudation above and non-exposure below, would indicate about the same thickness as on Willow river.

Description of Layers. Few features of this limestone are constant, and no two sections agree except in the more general characters. Above, the formation presents medium, even beds, fossiliferous layers often curved or arched, and frequently a rough, "rotten" surface on weathering.

Below, the limestone is usually heavy bedded or massive, and in ledges it presents an irregular, cavernous face. But in several exposures whose horizon is unquestionable, these characters, except the last, fail entirely. This was undoubtedly occasioned by local influences, for the massive features soon recur.

The exposures at Willow River Falls and vicinity may be taken as the type of all. These exposures are six to nine miles northeast of Hudson.

Section IX, Willow River.

In descending order:	*Feet.*	*In.*
j. Brown to yellow and white sandstone. Friable, except where cemented by iron. These are the lower layers of St. Peters sandstone.......	25	..
i. Thin layers of ferruginous sandstone and limestone alternate at the top. The transitional layers become more heavy bedded below. At the base oölitic layers and coarse granular beds containing gasteropods are exposed. Locally the rock is quite conglomeritic............	10	..
h. Buff to fawn colored limestone. Many layers are either oölitic or porous. The heavy beds above graduate into thin, compact layers below	20	..
g. Buff, granular, crystaline to compact layers containing gasteropods....	15	..
f. Fawn colors predominate. The rock is a very compact, thin bedded limestone; in part slightly silicious, and in part a nearly pure dolomite	20	..
Similar to **f**, except that many of the layers are quite heavy bedded, are more brecciated and porous, and show numerous layers of chert. Along the left bank of Willow river these layers form a succession of arches. One measured four rods between lowest points, and had an elevation of five feet. Beneath these arches the rock is imper-		

	Feet.	In.
fectly stratified, and is often very irregular and fragmental, with traces of minute gasteropods. The right bank did not show arches to correspond, and hence it is believed that those exposed are sections of mounds	30	..
d. Heavy buff beds, showing between several layers numerous cavities, apparently produced by the removal of brecciated masses two and three feet in diameter...	25	..
c. Heavy beds, somewhat regular and uniform	30	..
b. Similar to d, but more massive, showing few lines of stratification. The rock is fine in texture, and gray to light and dark buff in color.	20	..
a. Not exposed..	10–15	..

180 to 185 ft. limestone, 25 ft. sandstone.

The mounds mentioned under e seem to have been produced by unequal deposition, which left the calcareous material in irregular, nearly unstratified hillocks. Some of the layers thin out as they approach the mounds, while others are lost in reaching them, becoming irregular and ill-defined. Above, the layers arch over, retaining their normal thickness (Fig. 3).

The space a covers the estimated distance to the Potsdam below. This entire section is derived from a series of exposures from the falls to Big Mound.

At Mt. Hellen, midway, the uppermost layers are shown near the

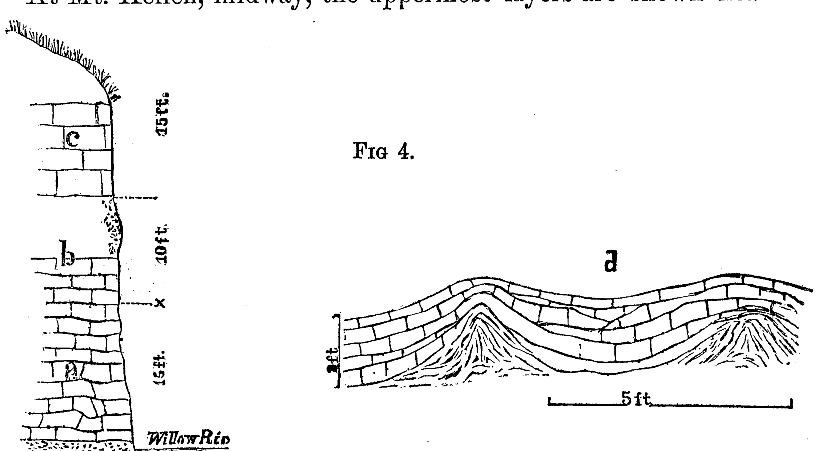


Fig 4.

Showing Curved Strata in the Lower Magnesian Limestone at Jewett's Mills.

base, the remainder of the slope being occupied by St. Peters sandstone and Trenton limestone. The same, likewise, is true of the Big Mound. The transitional layers are best exposed near the north line of Sec. 1, T. 29, R. 19 W., on Willow river.

In the bank of Willow river, at New Richmond, the oölitic layers are well shown; and at Jewett's Mills (Sec. 4, T. 20, R. 17, W.), curving lines of stratification, with several conical elevations, are exposed, about sixty feet below the line of junction. (See Fig. 4.) This would place the arching layers near Mt. Hellen and Jewett's Mills at about the same distance from the sandstone above. Midway, and at the same horizon, *sandstone* was penetrated in sinking three wells in Sec. 23, T. 30, R. 18 W.

This information was obtained from Mr. Straight, owner of well No. 1:

	(1.)	(2.)	(3.)
To rock	25 ft.	(about) 15 ft.	10 ft.
In limestone	28 ft.	(about) 15 ft.	3 ft.[1]
In sandstone	7 ft.	(about) 15 ft.	12 ft.

On visiting well No. 1, the material thrown from the well was found to consist of white and yellow sandstone and fragments of oölitic limestone. This sandstone must occupy a pocket, as other wells in the neighborhood do not strike it. The presence of thin layers of sandstone at the same horizon in other portions of the district, and the character and thickness of the limestone above and below, indicate that in this sandstone we have the eastern equivalent of the Jordan sandstone of Minnesota.

On Apple river near Star Prairie (Sec. 1, T. 31, R. 18 W.), twenty miles north northwest of Hudson, the lower layers are again exposed.

A section of the same will be given, as the rock shows an unusual amount of greensand, and is well exposed.

Section X, Star Prairie.

		Feet.
g.	Coarse, brecciated, non-uniform limestone. Much green material near the top,	15
f.	Compact, dark gray, angular limestone. Lower portion thin bedded with greensand between the layers and in cavities	10
e.	Compact, heavy beds below, with green particles uniformly distributed	10
d.	Medium beds composed of wave-like laminæ. Dark gray, compact to cherty,	5
c.	Heavy layers with one containing hummock-like elevations five feet from the base	10
b.	Coarse, crystalline limestone, dark buff to gray	10
a.	Alternating layers of limestone and sandstone. The upper layers of limestone are somewhat regular, but the lower ones are very irregular,— hummocky. The middle layer of sandstone is argillaceous and friable, while the lower one is composed of coarse sand, and is of medium hardness. The colors are buff to reddish yellow	10
		70

At Rose lake (Sec. 18, T. 31, R. 17 W.) is an exposure of massive or heavy-bedded limestone, at the same horizon as **b**, section X. Three and one-half miles east of Hudson, the *upper* layers of the formation are shown in a continuous ridge, at an elevation of three hundred

1 Thin, slaty limestone.

feet. This ridge trends to the southwest, and reaches Lake St. Croix at Catfish point, where the *base* of the formation is shown at an elevation of two hundred and eighty feet. These layers pass beneath the surface of the lake near the mouth of Kinnickinnick river. Along the Kinnickinnick, the entire formation is shown, but it presents no new features, except a layer of white sand about one hundred feet above the Potsdam.

At Sec. 11, T. 28, R. 18 W., the following fossils were found in the horizontal layers near the upper line of junction: *Straparollus ?* n. sp., *Bucania ?* sp. ? (strongly trilobed), *Leperditia*, sp. undescribed.

These layers seem to have been partially removed in central and eastern St. Croix county, as water is struck in sinking wells, after penetrating the limestone fifteen to twenty feet, or after reaching the horizon of the New Richmond sandstone. Furthermore, the transition to the sandstone above, instead of being gradual as Willow river, is quite abrupt, being uniformly marked by two to three feet of angular chert.

Near Wilson, on the West Wisconsin railroad, the cherty layers are well exposed, and the section will be given, as masses of chert are a prominent feature of the drift from this point southeastward.

Section XI, Wilson.

	Feet.
e. These layers are compact; fine grained at the top, and crystalline at the middle and base. Many cavities in the lower portion are lined with quartz crystals. Interstratified masses of chert are abundant. The limestone effervesces readily	38
d. Similar to e, but more heavy bedded. The rock has the appearance of a silicious limestone, but acids show it to be a nearly pure dolomite.........	30
c. Heavy beds, quite regular and free from chert. The rock is granular, crystalline in texture, and is an unusually pure dolomite in composition.........	14
b. Irregular, brecciated limestone. Locally all lines of stratification disappear, and the rock becomes cavernous. Some of the excavations are two and three feet in diameter. At the base the rock becomes more regular, and thin beds of sandstone are interstratified........	8
a. Transitional buff layers. Some of the upper are cross laminated, and several are brecciated........	5
	95

East of Wilson the lower layers of the Lower Magnesian limestone cap many of the bluffs and ridges, and south and southwest, exposures are numerous, but all are quite similar to the limestone at Wilson.

Uses. At all points, this limestone is well adapted for use in piers, walls of buildings, and other masonry; but, few of the layers burn successfully to lime. The lower layers seem best adapted to the latter purpose.

At Wilson, four to five thousand barrels of lime per year were burnt from the stratum **c**, Section XI. One cord of wood was used to twenty barrels of lime. Mortar from this lime is dark but durable. Other layers are used, but with comparatively unsatisfactory results. All the kilns visited were burning stone from the same horizon as **c**, Section XI, though these layers are not equally valuable for cement at the different localities.

IV. St. Peters Sandstone.

This formation rests upon the Lower Magnesian limestone, and in the southern part of the district is capped by a few feet of Trenton limestone. The lower layers of this sandstone have been described in Section IX, but at points further east, the transition from the Lower Magnesian does not seem to have been so gradual. In sinking wells in central St. Croix county, from two to three feet of brecciated, cherty limestone is struck at the line of junction. At about the same horizon in north-central St. Croix, layers of the kaolin are struck in wells after penetrating a greenish or chalky-white sandstone. Above these lower layers, the sandstone is composed of quartzose grains but slightly indurated.

At five or six points in St. Croix and Pierce counties, where the *thickness* could be measured, the same was found to vary little from one hundred and twenty-five feet, indicating a greater uniformity than in Eastern Wisconsin.

The color of the sandstone varies from red, buff, and yellow, to white; the last color being more characteristic of the upper portion.

Few traces of bedding are discernible, the rock being fissured in all directions.

Just beneath the Trenton limestone, the sandstone frequently stands out from the slope of bluffs in vertical walls and columns; but usually the stone is too friable to stand above the surface, and can be studied to advantage only in railroad cuts and river banks.

The uniform size of the grains of quartz which compose them, and their freedom from impurities, make most of the layers of this sandstone very valuable to the mason for use in mortar; and would make them valuable to glass and fire-brick manufacturers were such establishments in operation.

No fossil remains were discovered.

V. Trenton Limestone.

Capping the St. Peters sandstone are usually ten to fifteen feet (seldom more) of buff colored, thin bedded, fossiliferous limestone, with frequently two to three feet of blue shale at the top. The limestone holds many species of brachiopods, gasteropods and cephalopods, while the shale contains crinoid stems and an abundance of corals and brachiopods.

As the quarries are worked back from the snrface, the rock is less subdivided into layers, and a stone more suitable for ordinary masonry may be obtained. Frost and air, however, if allowed free access, are liable to subdivide the stone, as in the case of long exposed outcrops; though not enough to seriously impair its value.

The lower layers of this limestone are not usually burnt for lime, though they are thus treated at localities far removed from a purer limestone. It has been found that this stone burns best at a low temperature, on account of the impurities present.

CHAPTER III.

QUATERNARY FORMATIONS.

SURFACE FEATURES.

D. Topography. The formations of the Glacial, Champlain and Recent periods, will be considered in connection with the topography and soils of the region, as nearly all the surface features were evolved during the progress of these periods, and a discussion of their origin involves a history of the agencies at work during the progress of these periods.

The district inspected, comprising ranges X to XIX W., and townships 26 to 31, inclusive, is divided into two sub-basins tributary to the Mississippi, viz., *St. Croix River Basin* and *Chippewa River Basin*. In the south-central portion, however, is a region from which the waters empty directly into the Mississippi river; but the principal features of this valley are similar to those of the St. Croix River Basin, and will be classed with its subdivisions.

St. Croix River Basin. As Apple, Willow, Kinnickinnick and Rush rivers are the principal channels by which the waters of this basin are carried to the St. Croix and Mississippi rivers, the valleys of these streams will constitute its principal subdivisions.

By referring to the map it will be seen that all the valleys except that of Rush river, trend southwesterly. This is what would be expected from the nature and general dip of the rock formations beneath.

Numerous rapids mark the several streams, indicating the rapid descent of their valleys to join those of the St. Croix and Mississippi rivers. Their high and oftentimes rocky banks offer fine opportunities for studying the several formations. Aside from the beds of the several streams, the valleys present few features in common.

After crossing the county line, Apple river takes its way to the St. Croix through a rough, bluffy country.

Willow river, after flowing for a time through an elevated timbered region, has fashioned its valley, from New Richmond to Hudson, in the prairies and plains through which it takes its course.

The Kinnickinnick makes for itself a broad valley in south-central St. Croix county, in the rolling prairie of that region; but at River Falls it abruptly sinks below the surface and reaches the St. Croix river through a gorge, whose perpendicular walls of limestone are nearly one hundred feet in height.

Rush river has an uncertain beginning in the central portion of St. Croix county, and flows through prairie and lowland till it enters Pierce county. From this point it takes its course through a region, broken and bluffy by reason of the numerous tributary valleys, eroded by the several streams which join the river in this part of its course.

These, in brief, are the more important surface features of the subdivisions of St. Croix Basin; other characters will be mentioned in discussing the origin of these features.

It is evident that the rivers and lakes, as they now exist, could not have fashioned the valleys, hills, ravines, ridges and prairies, nor can all be accounted for by showing that a far heavier body of water once occupied the river courses and lake beds. Valleys have been eroded in the solid rock, afterwards filled by sand, clay and gravel, and these in turn have been cut to the depth of one hundred feet and more by rivers and creeks, making valleys nearly as deep but much narrower than the first. Prairie and woodland alternate throughout the basin. Numerous bluffs show at their summits rounded erratics, three and four feet in diameter, evidently from regions far to the north. The banks of the larger rivers expose similar bowlders. From Hudson to Eau Claire, bowlders and pebbles of granite, diabase and quartzite, are very abundant in gravel knolls, and in the above positions. The northwestern portion of St. Croix county is covered by a heavy deposit of drift, in which *kettle holes* are a common feature.

There is no known agency through which much of the above could have been accomplished or rendered possible except that of ice in motion.

The Geologist in Chief has shown, in Volume II, that there were at least two ice movements from the north and northeast during the Glacial period, in Eastern Wisconsin. It is probable that Northwestern Wisconsin was visited by arms of these glaciers, the ice moving southward by the way of the western end of Lake Superior. Glacial drift, however, compared with that of Eastern Wisconsin, is very light; subsequent denuding, burying, and eroding processes having removed most of it from the hilltops, except the larger erratics, concealed it in the valleys, plains, and prairies, and brought it to view from beneath in the banks of rivers.

A partial exception to this is found in the broken surface, the heavy deposit of drift, and the numerous kettle-holes, forty to sixty feet in depth, in the northwestern portion of St. Croix county, the leveling process not having been completed in that region.

These probably mark the course of an ancient moraine. A series of morainal deposits is said to be continuous with it in the adjacent district. No instance of planing and striating of rock surfaces was discovered in the entire district.

Preglacial river valleys must have existed for untold ages previous to the Glacial period, and were consequently very broad and deep. The glacier, in its slow movement southwards, would level the elevations and leave much of the material in these valleys when the movement ceased. Many of the old water-courses being thus filled with drift, the streams would be compelled to seek new channels for a portion of their course at least.

This seems to have been true of River St. Croix. It is difficult to believe that preglacial waters with the later ice eroded or even outlined the present narrow valley of the river north of Stillwater, but at Hudson the same objection does not exist; the bordering ledges of rock being two and three miles apart. To the northward of Hudson a broad valley flanked by bluffs extends as far as eye can reach. (This valley was observed from the high terrace in the rear of Lakeland, opposite Hudson.) A similar valley was crossed by our party near the north line of the county, which, having about the same course, may be continuous with it.

The nature of the rock formation beneath also gives strength to the supposition that this may have been the ancient valley of the St. Croix river, this being the course of a narrow belt of sandstone in the midst of a limestone area. The question is a very interesting one, and is well worthy the attention of the future investigator.

It is possible that, in the above, we have the reason indicated for the abrupt change in the course of some of the other rivers of St. Croix county in the region occupied by the ancient moraine.

During the **Champlain** and **Recent** periods, the heaps of pulverized rock and rock fragments, left by the melting ice, were first leveled by lakes and broad, sluggish rivers, and then cut into valleys and terraces by the latter, as increasing elevation at the north moved their waters more rapidly to the southward. But, like the change from spring to summer, no sharp dividing line exists between the work of these later periods. Characteristic features alone admit of presentation.

The ridges, bluffs and tablelands, rock-ribbed to the summit, simply stand as so many monuments, to tell the geologist of their escape from destructive agencies which, in times past, carved the valleys and plains out of the solid strata of rock that then covered the face of the country. The work of these periods, then, must be studied in the valleys and plains.

We commenced our field work at Hudson. Ascending the high bluff in the rear of the city and facing to the southwest, one is struck by the unmistakable evidence of terracing which he beholds upon the Minnesota shore of Lake St. Croix. There are at least two principal terraces, with as many minor ones. The first principal terrace rises about seventy feet above the lake, is quite level, and is covered by a scanty growth of vegetation. The soil is a sandy loam with an abundance of pebbles, rounded and water worn. The agency of water is here unmistakable. The minor terraces come next, and serve as steps to the second principal terrace, two hundred feet above the St. Croix. The slope of this terrace is quite precipitous, and the cause is seen in the sandstone which crops out at the summit. The surface is much cut and broken by water courses, but is otherwise quite level back to the hills which limit it in the distance. The first terrace can hardly be said to have a representative on the Wisconsin side of the lake, though the narrow strip between the bluff and the lake, occupied by Hudson, may have become land at about the same time. The second terrace, however, is well marked, and of large area. Commencing at Catfish Point (T. 28, R. 20 W., Sec. 24), it extends to Willow Falls, if not further. It is bounded on the right, for the first four miles, by a ridge of Lower Magnesian limestone, and the remainder of the way by broken sandhills. On the left, the bounding line leaves the St. Croix below Hudson, and, passing around Hudson bluff, continues north to the falls.

Along the St. Croix, northward, the surface is much broken, leaving but few traces of the terrace in this direction. On this terrace, so far as was learned, the wells sunk even within a short distance of the limestone ridge mentioned above, were all in sand and very deep; no sandstone being struck except in the vicinity of the Hudson bluff. Southward, rounding the ridge at Catfish Point, we enter another level district, with about the same elevation. Here the Lower Magnesian limestone has passed beneath the surface, and *islands* and ridges of St. Peters sandstone, capped with Trenton limestone, constitute the boundaries. Before the St. Croix had excavated its present channel, its waters must have covered both the valleys at River Falls and vicinity, and the terraces near Hudson. If the farmers east of Hudson bluff are right in saying that there is no rock within one hundred and sixty feet of the surface of the terrace, there must have been first an erosion, then a subsequent filling up of the valley, followed by another period of erosion, which outlined the terraces and gave the river its present channel. The Hudson bluff either occupied the eroded valley as an island, or, after the same was filled by drift, the lake-like river fashioned its principal channel in the sandstone along the western side, separating Hudson bluff from the main body of sandstone.

By referring to the Map of Vegetation accompanying this report, it will be seen that the central portion of St. Croix county is occupied by an extensive prairie, nearly surrounding the Trenton limestone shown in the Geological Map of that county. The formations underlying this prairie are in part Lower Magnesian limestone, and in part St. Peters sandstone. Directly upon these rest beds of loose sand and gravel. The prairie terminates towards the east in Rush river valley, and towards the north in that of Willow river. In the vicinity of New Richmond, however, the prairie crosses the latter river and stretches northward in detached areas to the county line. The soil, the underlying sand and gravel, the absence of forests, the precipitous slopes of bluffs and bordering ridges, together with the wooded summits, all speak of a time when these regions were under water.

As we follow Rush and Kinnickinnick rivers southward, the country is more broken. The level areas may have been built up and the bluffs worn away by the present streams, though at a time when they possessed a greater volume of water.

The watershed between St. Croix and Chippewa basins is very readily traced through St. Croix county by referring to the map. It follows very nearly the middle of range 16 to the north line of township 30, when it curves to the northeastward and passes out of the county. West of this line the surface is made up of level (or nearly so) plains with bounding hills, bluffs and ridges.

At the east St. Croix county is well timbered, but at the west, between Apple river and the St. Croix, the broken surface is scantily covered by shrubs and bushes.

Summary. Prof. Dana states, after a review of the drift phenomena of northern United States, that there must have been an upward oscillation at the north in the Glacial period, a downward oscillation in the Champlain period, and an upward one of moderate extent in the Recent period.

The first, with its southward ice movement, would plane down and refashion, to a large degree, the rocky floor of the St. Croix Basin, carrying the fragments to the southward and leaving upon its surface, when the movement ceased, a mixed assortment of clay, sand, gravel, and bowlders, from northern latitudes. During the second period, numerous lakes must have occupied the depressions, and lake-like rivers, the valleys, and thus commenced the work of leveling the huge heaps left by the melting ice. The shores of Lake Superior are said to have been depressed 330 feet, and the Arctic region 1,000 feet. In the St. Croix district the rate of flow to the south in the rivers must have been very small in consequence.

As the northern latitudes slowly increased in elevation, the waters would continue to slowly accumulate in the drift valleys and sandstone excavations, till the Lower Magnesian and Trenton limestone barriers were surmounted and eroded at the south, when the rivers would readily mark out their present channels. In the meantime, the Potsdam and St. Peters sandstones and the drift hills and ridges would rapidly give up their store of sand and clay to the encroaching waves to assist the clay and sand from the north, to fill up and occupy the lake basins and river valleys.

Then, as the Recent period progressed, the increasing elevation at the north would give increasing velocity to the waters, the several streams of the basin would accommodate themselves to narrower and narrower channels, and the beds of the rivers would sink lower and lower, leaving the old lake beds far above them, giving their present relationship.

This seems to be the history of St. Croix basin during the three periods mentioned above; and, in its essential portions, also, of Chippewa basin and the neighboring districts. Local histories vary with the surrounding rock formations, the nature and quantity of the drift, and the position, direction and dip of the valleys and ridges. The same grand march of events, but with infinite variations in the result.

Chippewa River Basin. This basin extends from the Mississippi river nearly to Lake Superior, and is characterized in its southern half by wide areas of sand together with numerous sandstone ridges. But a small portion of this basin is comprehended in my district, viz.: The valleys of Little Eau Galle, Red Cedar (or Menomonie) and tributaries, and that portion of the Chippewa valley between Chippewa Falls and Durand.

The Little Eau Galle valley north of Brookville P. O. (Sec. 18, T. 28, R. 15 W.) is broad and rolling, covered by a dense growth of timber; but south of this, while the high lands remain the same, the river soon cuts through the Lower Magnesian limestone into the underlying Potsdam sandstone and flows southward through a constantly widening valley of its own erosion, till both are merged into the Chippewa river and valley.

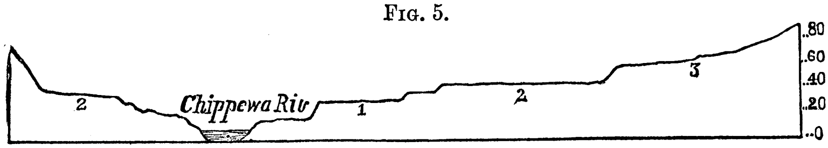
The valley of the Red Cedar and tributaries includes nearly the whole of Dunn county, and, with the exception of the western portion, lies in the Potsdam sandstone. By referring to the Geological Map, it will be seen that the minor valleys from the west have their origin on the Lower Magnesian limestone, soon breaking down, however, into the sandstone, leaving high ridges and tablelands on either hand.

The lower portion of these valleys, lying in a soft sand rock, was fashioned and determined, for the most part, by the successive stages of the stream which drains them. At least no direct evidence of other agencies was obtained.

In the Chippewa valley, however, additional facts were obtained bearing upon the Champlain and Recent periods. It will be noticed that the Chippewa has its headwaters near Lake Superior. In many instances it derives its waters from the same section of land as the streams that flow into Bad river, and that *deep indentation* of the shores of Lake Superior, Chaquamegon Bay. Southward to Chippewa Falls, the Chippewa flows for the most part over Archæan rocks, but at the falls it leaves the granites, and thenceforward takes its course in the Potsdam sandstone. The surface features are similar to those that are found in all sandstone districts — highlands variously cut and denuded by the streams which drain them.

The terraces, which are so marked a feature in the southern portion of the course of the Chippewa river, will be considered first.

FIG. 5.



TERRACING NEAR PORTER'S MILLS 5 MILES SOUTH OF EAU CLAIRE.

These terraces lie on one or both sides of the river from Chippewa Falls to Durand, to my personal knowledge, and vary greatly in their elevation above the bed of the stream. Two, three, and four may be counted at various portions of its course. On the west side of the river at Durand, the upper terrace lies about one hundred twenty-five feet above the river, and exposes at its brink nothing but loose sand. At Meridian, about midway between Durand and Eau Claire, we measured the terrace on the north side of the river, and found an elevation of one hundred feet with sand at the brink as before. In both these cases the level surface stretched back to the timbered hills and highlands.

Four or five miles north of Eau Claire, a terrace rises about one hundred and forty feet above the Chippewa, and is limited by a ledge of sandstone which rises above it nearly two hundred feet. The terrace is built up of sand and gravel for the last eighty feet, as shown by a well, and so is unquestionably a river or lake deposit. Between these three points, the terraces are just as marked, and the river or lake action just as evident. The above were selected for the sake of brevity, as representatives of all. Then, as in the St. Croix basin, there was first a period of erosion, then one of deposition, and, lastly, one of erosion.

The same influences, modified according to situation and elevation, gave the lowland and tableland, so marked on the lower Chippewa, and between the Chippewa and Black rivers.

The entire Chippewa basin, in my district, sympathized very deeply with the more immediate valleys of the larger streams, the only difference being a less complete erosion and leveling of the sandstone, leaving, as a consequence, a more connected and crowded system of bluffs and ridges. But these, as well as the fluvial or lacustrine deposits along the rivers, are being worn down slowly and surely to the level of the valleys and river beds below. The tributary streams are constantly lengthening their channels by cutting back into and through the bluffs and ridges. The waters roll the sands down their channels to the main stream, there to join the sands of the terraces in their slow journey toward the Gulf. Thus the topography of Chippewa basin is constantly changing,

The Potsdam sandstone offers little resistence to the elements, and the changes must continue so long as the waters continue to flow and a hill remains.

Elevations.

The elevation above Lake Michigan of stations along the West and North Wisconsin railways is that given in the railroad surveys. The elevation of other points in the district above the same level was obtained from a series of aneroid observations. These elevations will be of service in determining geological horizons, and in making calculations for flow in sinking Artesian wells:

For the elevation above the ocean, add 589 feet.[1]	*Feet.*
Baldwin, T. 29, R. 16 W.	
R. R. station, Sec. 30	560
Woodville station, Sec. 35	573

[1] Mr. James T. Gardner gives 589.15 feet as the mean of nine determinations of the height of Lake Michigan above mean tide of the ocean, and as this is undoubtedly a closer approximation to absolute accuracy than the height formerly given (578 feet), and adopted in the earlier work of this survey, it is here adopted in lieu of that. T. C. C.

	Feet.
Cady, T. 28, R. 15 W.	
Cady P. O., Sec. 16	537
Brookville, Sec. 18	510
Eau Galle river, near Brookville	449
Chippewa Falls, T. 28, R. 8 W.	
R. R. station	301
Duncan creek, 1½ miles north of city	276
Cylon, T. 31, R. 16 W.	
Sec. 33	506
Eau Claire, T. 27, R. 9 W.	
R. R. station, Sec. 16	266
Terrace, Sec. 3 (Seymour)	311
Highland, Sec. 3 (Seymour)	520.
Ellsworth, T. 26, R. 17 W.	
Sec. 18 (bluff)	525
Isabelle Creek, Sec. 17	490
Emerald, T. 30, R. 15 W.	
Fleming's Mills, Sec. 19	621
Blew's Mills, Sec. 34	504
Erin Prairie, T. 30, R. 17 W.	
Jewett's Mills, Sec. 3	454
Erin Center, Sec. 15	480
Elk Mound, T. 28, R. 11 W.	
R. R. station, Sec. 26	351
Hudson, T. 29, R. 20 W.	
R. R. station, Sec. 24	123
Lake St. Croix	90
Top of Hudson Bluff, Sec. 25	330
Hudson, T. 29, R. 19 W.	
N. Wis Junction, Sec. 20	295
Hammond, T. 29, R. 17 W.	
R. R. station, Sec. 28	525
Sec. 22	550
Sec. 26	510
Kinnickinnick, T. 28, R. 18 W.	
Sec. 11 (junction of Lower Magnesian and St. Peters)	385
Lucas, T. 28, R. 14 W.	
Gilbert Creek, Sec. 32	336
Menomonee, T. 28, R. 13 W.	
R. R. station	306
Sec. 26, E. half	290
Reservoir, Sec. 27	382
Red Cedar (below dam)	200
Martel, T. 27, R. 17 W.	
Sec. 25, S. W. corner	460
Sec. 23, N. W. quarter	400
New Haven, T. 31, R. 14 W.	
Sec. 22, S. W. quarter	490
River Falls, T. 27, R. 19 W.	
Sec. 1 (village)	285
Rock Falls, T. 26, R. 11 W.	
Sec. 22	186

	Feet.
Red Cedar, Town 28, R. 12 W.	
Rusk station, Sec. 15	331
Rush River, T. 28, R. 17 W.	
Sec. 35 (river)	400
Richmond, T. 30, R. 18 W.	
Sec. 29	375
Sec. 23	415
Star Prairie, T. 31, R. 18 W.	
Sec. 1, Apple river	366
New Richmond station, Sec. 36	411
Somersett, T. 30, R. 19 W.	
Sec. 3, Apple river	240
Stanton, T. 31, R. 17 W.	
Rose Lake, Sec. 18	356
St. Joseph, T. 29, R. 19 W.	
Willow river at Mt. Hellen, Sec. 1	288
Bonchea, Sec. 2	343
Willow river, below falls, Sec 3	151
Sherman, T. 29, R. 13 W.	
Hawthorne's kiln, Sec. 8	656
Springfield, T. 29, R. 15 W.	
Wilson station, Sec. 35	518
Hersey station, Sec. 28	588
Stanton, T. 29, R. 14 W.	
Knapp station, Sec. 35	349
Knapp bluff (top)	580
Tiffany, T. 30, R. 14 W.	
Brown's store, Sec. 25, S. W. corner	394
Trimbelle, T. 26, R. 18 W.	
Sec. 2, N. half, lowland	327
Sec. 2, N. half, highland	477
Troy, T. 28, R. 20 W.	
Catfish Point, Sec. 24, ridge	340
Lake St. Croix, Sec. 24	90
Warren, T. 29, R. 18 W.	
Roberts station	462
Twin Lake, Sec. 28	360

CHAPTER IV.

E. HYDROLOGY.

Prof. T. C. Chamberlin estimates, in Vol. II, that 165,512,000,000 barrels of water fall annually upon Eastern Wisconsin. Assuming that Northwestern Wisconsin possesses a somewhat less annual rainfall, about 20,000,000,000 barrels fall each year upon the district under consideration. Of this amount, it is estimated that one-third is carried from the district by its creeks and rivers, and that the remaining two-thirds is either taken up by the atmosphere, through evaporation, or is absorbed by the earth, to be carried away by underground water courses, if not arrested by vegetation and fountains.

The entire district is well drained, there being but few areas of swamp or marsh land. It may be questioned, indeed, whether the system of drainage is not too complete, as large tracts frequently suffer from drought during the summer season.

The rivers are quite uniformly rapid and offer to the manufacturer fine water privileges, especially in that portion of their course where they leave the Lower Magnesian limestone for the Potsdam sandstone, or leave the more compact layers of either formation for those less indurated below. At least three dams have been erected upon Apple river and its tributary, near the north line of the St. Croix county, and there is a fine water power on the river at the falls in Sec. 22, T. 31, R. 19 W. On Willow river, from Jewett's Mills to the mouth, four mills have been erected, and on the Kinnickinnick there are at least three. Rush, Eau Galle, and Red Cedar, each supplies power to nearly as many, the water power on the latter at Menomonee being one of the best in the country. The Chippewa, at the falls. and the Eau Claire river, near its mouth, run large manufacturing establishments. Were the supply of water in the above rivers more uniform throughout the year, many more dams might be erected with profit upon them and their tributaries.

Except in the dense forests, evaporation is very rapid from the surface after showers, owing to the porous nature of the soil and the heated condition of the atmosphere over the sandy tracts and treeless plains. The light loam likewise permits the moisture to escape readily from the surface to the watercourses beneath. The quantity of water thus lost to the farmer and manufacturer must be very great, for, let a well be sunk where it may, one or more of these underground streams is sure to be found soaking through the gravel or between the layers of rock below. It were far better if much of this water could be made to take the shorter circuit by causing it to return to the air at once through osmose and evaporation, than to allow it to run to the sea.

While studying the cause of an evident increase in rainfall over limited areas on the plains of Colorado, irrigated for five or six years, and planted to trees and small grains, it occurred to me that vegetation has contributed to this good work by restoring to the atmosphere water that is running below the surface. The roots of many trees penetrate the ground to a depth of ten to twenty feet and more, in search of water, pushing downward until they find it.

It is not necessary for the plant to send its roots to the water-bearing layers for water; for the soil is kept more or less moist through capillary attraction, by which the water is made to rise slowly to the surface, there to evaporate. The quantity of water thus restored to the atmosphere is said to be quite large, even from tracts barren of vegetation. But plants very much hasten this process, as they are able by their roots to approach very near, if not penetrate, the water-bearing strata. Met or arrested by the roots, as the case may be, the water is drawn by osmose through root, stem, and branch, to the leaves, from whence a large proportion is evaporated to the atmosphere.

Prof. Gray says that a sunflower plant, a little over three feet high, with about forty square feet of surface in foliage, etc., has been found to exhale between one and two pints of water per day. A fair sized forest tree possesses between one and two hundred thousand square feet of area in foliage. Assuming that the evaporation from each square foot of its surface is two-thirds as rapid as from the same in the sunflower, over one thousand barrels of water would be poured into the atmosphere by the tree during each season of growth.

Since the above was written, the results of a series of experiments on transpiration, by J. M. Anders, M. D., Ph. D., have been published in the American Naturalist for March, 1878. In his summary, he says that evaporation is more rapid in clear than in cloudy weather, about 5 to 3; in day time than at night, 5 to 1; and more rapid when the wind is blowing than when it is calm, 6 to 5 (when the current is strong).

He further says: "The following table will serve to exhibit the average transpiration by day, which took place in the open air, together with the leaf-surface, temperature, etc.:

No.	Name of Plant.	Duration of Exeriments.	Average Evaporation.	Evaporating Surface.
1.	Calla.	12 hours.	2.850 grs.	All parts green.
2.	Geranium.	"	3,500 grs.	
3.	Fuchsia.	"	1,975 grs.	450 sq. in.
4.	Hydrangea	"	2,858 grs.	744 "
5.	Camellia.	"	710 grs.	479 "
6.	Lantana.	"	1,717½ grs.	330 "
7.	Dracaena.	"	2,422 grs.	817 "

No	Weight of Plant.	Average Temperature.	Average Dew Point.
1	2 lbs. 2 oz. (Troy)		
2	4420 grains		
3	1920 grains	64.5°	49.6°
4	2170 grains	73.0	56.7
5		75.5	63.3
6	720 grains	75.1	61.7
7		75.5	62.0

"After an inspection of this table, the average rate of evaporation for soft, thin-leaved plants, in clear weather, may be put down at about 1¼ ounces (Troy) per day (12 hours) for every square foot of leaf surface. The Lantana shows nearly two ounces to the square foot of surface. The Camellia, with its dense, smooth leaves, averaged less than half an ounce to the square foot of surface, per day.

"According to the above rate, the Washington Elm, at Cambridge, a tree, it is stated, of no very large size, with its 200,000 square feet in leaf surface, would transpire 7¾ tons of watery vapor in twelve hours (day) of clear weather."

If, on the average, seven-eighths of an ounce (Troy) of moisture per day is evaporated from each square foot of foliage in the oaks, maples, etc., of Northwestern Wisconsin, a grove of one thousand trees, each with a leaf surface equal to that of the elm, would pour into the atmosphere over 45,000 barrels of water during every clear day of its season of growth.

This is much greater than the previous estimate, based upon the evaporation from the sunflower, and, of course, gives increased weight to the statement there made: that forests increase the amount and value of the annual rainfall, as they help to supply one of the essential conditions of light and frequent precipitation — a moist and cool atmosphere — by exhaling from their leaves vast quantities of water that would otherwise be lost in the rivers and seas before it could reach the rain-cloud. This constant evaporation from forest vegetation, through the power which water possesses of absorbing or releasing vast quantities of heat as it condenses or vaporizes, serves to modify those disastrous extremes in water-supply, floods and droughts, by rendering sudden changes of temperature less possible, and by lessening the heat of summer and the cold of winter. In Europe, floods are known to be more numerous, and in Asia droughts more frequent since vast forests have been removed.

A recent writer says that the famine in China, which has reached its crisis the present year, has been caused by the failure of the rice crop for three seasons, owing to the terrible drought which followed the destruction of the timber in Shan-tsi and Chihli. In much of the prairie region of America it is claimed that the annual rain-fall is sufficient, three years out of five for all the purposes of agriculture, and that more would be a damage; but it seems to the writer that this is fallacious, for were the heavy rains lighter, and the lighter showers more frequent, though the sum total be not increased, the vegetation could but be more luxuriant and fruitful. It is the long-continued and heavy rains that work damage.

Northwestern Wisconsin needs an increased and more uniform rainfall during the summer season, instead of a diminishing one. The air over the extensive, treeless plains, prairies and terraces, becomes intensely heated during the summer, and many rain-clouds are thus dispersed when water is most needed; and consequently freshets are not uncommon, and droughts are frequently experienced throughout the district. To what degree tree-planting would remedy these climatic defects, opinions differ; but as to the fact, theory and experiment are agreed.

Springs, fed by water from the drift, and from the rock formations, are of not unfrequent occurrence. At Hudson and Menomonee, water appears at the surface midway up the bluffs, from layers not far beneath the Hudson Trilobite beds. A spring was reported near Somersett post office, probably from the same layers, for the water of which, valuable medicinal properties were claimed. South of Star Prairie post office, a spring was noticed that is fed by water from the upper portion of the Potsdam sandstone.

In Sec. 6, T. 31, R. 17 W., Stanton, is a swampy tract from which issues a brook of considerable size. Among the springs which feed this brook, is a cluster, termed by the proprietor "New Saratoga Springs," the waters of which are much used by invalids. Prof. Gustavus Bode analyzed the water for the proprietor, September 9, 1875, with the following result:

	Grains, Per U. S. gallon.
Chloride of sodium	0.1344
Sulphate of soda	0.0784
Bicarbonate of soda	0.8120
Bicarbonate of lime	3.9984
Bicarbonate of magnesia	3.0744
Bicarbonate of iron	0.7392
Silica	1.0360
	9.8728

From this analysis it will be seen that the water is quite pure and possesses a relatively large percentage of iron. The soil is deeply colored with iron stains wherever the water has penetrated.

No springs were noticed in the Lower Magnesian limestone; but water is almost universally struck in sinking wells into this formation. In East Central St. Croix county, water in abundance is found after penetrating the rock fifteen to twenty feet.

No Artesian wells have been sunk in the district, but the indications are in part favorable for a flow, especially in Middle St. Croix and Pierce counties, north and south. Several Artesian fountains in Eastern Wisconsin derive their water from the upper portion of the Potsdam sandstone, evidently from layers nearly parallel with the shaly layers below the Hudson trilobite beds. These layers, where they come to the surface in Barron and Polk counties, have an altitude about five hundred feet greater than they possess at North Wisconsin Junction. At the latter point the impervious layers lie about three hundred feet below the surface, and do not outcrop to the south and west except near the crest of the Hudson anticlinal. (See Plate II.)

The surface at La Crosse is below these impervious layers, and the owners were consequently obliged to sink the Artesian well in that city to the granite below. At all localities in Middle and Eastern Dunn county, the same would probably be necessary.

The average dip of the Potsdam sandstone is about twelve feet per mile S. S. W.: and by bearing this in mind the probabilities for and against a flowing well at any point may be readily obtained, provided the necessary conditions of a flow, stated in Vol. II, near the top of page 150, are observed in connection with these data. Of these conditions the one which states that the water in the water-bearing strata must not have a natural outlet at a level lower than the surface at the proposed well, is the one that presents the most serious objections to sinking a well in central St. Croix county, for the impervious layers come to the surface along Lake St. Croix. But they are exposed only on the face of the anticlinal ridge, and this, too, out of the line of dip of the formation, and thus a flow may not be impossible. In Pierce and Dunn counties, this objection does not exist, as the dip in the strata is so much greater than the slope of the surface that they are not exposed to the south southwest.

CHAPTER V.

F. VEGETATION.

An entirely satisfactory treatment of this subject is, for several reasons, nearly impossible. Several large areas in the district could not be visited, and consequently but a general knowledge of their vegetation was obtained. Large tracts that were once covered with pine have been stripped of this timber, and a miscellaneous growth of shrubs has succeeded, which, with the hardwood timber that was left standing, make up a forest altogether different from the original one. The several groups shade into each other by almost imperceptible degrees, and, as from the nature of a map, this cannot well be shown, the lines of separation give a false impression to the eye, and, in many instances, may cause the map to seem inaccurate.

But by making the proper allowances, it is believed that the consideration of this subject will present much that is valuable to a good understanding of the resources and capabilities of the district. Indeed, so close is the relationship that exists between the vegetation on one hand, and the rainfall, soil and subjacent rock formation on the other, that a person with a thorough knowledge of the kind and degree of this relationship may gain from an accurate map of vegetation most of the information necessary to a good understanding of the character of the three associates. Only one or two illustrations of this truth will be given here, as its full consideration is evidently beyond the scope of this report, and these, with what follow, will be sufficient to call to mind many more of kindred nature from which each observer may easily erect a system of his own of greater practical utility to himself.

Sugar maple, white oak and basswood are seldom found in a region where the soil is poor and the rainfall scanty.

The evaporation is so slight from the smooth, needle-like leaves of the pine, that it may thrive in a light sandy soil, though it is not averse to plenty of moisture and rich earth, if there is a substratum of sand, or the rock formation lies near the surface. It is probable that its peculiar power of growing in so shallow or porous a soil is due to the economy of the pine in the use of water, and to its dense foliage and social habits which prevent the moisture from evaporating as

MAP OF VEGETATION OF LOWER ST. CROIX DISTRICT
by
L. C. Wooster 1876 77.

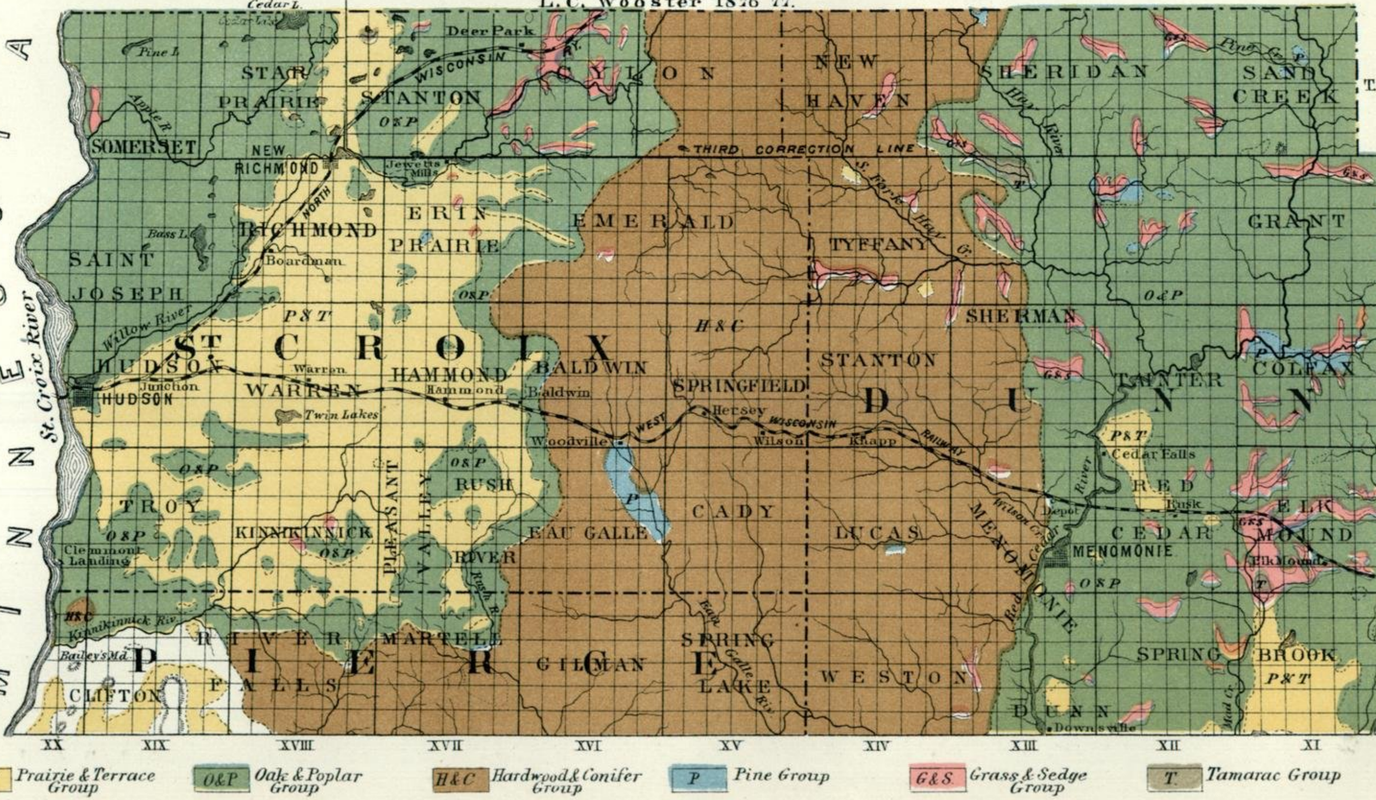


PLATE VII

rapidly as it otherwise would from the leaves and from the surface of the ground underneath. Be this as it may, areas of pine are most often found to represent poor farming lands.

Then again, different species of the same genus are frequently best adapted to widely different habitats. I have never seen the white oak growing in other than excellent soil, while the black-jack or barren oak seems to be confined to sandy tracts, where it stands a fit representative of the region.

In the vegetable, as in the animal kingdom, each individual owes its existence to its combative energy, and the "fittest survives." The weaker must either retreat to a locality where it may be master in strength, or it must lead a half-starved existence where the stronger has not the power or the inclination to follow.

So in these illustrations, it should not be understood that those plants we find in barren regions flourish best here, and are better adapted to these surroundings. When transplanted, the contrary is nearly always found to be true when care has been taken to give the plant time to adapt itself to its new habitat. Sudden prosperity ruins here as well as elsewhere.

Frequently nature allows one or more of these weaker plants to gain a place in more fertile earth, and a tree of unusual size and beauty is the result; but the number of instances where a forest thus gains possession is too few to constitute a valid exception to the general rule.

Of course, if we are to take vegetation as a guide to a knowledge of the preëxisting soil and rainfall, and the rock-formation, we must eliminate all the changes produced directly or indirectly by man, and so in the following paragraphs we shall endeavor, so far as possible, to give the vegetation of the district as it existed before the advent of the settlers and lumbermen.

In presenting the result of our investigations, a consideration of most of the herbaceous plants will be omitted, not that they are less important, but that fewer have studied the nature of their relationship to soil, rainfall, and subjacent rock-formation, and furthermore, a description of the more striking groups is, perhaps, sufficient.

Class I. Prairie and Terrace Group. The vegetation growing upon the prairies and terraces of the district is so nearly the same in kind, that no attempt will be made to separate these areas. In many localities this would be impossible, were it desirable.

Much of the soil, being a light loam and not very deep, is quite porous, and so the vegetation differs somewhat from the prairie vegetation in Eastern Wisconsin, both in kind and abundance; but in the more general features, it is the same, probably owing its existence to similar causes. But a light soil is not universal, for here and there in the larger areas of prairie and terrace, a deeper soil, a lower and more moist district, or a higher level where glacial drift still remains, supports a rich growth of grass, or may be covered by oak and poplar. Many of the deeper hollows are occupied by lakes or ponds with a circling border of marsh vegetation, or the water remains but temporarily, leaving the entire area a hay marsh. Most of these, being quite small, are not shown on the map (Plate IV).

In Dunn county, patches of prairie and strips of terrace are found in nearly every township. Most of the larger areas are represented, but many of the lesser ones either escaped our notice or were too small to be shown. These afford farming lands next in value to the "coolies" and river valleys.

In numerous localities, a light growth of oak now covers many detached areas and bordering lands that once belonged to this class, so it is well nigh impossible to fix the original limits; but as this and the succeeding class are closely related in all that pertains to soil and moisture — the latter simply indicating a less permeable subsoil or a more uniform supply of water — the present boundaries and distribution of the group will show all that is desirable in the presentation of this outline.

The main body of the terraces and prairies rests upon sandstone, as may be seen by comparing the Map of Vegetation with the Geological Map of the district; and thus unfortunately the drainage is very good, and nothing but a more constant rainfall can save these areas from frequent droughts. As timber requires a *uniform* supply of water throughout the year, its absence over these regions may be due to the porous nature of the subsoil and rock formation. Indeed, both prairie and terrace vegetation may owe their presence in part to the nature of the sandstone underlying them.

Much of this group in St. Croix and Pierce counties is underlain by but a few feet of sandstone, and under a portion the Lower Magnesian limestone is the subjacent rock. In these cases, a richer, more productive soil is the result, except in the immediate vicinity of the St. Peters sandstone bluffs. The fluvial or lacustrine deposits near River Falls, and the level areas near Willow and Rush rivers, illustrate this very finely.

All this prairie soil is capable of yielding rich returns to the farmer who understands its deficiencies and endeavors to remedy them. Much of it needs more lime and magnesia to make the growing of small grains continuously successful. Limestone from the Lower

Magnesian or Trenton formation will yield these elements. As it readily parts with soluble manures, its absorptive and retentive powers should be increased. In nature, clay and carbonaceous matter serve these purposes. This result would, perhaps, be most readily attained by giving the soil fertilizers in greater quantities, and adding to its absorptive power by frequently plowing under a crop of clover, thus furnishing a fresh supply of carbon as well as adding other valuable elements. Wheat, corn, oats with clover, and clover constitute an approved succession of crops. On one of the premium farms in England, with a dry, porous soil, the following order was used with great success: "First, potatoes, after lea; second, wheat; third, oats or barley; fourth, hay; fifth, hay." The last two years, after the crop was secured, the grass land was pastured.

In any section of country, a uniform and plentiful supply of rain is one of the most essential prerequisites to a successful cultivation of the soil. The only exception exists in those countries where irrigation may be practiced. After all that has been written upon the subject of rainfall, after the repeated warnings nature has given in the form of droughts, and floods, and extremes of heat and cold, it certainly seems strange that farmers should not only persist in the destruction of timber, but should neglect to restore the forests by replanting, till the state or general government should offer a bounty for so doing, when they themselves are the principal sufferers. It cannot be a want of care for the welfare of the next generation for the evil effects of this course are felt already. If people are not convinced of the evil influence of forest denudation upon climate and rainfall, it must be, in the opinion of the writer, that they have not fully considered the subject. To secure the best results, concerted effort is necessary; but individual work is not without profit when many valuable forest trees have so rapid a growth, though unfortunately in a new country few think that they can afford to wait for the return. After a careful consideration of the subject, the writer believes that a single township may have the benefit of a more uniform water supply by tree planting; but to effect a marked change in rainfall and climate the large treeless tracts denuded of timber, and the prairies and terraces throughout the district and regions to the west in Minnesota must be occupied by numerous groves of forest trees, that the intense radiation of heat and the rapid evaporation of moisture may be checked.

Where so many seem indifferent, and where all would be benefited, it is the duty of the state to protect its interests, present and future, by legislation: first, by granting assistance in money; then, if this is not fully successful, by pains and penalties. At least one-fourth of every farm should be timber; and every year trees should be planted to take the place of those cut down, that this ratio may be maintained.

The annual rainfall may not be increased largely, but beyond question the moisture precipitated will be more uniformly distributed throughout the year. This is exactly what grain, fruit and forests require, and what the land must have to make its continued tillage profitable. The *way* in which forests accomplish this, with the several reasons therefor, is briefly outlined under Hydrology (pp. 139–142), and need not be repeated here.

Though the résumé of the subject is presented under Class I, its careful consideration is commended to the people of the entire district, both in those regions where the destruction of forests still continues, and in all those localities where the timber is light and soil porous.

Class II. Oak and Poplar Group. Lying between Groups I and III, geographically, this group partakes somewhat of the nature of both, and frequently shades into them by almost imperceptible degrees.

Unlike the the oak groves in the limestone and heavy-drift regions, much of the timber is quite light, being composed largely of shrubs and bushes. The species were not observed, but so far as remembered they are smaller varieties of Red Oak *(Quercus rubra)*, Black Oak *(Quercus tinctoria)*, Aspen *(Populus tremuloides)*, Great-toothed Poplar *(Populus grandidentata)*, and, in the vicinity of the pine barrens, a dwarfish oak with dark foliage, Black Jack Oak *(Quercus nigra?)*.

In the richer soil in the vicinity of the next group, fair sized individuals of White Oak *(Quercus alba)*, and Burr Oak *(Quercus macrocarpa)*, are mixed with larger forms of a portion of the preceding.

In the northwestern portion of St. Croix county, west of Willow and Apple rivers, dwarf oaks and poplars, with hazel bushes *(Corylus Americana)*, occupy the surface except over the Lower Magnesian limestone in the eastern and western borders of the region. Though the subsoil is composed in part of glacial drift, in this portion of the country, this usually rich earth contains so large a proportion of sand from the large area of Potsdam sandstone at the north, that the water soon leaves the surface and sinks to a great depth below, as shown by wells. The greater tenacity of the surface soil is all that saves these townships from the treeless condition of the prairies and terraces. By supplying the soil with calcareous and carbonaceous matter through fertilizers and the rotation of crops, indicated under the preceding group, this region could be brought more largely under cultivation.

In southern St. Croix and Pierce counties over the Trenton and Lower Magnesian limestones, and where these formations border upon the underlying sandstones of the valleys, thus giving the surface a continued supply of calcareous material through wash, a heavier growth of timber and a richer soil prevail. This soil resembles quite closely the light marly-clay soil of the oak-openings of the land bordering upon Rock prairie of southeastern Wisconsin, and, like it, is rich and productive. The same is likewise true of the belt north of St. Croix prairie, belonging to this group. With proper care and attention, the soil of these two areas should continue to yield abundant returns to the farmer.

In central and eastern Dunn county, a somewhat greater diversity exists, as may be seen in part by referring to the map (Plate IV). In Central Dunn county a few island like bluffs, either capped or recently capped (geologically speaking) by Lower Magnesian limestone, supply the contiguous regions with calcareous loam, and consequently a vigórous growth of vegetation is the result. Nearly all the bluffs and ridges in this part of the county expose one or both of the calcareous bands and the shaly layers of the Potsdam sandstone to the denuding action of wind, rain and frost, and thus much of the soil is rendered quite productive by wash.

At the east the trees are small and scattering, except along the several streams, and the soil, in general, light and porous. Here and there an old lake bottom or water course, or a detached, irregular area of clay soil, possibly a remnant of the drift from the granite to the north, supports a heavier growth of timber, and gives to one or more farmers quite productive land for cultivation. Such areas are probably more prevalent to the north and east, in the more immediate vicinity of the Archæan rocks.

The timber of this group is quite mixed throughout Dunn county. The prevailing kinds are Black and Red Oaks, and Poplar, with here and there small groves of White Birch *(Betula alba, var. populifolia)*, Red Cedar *(Juniperus Virginiana)*, Spruce *(Abies sp. ?)*, Balsam Fir *(Abies balsamea)*, and Pine *(Pinus sp. ?)*. The slopes of the bluffs and the lower barrens are frequently covered by Blueberries, Blackberries *(Rubus villosus* and *R. Canadensis ?)*, and Red and Black Raspberries *(Rubus strigosus* and *R. occidentalis)*. This would indicate that the culture of small fruit might be made quite successful.

In the northern portion of the county, the timber becomes much heavier, and valuable pine lands still exist. Very little land is under cultivation, and the resources and capabilities of these townships are but little known. We did not have the time to visit them; but from what we learned, should judge that much good land may be brought under cultivation.

The portions of Chippewa, Eau Claire and Pepin counties visited differ but little from those portions of Dunn county that correspond geologically. Here, as in Dunn county, the underlying sandstone and the calcareous and clayey layers exposed in the bluffs and ridges, together with the patches of glacial drift, determine, to a great degree, the character of both vegetation and soil. As the subsoil possesses but little tenacity, being quite universally porous, an abundance of fertilizers and a constant supply of water are essential to continued good crops.

Class III. Hardwood and Conifer Group. This group includes a great variety of species of forest trees, owing to the diversity of soil and subsoil and conditions of moisture and elevation which the belt occupied by the group presents; but with few exceptions, whatever the species each finds here the most favorable conditions for growth and continued existence the entire district presents, and hence the entire belt is usually denominated the "The Heavy Timber." The uplands on the west and north are underlain by Lower Magnesian limestone, with here and there low hills of St. Peters sandstone. The numerous creeks and rivers which find their source in these uplands soon cut their channels into and through the limestone to the Potsdam sandstone below, leaving the limestone in nearly vertical ledges, and thus exposed to constant erosion by the elements. As the channels sink lower and lower into the Potsdam sandstone, first the calcareous bands then the shaly layers are given to the elements, and when these are no longer shown in their banks, the streams have passed out of the group.

Nothing could show more unmistakably that both soil and subsoil obtained the greater part of the elements which compose them from contiguous rock formations where glacial drift is light or absent; and that they still depend upon the limestones and calcareous sandstone for a continued supply of natural fertilizers and other elements to preserve the proper strength and tenacity of the soil, that the vegetation may have a constant supply of food for its rapid growth.

Of the three formations which have contributed to the soil and subsoil, the Lower Magnesian limestone has given most that is essential to a good soil, and thus may be said to be the formation which rendered so magnificent a growth of timber possible. The varying proportion of material obtained from the three strata has given the great variety, making the group a collection of groves, rather than a body of mixed timber having like affinities.

White Pine *(Pinus strobus)* finds on the high lands, where sand from the St. Peters sandstone remains, and in the river and creek valleys in the Potsdam sandstone, the warm, silicious soil it seems to prefer. Large quantities of pine logs have been run down the several streams since the advent of the lumberman, and a number of mills are still in operation, converting the trees that remain on the smaller creeks into lumber, so that few of the large, handsome trees that once grew in this group still remain. In the richer, deeper soil over the limestone, and where the wash is deep in the valleys below, White, Red, and Burr Oaks grow with Sugar and Red Maples *(Acer saccharinum* and *A. rubrum)*, Basswood *(Tilia Americana)*, Slippery and American Elms *(Ulmus fulva* and *U. Americana)*, White Ash *(Fraxinus Americana)*, Ironwood *(Ostrya Virginica)*, Black Alder *(Almus incana)*, Butternut *(Juglans cinerea)*, Bitternut *(Carya amara)*, Poplars and Thorn Apple *(Cratægus coccinea)*, American Crab *(Pyrus coronaria)*, Wild Red Cherry *(Prunus Pennsylvanica)*, Chokeberry *(Pyrus arbutifolia)*, and Wild Plum *(Prunus Americana)*. In many of the damper woods, Black Ash *(Fraxinus sambucifolia)*, Red Maple and Water Beech *(Carpinus Americana)*, are the prevailing species.

In the northern portion of this belt, Pine is more prevalent, while at the south, Oak, Maple, and Elm are more characteristic.

Except in Pierce county, but a small proportion of this wealth of soil has been brought under cultivation; but whenever the ax clears the way for the plow and reaper, the farmer may expect generous returns for his labor, if he but uses the land wisely, and restores the food his crops remove for their tissues, as the soil is by no means inexhaustible.

Class IV. Pine Group. Apart from the areas assigned to the two preceding groups, little land covered exclusively by pine exists in the district. The location of several bodies is shown in Plate IV. More probably exist in those regions, as the conditions are quite favorable for its growth, but these are all that came to our notice of sufficient size to merit separate mention.

The bodies of White Pine are frequently skirted by Red Pine, *(Pinus resinosa)*, wrongly called Norway Pine with a tree termed Black or Jack Pine *(Pinus Banksiana)* in the drier situations. The rock formation, or the body of sand beneath the surface chosen by conifers as a habitat, renders the soil of pine lands, for the most part, unsuitable for agricultural purposes, but there is no reason why these areas may not be replanted to pine, and thus provision made for the coming generations, and large tracts rendered rain-inducing instead of a dry, barren plain.

Class V. Grass and Sedge Group. Bordering nearly every stream in the district are more or less extensive bottom lands, flooded during portions of the year, that produce the well known marsh vegetation.

The borders of many lakes in the more elevated regions show nearly the same species; so also do the ponds and moist hollows in similar situations. The greater proportion of the marshes are used for hay and meadow lands, the poorer sedge marshes being very fortunately in the minority. No cranberries were seen growing with this group, but there seems to be no reason why they should not flourish in peat marshes, over the Potsdam sandstone, that may be flooded and drained at pleasure.

Class VI. Tamarac Group. These well-known conifers cover a few peat marshes in the district, in the midst or apart from the preceding group. They prefer those marshes that are quite moist throughout the year. The Tamarac or American Larch *(Larix Americana)* is very exclusive in its habits, permitting but few other arboreal species in its midst. The Ericaceæ constitute almost the entire undergrowth, and the wet, peaty bottom is carpeted with Sphagnoid mosses. In some portions of the state where the Tamarac has been destroyed by fire or other agencies, the last species, with its near relatives, continues its growth till the fallen Tamaracs are covered by several feet of peat. In some portions of the eastern part of the district, the Tamarac is replaced by Cedar and Spruce, and by Black Ash.

Much of the land covered by this group is too wet, or, if drained, too sour to be cultivated at once for small grains; though this depends so largely upon the mineral and organic constituents, that it is by no means universally true, and if this soil is treated patiently and wisely, the best of meadows frequently result. Quick-lime is an excellent corrective, and fifty bushels per acre are frequently sown on wet lands, making them sweet and productive.

On account of the extent of the district, and the necessarily limited size of the plate, a number of the southern townships could not be shown on the map; but this is not so much to be regretted, as the vegetation is quite similar to the contiguous townships on Plate IV, and in the treatment of the subject, the entire district has been kept in view.

The discussion of this topic has been somewhat extended, and much has been given in regard to soil and subsoil, that the way may be prepared for a clear and concise exposition of the following important topic, so difficult of treatment:

CHAPTER VI.

G. SOILS AND SUBSOILS.

Outline.

- I. ORIGIN.
  - a. *Mineral* — By attrition from
    1. Igneous rocks.?
    2. Metamorphic,— granites, etc.
    3. Semi-crystalline, some limestones, etc.
    4. Fragmental,— sandstones, etc.
  - b. *Vegetable* — By decomposition from
    1. Herbs.
    2. Shrubs.
    3. Trees.
  - c. *Animal* — By decomposition from
    1. Vertebrates.
    2. Articulates.
    3. Mollusks. (Post Silurian.)
- II. KINDS.*
  - d. *Silicious.*
  - e. *Calcareous.*
  - f. *Argillaceous.*
  - g. *Carbonaceous.*
    1. Origin.
    2. Characteristics.
    3. Prevalence.

But a small proportion of the tissue of a plant is made from soil, as may be seen by comparing the ashes from a burnt log with the matter it contained before burning.

Its chief food is found in the gases and liquids of which a part, mostly the former, are derived directly from the atmosphere, and the remaining portion of the gases and liquids from the ground; and thus one of the principal offices of the soil is to serve as a reservoir for the fluid part of the plant food.

Remove the absorptive and retentive powers of a soil and it becomes worthless. A like result follows if these powers are given to excess. Then the structure and composition of a soil are the important factors that determine its value.

In the treatment of this topic I shall endeavor to make it simple, rather than exhaustive. The more important kinds and the chief characteristics, alone, will be considered; and thus the facts and suggestions will, it is believed, be rendered more available.

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* Named from leading constituent.

The relationship that exists between the soils and subsoils and the accompanying vegetation is so intimate, that much of interest in this subject has been more conveniently presented with the latter, and so will be found in that connection.

1. Origin of the Soils and Subsoils of Lower St. Croix. a. *Mineral by Attrition.* Few people have not noticed that from day to day and from year to year, the large masses of rock around them are slowly crumbling down and wearing away.

Acid and alkaline waters, frost, storms of wind and rain, and multitudes of minute cryptogamous plants are constantly at work lowering the limestone bluffs, the sandstone mounds and the granite ridges. Prof. Dana states that the Appalachians have probably lost by denudation more material than they now contain. The rock foundations of Wisconsin were exposed to the elements ages and ages before many of the Appalachian peaks were lifted above the surface of the Paleozoic seas. Is it any wonder, then, that our mountains are so low and our soils and subsoils in many places so deep?

All the materials which compose our soils, excluding those under b and c, are found as the constituent elements of these mountains. Fragments are found miles away which may almost be taken to the parent ledge. Fossils have been found by me in bowlders at many points in Southern Wisconsin, which unquestionably have traveled hundreds of miles; and the laborer throws from his gravel pit, pebbles which once must have rested snugly in the granite and diorite ledges of Northern Wisconsin and Michigan.

Lastly, the origin of our soils from solid rocks by attrition (except b and c) is indicated by the rounded grains and pebbles which show by their very form that they have endured the wearing, grinding action of transportation by water in one of its forms.

b and c. *Vegetable and Animal, by Decomposition.* Materials derived from this source are of the utmost importance to our surface soils, giving to them elements and absorptive powers which are essential to most plant life and growth.

Forest upon forest has lived and decayed, burying with its falling trunks the countless multitude of animals that have sought its depths for food and protection.

For ages the vegetable world has been engaged in separating carbon from the oxygen of the carbon di-oxide of the air, storing it up in its tissues, till they in turn give it up to the soil to aid in the growth of the next generation of plants.

2. Kinds of Soils. d. *Silicious.* 1. *Origin.* The Archæan rocks to the northward are rich in silica, and thus would furnish an abundance of silicious sand when worn down by erosion. The Potsdam sandstone lying next on the south, and occupying nearly the whole of Dunn county and extensive areas in St. Croix, is capable of furnishing an unlimited amount of sand; while the St. Peters sandstone of St. Croix and Pierce counties is but an immense sandbank.

2. *Characteristics.* Sandy soils are hot and dry, because they quickly give up their moisture; give free access to atmospheric air, and soon lose soluble manures.

3. *Prevalence.* Were it not for the fact that grains of sand, except when very minute, are only transported by being rolled along by running water, or carried by moving ice, large areas which are now cultivated would be utterly barren. As it is, the sand is not transported long distances except by streams of considerable size, so that the map for the sandstone formations answers very well for a map of sandy soils.

Exceptions, due to the fact that the sand has been covered by other material, will be mentioned under f, 3.

e. *Calcareous.* 1. *Origin.* Lime and magnesia are constituents of the Archæan rocks in Northern Wisconsin; but we must look to limestones, sandstones, and remains of modern animals, for the more immediate source of supply of these important components of our surface soils. The Lower Magnesian and Trenton limestones, and the calcareous layers of the Potsdam sandstone, have furnished the larger percentage.

2. *Characteristics.* A lime soil absorbs large quantities of water without becoming sodden; it has greater tenacity than sandy, but less than a clay soil, and it shrinks less than the latter on drying up. Alone, lime makes a soil that is poor and hot, but, mixed with a little clay, the soil is excellent. Both lime and magnesia are essential to most plant life and growth.

3. *Prevalence.* The areas possessing the above characters are confined, principally, to St. Croix and Pierce counties, and for the most part overlie the Lower Magnesian and Trenton limestones. Sand and clay so predominate that the calcareous material is almost entirely disguised in the surface soils. The particles of carbonate of lime and magnesia have been removed from the surface by vegetation and water sinking to lower levels, and are partially restored by wash from limestone or calcareous sandstone ledges, by subsoil plowing, and by water that is slowly raised to the surface by capillary attraction.

f. *Argillaceous.* 1. *Origin.* Fortunately for Wisconsin, the Archæan rocks at the north are quite rich in clay-making material; fortunately for Northwestern Wisconsin, the Potsdam sandstone and

Lower Magnesian limestone contain, in many layers, a large percentage of clay.

2. *Characteristics.* Clay is not food for plants, but unites the looser ingredients of the soil. Loam is to be regarded as clay intimately mixed with iron rust (hydrate of the peroxide of iron) and large quantities of sand, obtaining its brown or red color from the former. This form of clay soil is more porous than pure clay, being also milder, softer, weaker, warmer, and more permeable.

3. *Prevalence.* Fortunately and unfortunately, clay is very readily transported by water, as may be seen after any shower. Fortunately, for otherwise, sandy tracts, as the coolies along the ridges, are thus made very productive; unfortunately, because the clay is carried away by the creeks and rivers, leaving most of the sand behind.

Forests are so dependent on a moist soil that the best map of the clayey-loam soil will be found in the map of vegetation.

The areas marked prairie in St. Croix and Dunn counties are usually quite productive, but these prairies have so large a body of sand underneath that they are often seriously affected by drought. The surface soil is, for the most part, a light loam. This is likewise true of the terraces along the St. Croix and the Chippewa rivers. Many of the bluffs and ridges in the vicinity and in the midst of the areas of Potsdam sandstone furnish a constant supply of calcareous loam, so that the *narrow* valleys rank among the most productive lands of the state.

g. *Carbonaceous.* 1. *Origin.* As has been already stated, plants and animals supply our soil with carbonaceous material.

2. *Characteristics.* Carbonaceous earth is a powerful absorbent of gases, and is a deoxidizer as well. Thus the plants get the gases so essential to their existence.

3. *Prevalence.* This constitutes the surface soil of the entire district, and its varying depth, indicated by its dark color, furnishes one of the best proofs of productiveness, aside from actual trial.

This topic very fittingly closes this report, as most of general interest in the Geology, Topography, Hydrology and Vegetation of the district centers here.

None of the more important ores — iron, lead, copper, etc.— was discovered, though the presence of the first two was claimed by those who believed in the stories told by Indians and *very secretive* white men.

It is possible that lead ore (galenite) exists in the Lower Magnesian limestone as in the Lead Region, but from all that we learned we do not think that such a desideratum is very probable.

It is entirely useless to look for coal, and nearly so for iron and copper in paying quantities. These latter are certainly not to be found in any of the limestones and sandstones except as impurities, and the rocks that may possibly contain them lie without the district or beneath the Potsdam sandstone.

Most of the clay is too impure for *brick making*. The only locality known where clay is used for brick is near Menomonie. Two kilns are here in successful operation. We had the opportunity of visiting but one, that owned by Mr. William Drowley. The clay contained sufficient sand to work well; and the molding is done with sand by hand. Six to seven days are required in burning. Wood was worth $1.50 per cord for soft, and $1.75 to $2.00 for hard, when the yard was visited in 1875. During the year preceding, 450,000 brownish red brick were burned, mostly for consumption within the district.

Thus it will be seen that the wealth of Lower St. Croix district lies chiefly in its farming lands. Several large saw-mills are now in constant operation manufacturing lumber from pine cut for the most part without the district; but the amount of wealth from this source is small compared with that which is locked up in its soil, and the sooner capital and labor are turned more exclusively to the development of the agricultural resources, the sooner will continued prosperity be brought to its people.

PART III.

PALÆONTOLOGY.

BY R. P. WHITFIELD.

PRELIMINARY REMARKS.

The species described in the following pages are not offered as a complete representation of the fauna of the several geological formations of the state, but only as a few of the more prominent known species, together with some of the most characteristic new ones of the several localities from which they have been obtained. Many of the forms illustrated have been given previously in the geological reports of other states; or have been partially illustrated in papers published elsewhere, which are either out of print or otherwise inaccessible to most of the citizens of the state. It has therefore been thought advisable to give, in this connection, a few well marked forms from each principal geological formation, to enable those living within the region occupied by them, to identify the different beds from a report which it is hoped may be placed within the reach of all. Of the new forms, those which are the most abundant, or those which are most likely to attract attention, have usually been selected from the several localities, and do not by any means include all of those recognized as undescribed, or new to science. In a few instances, uncommon or obscure forms have been given; but such as are expected, from their peculiarities, will most likely be found at other localities, and will serve as guides in determining or identifying their equivalent strata at other points. For this purpose, partially, the localities where the several species have been found are given at the end of the description, so that by reference to the locality where mentioned in the Report previously published (Vol. II), the relative geological position of the strata in which they occur may readily be determined.

It is a matter of considerable interest that, in different localities of the Potsdam formation, the forms of Trilobites found are generally specifically distinct; and, notwithstanding the large number of species already described from this formation, both in this state and from other parts of the country, other new forms, readily detected by those familiar with the several details of structure peculiar to these animals, are met with at almost every new locality examined. This change in species between different localities is usually accompanied also by some slight difference in the material or composition of the rock, which not only shows that the species were of short duration in time, or that they were restricted to limited geographical areas, but that a change in the conditions of life and circumstances under which the animals existed, and with which they had to contend, was constantly taking place. How much these circumstances or conditions had to do with the production of forms, or modification of types among them, it would be difficult to determine; but one thing is certain, that where the same character of rock, and apparent conditions of deposition prevail over a limited geographical area, or are repeated within a slight vertical range, we are pretty sure to find the same, or closely allied, forms represented, showing that, under like conditions, similar forms prevail.

Among the new forms described from the Potsdam sandstones, the genera *Palæacmaea*, *Bellerophon*, and *Ellipsocephalus*, are here noticed for the first time in the formation in Wisconsin. The first of these has only been noticed in the rocks of this age in New York, where the typical species occurs. The Wisconsin form, although differing specifically, closely resembles the New York form, and occurs in a rock of precisely similar character; namely, a hard, light colored, siliceous sandstone, compactly cemented by a siliceous cement, and resembling a quartzite. The genus *Bellerophon* is, I believe, here noticed for the first time at so low a geological horizon. The species is a well marked form, and although represented only by internal casts, is clearly seen to belong to the *imperforate* section of the genus. Of the trilobitic genus *Ellipsocephalus*, no species has hitherto been described from the rocks of this country; and in Europe it is credited to the lower beds of the Primordial strata. The form herein described is very characteristic of the genus, the part preserved having strong affinities with the European *E. Hoffii*, Schlot., and indicates the low geological position of the strata.

The group of Gasteropods from the Lower Magnesian limestone of Eikey's quarry, near Baraboo, will be found to possess considerable interest, not alone from their geological position, but also from the fact that all but two of the entire group have reversed spires, or are recurved at their apices, while the exceptions are capuloid in form and have no twist.

Of the Trenton and Galena limestone species, a few only of the more characteristic forms have been selected, and these from some of the typical localities. Among the fossils of the former group at many localities, there usually occur an abundance of Brachiopoda, some of which are eminently characteristic of the formation, but most of them have been so often described and illustrated, and are so generally known, that it has seemed unnecessary to repeat them here, at considerable expense; while other forms, as widely spread and equally abundant in the formation within the state, would then necessarily be left untouched. Throughout the Blue and Buff limestones of the formations in southern Wisconsin, the *Gasteropods* and *Cephalopods* characterize the formation, almost to the exclusion of *Brachiopods*, the few forms of the latter class which are common being principally Strophomenoid forms, and are mostly of the three species, *Strophomena alternata* and *S. camerata* Conrad, and *S. incrassata* Hall, or one usually referred to that species. But by far the greater proportion of the organic remains of the beds consists of the true mollusca, *Lamellibranchiata*, *Gasteropoda* and *Cephalopoda*. In the upper blue beds of the group, there are usually large numbers of *Orthis* of two or three species, but they are mostly confined to the few feet constituting this bed, which occurs immediately below the Galena beds, and but few individuals of the species occur below. Among the *Lamellibranchiates*, the genera *Cypricardites* and *Tellinomya* are much the most common. A few other genera are represented, but by comparatively few species and individuals. The Gasteropods are more numerous, but consist principally of the genera *Maclurea*, *Ophileta*, *Raphistoma*, *Trochonema*, *Murchisonia*, *Pleurotomaria*, *Subulites*, *Bucania* and *Bellerophon*, some of which are quite abundantly represented in individuals, especially the last mentioned, which often forms a thin but almost continuous layer of considerable extent, in the lower blue beds.

Among the *Cephalopods* of this formation, the great development of the genera *Oncoceras* and *Cyrtoceras* may be mentioned as a peculiar feature, both as regards the number of species and individuals; and among them some aberrant forms occur, such as those flattened on one side, as represented by *Cyrtoceras planoconvexum* (*Orthoceras planoconvexum* Hall) and *C. planidorsatum* Whitf. The *Orthocerata* are also represented by several genera other than the typical one. In fact, true *Orthoceras* is rare, except as represented by the annulated forms; while *Endoceras*, *Cameroceras*, *Ormoceras* and *Actinoceras* are the prevailing types.

The fossils representing the fauna of the Hudson-River (Cincinnati) shales have been found at but few localities, but are so characteristic where obtained, as to leave no doubt of the identity of the beds with those recognized in other parts of the country. The prevailing forms at most localities are Chætetes-like bodies and Bryozoans; of which there are represented in the collections many species entirely new to science. A few of these only have been described and illustrated. Certain forms of Brachiopods are also not uncommon at some of the localities, though not abundant in individuals to the extent to which they often occur in other parts of the country. A few of the new forms which have proved most abundant, and which are known to occur at several localities, have been figured on Plate 12, which, together with the other forms illustrated, will greatly aid in determining the formation at new localities.

Of all the geological formations of the state, the Niagara group is by far the most abundantly fossiliferous, and the fauna presents many peculiarities. Among these, perhaps the most noticeable is the great abundance of corals which occur in some of the beds extending over a large territory within the state. Among them are many very striking and beautiful forms, which must have occured in great abundance, for their remains are found imbedded in the drift and scattered over a great extent of country, as well as in the rocks in place. It is to be regretted that a complete illustration of these species could not be given, but it would involve considerable expense and require a large volume for these alone. I have endeavored to present a few of the most prominent forms, or those which appear to be the most characteristic. It is possible, however, and even probable, that some of these may ultimately prove to be characteristic of certain beds only, and may occur at but few localities. Among the Brachiopods of the group, the genus *Pentamerus* appears to be the most abundant and widely spread, both geologically and geographically. There are, however, many local varieties of the principal species *(P. oblongus)*, that are confined to quite limited areas, and in many cases, as shown by the collections of the survey, to a limited vertical range in the formation: showing a greater amount of local variation than has been noticed in any other group of shells. The changes which are seen to have taken place, among those referred to in this species, are entirely too great to be satisfactorily included within the limits of a single species, or to be ascribed to individual variations only; and the fact that any certain form or type prevails over a given area, almost to the total exclusion of all other varieties, is, I think, pretty strong evidence of its specific value. Certainly if we should find among living forms, even at the same locality, the same amount of variation, there would be strong inclination on the part of most persons to regard them as of specific value; especially as these variations involve both the external and internal features of the shells. On plate 17 a few of these varieties have been shown.

The upper portion of the Niagara group is particularly characterized, at most of the localities, by the great abundance of crinoidal remains; but as many of them have been illustrated elsewhere, it seemed undesirable to incur the expense of republication at this time.

The recognition of the true equivalent of the Guelph limestone of Canada at several points within the state, characterized by a number of its peculiar fossils, and with an expression of the entire fauna differing materially from that of the Niagara limestone below, is also an interesting fact, and the impossibility of illustrating the entire fauna, a matter of considerable regret. The recognition of these beds, and the discovery of Lower Helderberg fossils below the cement beds around Milwaukee, will probably tend to throw additional light on the question of the relative age of some other formations of this and the adjoining states. The higher beds around Milwaukee have shown by their fossils, a closer affinity with the Hamilton group of New York than with the Upper Helderberg group, as heretofore supposed. The positive identity of so many species leaves little or no question as to the age of the formation, and its occurrence at this point, when taken in connection with the trend of formations in Michigan, across the lake, shows unmistakably its relation to, and former connection with the beds in the northern part of that peninsula. And the fauna taken collectively, would perhaps indicate that it represents the entire Devonian series, as represented at other points.

SPECIES FROM THE POTSDAM SANDSTONE.

PLANTÆ.

Genus PALÆOPHYCUS, Hall.

Palæophycus plumosus.

Plate I. Fig. 1.

Palæophycus plumosum —Whitfield; An. Rept. Geol. Survey Wis. for 1877, p. 50.

Remains consisting of slender and elongated, slightly flattened or cylindrical stems of about a twelfth of an inch in diameter, and somewhat flexuous; dividing and subdividing at the upper extremity into several branches, forming feather-like tufts, the divisions of which almost immediately attain the same dimensions as the parent stem, and are from half an inch to an inch and a half in length. Surface apparently roughened by indistinct longitudinal corrugations.

The remains at first sight somewhat resemble those described in Vol. I, Pal. Foss. Canada, under the generic name *Licrophycus*, but when more closely examined, are seen to have an entirely different mode of bifurcation, the divisions being of the size of the parent stem and taking place apparently one at a time, although very near each other, instead of the parent stem breaking up at once into a great number of smaller branches.

Formation and locality. In thin, greenish sandstone layers, of the Potsdam period, below Mendota, Wis.

BRACHIOPODA.

Genus LINGULEPIS, Hall.

Lingulepis pinnaformis.

Plate I. Figs. 2 and 3.

Lingula antiqua — (Conrad) Hall; Pal. N. Y., Vol. I, p. 3. Pl. I, fig. 3 a–c.

Lingula antiqua — Hall; Foster & Whitney's Rept. Lake Superior, p. 204. Pl. XXV, fig. 2.

Lingula pinnaformis—Owen; Geol. Rept. Wis., Ia. and Minn., p. 583. Pl. I B, fig. 468.

Lingula pinnaformis — Owen; Rept. Wis. Vol. I, p. 21, fig. 3, and p. 435.

Lingulepis pinnaformis — (Owen, sp.) *Hall;* 16th Rept. State Cab., p. 129. Pl. VI, figs 14 and 16, and 12, 13 and 15?

Shell spatulate, prolonged and attenuate in the upper part of the ventral valve, rounded on the sides and in front; the cardinal slopes, often slightly concave, surface of the valve convex, appearing smooth but showing fine concentric laminæ of growth under a lens. Dorsal valve short-ovate, with a short, obtuse and slightly incurved beak. Surface as in the other valve.

This is a very characteristic species of the lower beds, often occurring in great numbers, and in a beautiful state of preservation. The extended beak of the ventral valve is a distinguishing feature.

Formation and locality. In the lower part of the Potsdam formation, at St. Croix Falls, and at various other localities in Wisconsin.

Genus ORTHIS, Dalman.

Orthis pepina.

Plate I. Figs. 4 and 5.

Orthis pepina — *Hall;* 16th Rept. State Cab., N. Y., p. 134. Pl. VI, figs. 23-27.

Seen only as casts of the interior and impressions of the exterior.

Shell semielliptical to paraboloid, unequally biconvex in profile. Ventral valve the largest, depressed convex, with a broad shallow sinus marking the anterior half; beak pointed; cardinal area moderately large, flattened and overhanging, with a large triangular fissure. Internal cast characterized by a strong projecting process on the cardinal margin which has occupied the rostral cavity and muscular imprint, and which is marked in its lower portion by a pit representing the adductor muscular scar. Dorsal valve depressed convex, scarcely marked by a mesial fold; hinge-line straight; area obsolete. Interior marked in the cast by a pair of pits near the hinge, resulting from the removal of the crura, which were widely divergent. Surface of the shell marked by rather strong radiating striæ, and by numerous concentric lines of growth.

The species is probably not a true *Orthis*, as that genus is recognized and represented in such forms as *O. hybrida* and *O. elegantula*, but appears to have been one of those representative forms which combine the features of several genera or types of a genus in an incipient degree, which, as they become developed more strongly in subsequent species, present features which are recognized as characteristic of distinct genera. The ventral valve of this form possesses all the essential features of that valve of Orthisina, as illustrated in *O. anomala*, but the dorsal valve seems to have been entirely destitute of the cardinal area, and to have possessed the cardinal process and hinge features afterwards shown in the genus STREPTORHYNCHUS, as illustrated in *S. fititexta* Hall of the Silurian and *S. crenistria* of of the Lower Carboniferous formation.

Formation and locality. In brownish, friable sandstone of the Potsdam period, at Berlin, Wisconsin. Prof. Hall recognized it at Reed's Landing, Lake Pepin; at Miniska and at Osceola.

GENUS LEPTÆNA, Dalman.

LEPTÆNA BARABUENSIS.

Plate I. Figs. 6 and 7.

Orthis Barabuensis — Winchell; Am. Jour. Sci. and Arts, Vol. XXXVII, p. 229, 1864.
Leptœna Barabuensis —Whitfield; An. Rept. Geol. Surv. for 1877, p. 60.

Shell of medium size or smaller, measuring about half an inch or less than half an inch along the hinge-line; form semielliptical, longest on the hinge and more than half as wide again as long; extremities of the hinge often submucronate; front of the valves rounded or slightly emarginate in the middle. Ventral valve the most convex, and marked by a strong, angular mesial elevation, nearly one-fourth as wide on the front of the valve, as the width of the shell; area moderately high and nearly in the plane of the valve; cardinal borders very gradually sloping from the center to the extremities of the cardinal line. Dorsal valve less convex than the opposite, and marked by a subangular mesial depression, corresponding to the fold of the opposite valve; area linear. Surface of the shell apparently smooth, or at least so far as can be determined from either the internal casts or from the matrix.

I had some doubt regarding the positive identity of this species with that described by Prof. Winchell in consequence of the following remarks which occur in his description: "Surface with sixteen or eighteen ribs visible on the casts, the strongest of which limit the mesial sinus;" and again, "apparently of the type of Orthis biforata." In examining a number of specimens, I had not been able to detect any striæ or ribs, and felt somewhat inclined to regard it as a distinct species from that one. I have, however, through the kindness of Prof. W., been able to make a direct comparison with one of his original specimens, and should consider them as identical. The specimen sent me has the mesial fold (of the ventral valve) remarkably strongly defined by a depressed line on each margin, the center appearing tumid, which I think is in part due to accident. The specimen corresponds closely with the ventral valve we have figured, except in the strongly defined mesial fold.

The generic relation of the species is apparently much stronger with *Leptæna* than with *Orthis*, although it is possible it may not be a true *Leptæna;* but in the conditions of the specimens it is impossible to see wherein they differ. It differs from *L. Melita*, H. and W. Geol. Rept. 40th Parallel, Vol. IV, part 2, p. 208, Pl. I, figs. 13 and 14, in wanting the striated surface and in being proportionally shorter on the hinge-line in comparison with the length from beak to base.

Formation and locality. In the upper layers of the Potsdam sandstone, near the north end of Devil's Lake, near Baraboo, Wisconsin.

Genus TRIPLESIA, Hall.

Triplesia primordialis.

Plate X. Figs. 1 and 2.

Triplesia primordialis — Whitfield; An. Rep. Geol. Surv. Wis. for 1877, p. 51.

Shell small, measuring less than half an inch in width; transversely oval in outline, and quite ventricose in profile; hinge-line straight and about half as long as the width of the shell below; area narrow. Ventral valve with a strongly depressed, rather narrow and rounded mesial sinus. Dorsal valve with a narrow, sharply elevated fold not extending quite to the beak; sides of the valve rounded. Surface smooth in the casts, but presenting the appearance of having been externally striate. Processes in the interior of the dorsal valve apparently forming a small spoon-shaped pit at the beak.

There may be some little doubt as to the right generic reference of this species; the apparent spoon-shaped pit beneath the beak of the dorsal valve would seem to indicate a relation to the genus *Camerella* Billings, but the external form is much more like that of *Triplesia extans* of the Trenton limestone, and the apparent pit may have been misinterpreted in the only specimen observed.

Formation and locality. In the Potsdam sandstone at Roche à Cris Bluff, Adams Co., Wisconsin.

GASTEROPODA.

Genus PALÆACMÆA, H. and W.

Palæacmæa Irvingi.

Plate I. Figs. 8 and 9.

Palæacmæa Irvingi — Whitfield; An. Rept. Geol. Surv. Wis. for 1877, p. 51.

Shell rather large, depressed, conical, petaliform, about half as high as wide, and the length slightly exceeding the width, giving a broadly oval or ovate outline to the margin; apical half of the shell rather more abruptly conical than the basal portion, the apex situated slightly in advance of the middle of the length and laterally compressed; body of the shell marked by strong, concentric or encircling undulating wrinkles or folds, and also by lines of growth.

The species differ from *P. typica*, H. and W., from the Potsdam sandstone of New York in its greater size, more circular form, compressed apex, and stronger undulations. The species appears to have been not uncommon, but as it occurs in a hard quartzitic sandstone, it is not readily obtained in good condition, but appears mostly in the form of rings or parts of rings on the surface of the rocks, and is consequently not easily recognized.

Formation and locality. In the quartzite layers of the Potsdam group, in Jackson Co., Wisconsin.

Ophileta (Raphistoma) primordialis.

Plate I. Figs. 10 and 11.

Straparollus (Ophileta) primordialis — Winchell; Am. Jour. Sci. and Arts, Vol. XXXVII, p. 228, 1864.

Comp. *Ophileta complanata — Vanux.* Geol. Rept., 3d dist. N. Y., 1842, p. 36, fig. 2; Pal. N. Y. Vol. I, p. 11, fig. 2.

The following is the description of this shell given by Prof. Winchell, as above cited:

"A planorboid shell, three-fourths of an inch in diameter, and having the apex of the spire depressed below the level of the outer whorl. The number of the whorls is probably about five, but only the last two are preserved in the best specimens. The tube enlarges very gradually, and is marked by a distinct carina just above the peripheral line, above and below which is a shallow groove."

During the examination of the blocks of sandstone, at the locality near Devil's Lake, I had an opportunity of examining quite a number of specimens of this species, and I obtained several which show the entire upper surface of the shell. The greatest diameter is usually between three-fourths of an inch and one inch, the form flattened planorbiform or slightly concave on the upper surface, and the number of volutions from three and a half to nearly five in the largest individual; volutions closely coiled and very slightly increasing in diameter with increased age; the height of the volution is about equal to the transverse diameter, or a little greater, leaving the umbilical depression very broad and shallow. Surface of the volution, so far as can be ascertained, flattened or but slightly convex; outer edge acute and the under side rapidly receding from the edge to the umbilical margin.

The form of the shell, as seen on the upper surface, is that of *Straparollus*, but the lower side, as shown both by the matrix in the sandstone and on a small example figured, is seen to have the form of that of *Raphistoma* as exemplified by *R. lenticularis*. The general form of the shell is so exactly similar to *Ophileta complanata*, as figured by Vanuxem, *loc. cit.*, and as repeated in Vol. I, Pal. N. Y., that the figure above cited would answer perfectly well for one of the Wisconsin shells; but as the under surface of the New York species is not yet known, it will be impossible to fully determine their positive identity without further evidence. Prof. Winchell speaks of a "distinct carina, just above the peripheral line, above and below which is a shallow groove," features which we have not observed.

Formation and locality. In sandstone of the Potsdam formation; near Devil's Lake, Wisconsin.

GENUS HOLOPEA, Hall.

HOLOPEA SWEETI; n. sp.

Plate X. Fig. 3.

Shell of moderate size, the largest specimen observed having a length of one inch and an eighth, and a transverse diameter of the outer volution, of seven-eighths of an inch. Volutions four in number, rapidly increasing in size, very ventricose and rounded, with deeply marked sutures; which present the appearance of having been channeled in the perfect condition. Body volution forming nearly one-half the length of the shell; aperature large, broadly subovate or semilunate, widest below the middle; the columellar lip being straight and vertical in the upper part, but rounded into the basal margin below. Apical angle sixty-five to seventy degrees. Surface smooth and the substance of the shell thin.

The examples are all internal casts and impressions, preserved in a very friable brown sandstone; but are perfectly free from compression, and show the shell to have been very thin, and the axis minutely perforate. The species differs from that described by Prof. A. Winchell as *Pleurotomaria? advena* (Am. Jour. Sci. and Arts, Vol. XXXVII, March 1864, p. 228) in having strongly convex instead of depressed convex whorls; in its more rapidly increasing volutions, and in not having three of "nearly equal height." It will also be noticed how nearly it resembles *Scævogyra elevata*, herein described from the Lower Magnesian limestone; but they differ very materially in the size and form of the umbilical opening, which in that species has been rather large and open; while in this one it is only minutely perforate in the cast, and may possibly in the perfect state have been entirely solid.

Formation and locality. In the Potsdam sandstone at Osceola Mills, Wis., named in honor of Mr. E. T. Sweet.

PTEROPODA.

Genus HYOLITHES, Barrande.

Hyolithes primordialis.

Plate I. Fig. 12.

Theca primordialis — Hall; Ann. Rept. Progress Geol. Surv. of Wis., 1861. p. 80.
Theca primordialis — Hall; Geol. Rept. Wis., 1862, Vol. I, p. 21.
Pugiunculus primordialis — Hall; 16th Rept. State Cab., p, 135.
Theca primordialis — Hall; 16th Rept. State. Cab., p. 135. Pl. VI, figs. 30 and 31.

Shell rather small, or of medium size, seldom exceeding one inch in length, regularly tapering throughout. Transverse section subtriangular or, in some individuals, nearly planoconvex, the width being nearly twice the thickness. Convex side, rounded or slightly angular along the middle; opposite side very depressed convex, the outer margin semicircular and projecting beyond the aperture equal to one-half its width. Surface marked by fine striæ of growth, which is directed nearly straight across the convex side, but on the flattened surface is parallel to the margin of the projection.

The species is only represented by casts of the interior and impressions of the exterior surface; no remains of the shell having been detected, so that the surface markings are not usually very perceptible; enough remains, however, on some of the impressions, to show their character.

Formation and locality. In soft friable sandstone of the Potsdam period, at Trempealeau, Wisconsin. Prof. Hall mentions having obtained it from Trempealeau, the mouth of Black river, and on the Chippewa, Wisconsin.

GENUS BELLEROPHON, Mountfort.

BELLEROPHON ANTIQUATUS.

Plate I. Figs. 13 and 14.

Bellerophon antiquatus — Whitfield; Ann. Rept. Geol. Surv. of Wis., for 1877, p. 52.

Shell small, generally measuring not more than five-sixteenths of an inch in its transverse diameter; globose in form, involutely and closely coiled, having but a very narrow aperture, the preceding volution projecting into and occupying the greater part of its area; auriculations rounded, not projecting beyond the general rotundity of the shell; axis probably imperforate in the perfect condition, but in the cast, in which state they all appear so far as yet observed, it is seen to be minutely perforate, from the removal of the solid axis. Margin of the aperture characterized by a broad, shallow sinus, angular at the center. No appearance of any reflexion or thickening of the margin can be detected. Surface marking not satisfactorily determined. There are, however, on the best preserved individual, faint indications of regular transverse lines parallel to the margin of the aperture, but owing to the friable nature of the sandstone, they cannot be positively determined.

So far as we know, there has been no species of this type of the genus recognized in rocks of this horizon before, and none with which it need be confounded.

Formation and locality. In soft friable sandstone of the Potsdam group, at Osceola Mills, Wisconsin, associated with other species of the same age.

VERMES.

Genus ARENICOLITES, Salter.

Arenicolites—*Salter;* Quart. Jour. Geol. Soc., London, 1856, Vol. 13.
Scolithus of authors, not of Haldeman.

Arenicolites Woodi; n. sp.

Plate II. Figs. 1-3.

Certain layers of the sandstone of the Potsdam formation in the Devil's Lake region, and near Baraboo, are abundantly marked by numbers of vertical and usually cylindrical perforations, of about a line or little more than a line in diameter, and varying in length from one to several inches. These perforations, when seen in vertical sections of the rock, are straight or variously bent, and although often seen interfering with each other in their course, do not bifurcate or branch. The walls of the tubes are usually smooth, but occasionally one may be seen presenting a corrugated appearance, as if from irregular annulations. In examining the layers of sandstone, the perforations are commonly seen penetrating a certain layer in great numbers, up to a certain elevation, at which point they all become interrupted; and the next layer above apparently destitute of any such feature. In selecting examples for cabinet specimens from among those near Devil's Lake, this feature was particularly noticeable.

These vertical perforations have been generally referred to *Scolithus linearis* Hall (Pal. N. Y., vol. I, p. 2. Pl. I, fig. 1), which is a common fossil in the Potsdam sandstone in Vermont, Massachusetts and Pennsylvania; but these western forms differ from that one in several particulars. The *S. linearis* is said to be from an eighth of an inch to half an inch in thickness, and often occurs of several feet in length, and is generally rigidly vertical and parallel; while the surface is said to be sometimes striated. These western specimens are seldom seen to occur of even an eighth of an inch in diameter, and are generally less than one-tenth; they are, although normally vertical, nevertheless commonly deflected at various angles near the surface of the layers, and not unfrequently run quite obliquely for considerable distance through the rock; and along the natural surface of a layer are often horizontal for a short distance, or open obliquely on such surface.

There has long been much doubt as to the true nature of *Scolithus.*

The genus was at first supposed, by its author, to be of vegetable origin, and such appears to have been the impression entertained by Prof. Hall, when describing them in the Pal. of N. Y., as above cited. The specimens used in that description would also naturally lead one to such a conclusion, as their resemblance is much greater to plant forms than to the borings of annelids, especially if the assertion that they are occasionally found of several feet in length is correct, and not a misapprehension; while these western forms are as distinctly the work of worm-like animals as are those on any of our modern sea beaches. Among the specimens from Wisconsin are some from Baraboo, collected by Mr. J. W. Wood, of that place, and for whom we have named the species, that clearly demonstrate this fact.

The specimens above referred to, preserve on the blocks the natural surface of the layer, over which and in which the worms have crawled and burrowed; and on one large block the little hillocks, thrown up and formed about the opening of their burrows, are as perfectly preserved as if they had been recently made. In many cases the perforation is still to be seen, rising through the elevation, with its margins excavated into a funnel-shaped depression, as if by the circular or wave-like motions of the animal while extended beyond the opening. Other blocks, which have been worn away or split horizontally just below the natural surface, show the tubes which have been excavated so near to others, previously filled, as to cut out a part of the same area, so as to form a series of semilunate perforations, on the removal of the fillings by decomposition.

Taking into account the above considerations, I have preferred to use the name *Arenicolites* for the specimens here described.

Among the specimens collected and sent by Mr. Wood, is one of peculiar form which he had supposed to be due to the decomposition of some vegetable substance. It is an impression in the sandstone formed by the removal of a root-like body, from four to five inches across, and elevated in the middle about one and a half inches; composed of a central prominence dividing up into numerous rootlets of varying thickness, from an eighth to more than one-fourth of an inch, and quite tortuous and rugose in character. The form of the object would indicate a plant of upright growth and of an order somewhat higher or more advanced than either *Palæophycus* or *Lycrophycus*. The specimen is quite distinct and well marked, but of obscure nature, so it has not been thought necessary to incur the expense of figuring.

CRUSTACEA.

Genus CONOCEPHALITES, Zenker.

Conocephalites calymenoides.

Plate III. Figs. 2-5.

Conocephalites calymenoides — Whitfield; An. Rept. Geol. Surv, Wis. for 1877, p. 52.

Species of less than medium size, the largest head noticed measuring scarcely three-eighths of an inch in length. The glabella and fixed cheeks, the only parts of the carapace positively identified, present much the general appearance of a species of *Calymene*. Glabella proportionally small, not exceeding half the entire length of the head, conical in form and obtusely pointed above, the width across the base rather more than equalling half the length, separated from the fixed cheeks by deep, abrupt dorsal furrows; surface convex, prominent, and destitute of glabellar furrows; frontal limb nearly twice as wide between the suture lines as the greatest width of the glabella, its surface elevated into a highly convex, transversely oval boss or tubercle, which is separated from the glabella by a wide, deep furrow; fixed cheeks highly and abruptly elevated, and of proportionally large size; palpebral lobes semilunate or crescentiform, and situated opposite the upper end of the glabella; occipital furrow narrow, but deeply depressed; ring narrow, rounded and prominent. Facial suture nearly straight in front of the eye lobes, to the middle of the tuberosity of the frontal limb, around the front of which it seems to curve; behind the eye it is directed outward for nearly half the width of the lateral limb, where it changes abruptly, forming an obtuse angle, and is then directed outward and backward, with a slightly convex curvature to the posterior margin of the head, at a point distant from the dorsal furrow about equal to the length of the glabella and occipital ring, forming large, triangular postero-lateral limbs.

Thorax long and narrow, the length exceeding once and a half the greatest width; regularly and gradually narrowing from the occiput posteriorly, very highly arched transversely, and strongly trilobed, consisting of twenty-two or more articulations. Axial lobe forming rather more than one-third of the entire width of the thorax, highly elevated, the curvature quite equaling a semicircle; lateral lobes narrower and deeper than the axial, the sides nearly vertical; dorsal furrows strongly marked; segments very short, the axial portion strongly rounded from front to back; pleura less strongly rounded than the axial portion, the anterior element forming nearly one-half the width at the inner end, but decreasing outward; the furrow separating the two portions deep, and extending more than half the length of the pleura; outer portion flattened on the articular surface, and rounded on the posterior margin; extremity rounded. Pygidium unknown.

The tuberosity of the frontal limb, the large, elevated fixed cheeks, deep dorsal furrows and small size are prominent features, and will serve to distinguish it from any known species.

The only individual preserving the thorax consists of an impression in soft, friable sandstone, from which a gutta percha cast was taken for the purpose of figuring. The cast is seen to be imperfect on the anterior portion of the head, and does not preserve the pygidium. Twenty-two segments can easily be counted, with possibly one other. The species is remarkable for the narrow, elongated, deeply lobed thorax, and the prominent features of the head.

Formation and locality. In sandstone of the Potsdam formation (middle), associated with *Agraulos Woosteri*, at Eau Claire, Wisconsin.

CONOCEPHALITES? QUADRATUS; n. sp.

Plate I. Figs. 15 and 16.

Entire form of body unknown, the species being founded upon detached portions of the head only.

Glabella and fixed cheeks when united, minute, quadrangular in outline, the glabella forming but a small portion of the whole. The form of this latter part is quadrangular or very slightly tapering upward, and squarely truncate at the summit, the length being about once and a half as great as the greatest width, which is across the base. The surface is highly convex and destitute of glabella furrows, its margin abruptly limited by very deep and narrow dorsal furrows, which are continued in equal depth in front. Fixed cheeks, large and gently convex, their width being nearly once and a half that of the glabella, and their surface even with that of the posterior half of the frontal limb immediately in front of the glabella, marked on their margins by semicircular ocular sinuses of medium size. Anterior half of the frontal limb depressed, with the outer margin recurving, forming a broad, concave channel on the anterior half of this portion of the plate. Occipital ring very narrow, prominent and rounded, the groove narrow and deep, being a continuation of, and of similar character with the dorsal furrows bounding the glabella. The occipital furrow is entirely obsolete on the glabella, the posterior portion of this member being continued backward in a long curved spine, having a length equal to that of the glabella itself.

Movable cheeks short, but much extended laterally, the entire lateral length of each being nearly twice as great at the longitudinal diameter of the cheek along the line of the facial-suture. Form of the cheek short-falcate, the posterior angle being curved slightly backward from a point opposite the eye lobe; anterior margin curved, with a constantly increasing curvature, from the anterior angle to the posterior projection. Surface of the cheek gently convex, the outer border much thickened on the under side, leaving a wide, deep groove on the cast, as seen in the rock.

There are remains of thoracic segments and minute pygidia associated in the rock with the parts described, but owing to their minute size, and the fact that they are associated with at least three other species of trilobites, I have deemed it most prudent to leave them uncharacterized.

The species is of minute size, and is peculiar for the quadrangular glabella, deep dorsal furrows, wide fixed cheek, and the quadrangular form of the central parts of the head when together. The head shield, when provided with the movable cheeks in place, would be several times as wide as long, and this feature alone would serve as a guide in identification, should it be found in a more entire condition than the specimens under consideration.

Formation and locality. In yellow sandstone of the Potsdam group, at Eau Claire, and at Ettrick, Wisconsin.

CONOCEPHALITES (PTYCHASPIS?) EXPLANATUS; n. sp.

Plate I. Figs. 27 and 28.

Species known only by the glabella and fixed cheeks, and these in a somewhat fragmentary condition. The form of these parts, as seen united, is somewhat quadrangular, rather longer than wide, and with rather prominent surface features. The glabella is elongate-quadrangular, narrowest across the anterior third of its length, rounded anteriorly and widening posteriorly to the back of the occipital ring; its length, when measured from the occipital furrow, is equal to once and a half the smallest transverse diameter; surface moderately convex and marked by three pairs of transverse furrows, the middle one of which is a little anterior to the middle of the length, deeply marked near the outer ends, and barely perceptible on the inner third of the length, their direction being slightly backwards toward the center. The posterior pair is very oblique, equally well marked, but narrower, and extends entirely across the glabella, but only faintly marked in the center. The anterior pair is short, more faintly marked, and situated about one-fourth of the width of the glabella from the anterior end. Fixed cheeks and frontal limb proportionally wide, the anterior half of the latter bent upward, forming considerable of an angle with the flattened portion around the glabella. Palpebral lobes proportionally large and moderately prominent; ocular ridges very distinctly marked, and very oblique, arising from the posterior part of the anterior glabellar lobe, and passing to the anterior extremity of the eye lobe. Occipital ring flattened or very depressed convex on the surface, narrower than the glabellar lobes, and the furrows shallow and only moderately well marked. Facial suture passing from the eye with a strong outward curvature to the anterior border, which it reaches nearly on a line with the eye; its course behind the eye not determined. Surface apparently smooth.

In the form of the glabella, this species presents features corresponding to those of the genus *Ptychaspis* Hall, but differs in the direction of the facial suture, and in the form and character of the eyes. It also somewhat resembles some specimens of *Conocephalites diadematus* H., but differs in wanting the thickened anterior border of the head of that species, and in the great width of the fixed cheeks. Except for this latter feature, it would correspond very closely with *Dikellocephalus pepinensis* as seen in the central part of Fig. 14, Plate X, of the 16th Rept. State Cab. N. Y.; but not with any other specimen of that species among a large number in that same collection. The one referred to is the only one showing the constriction in the width of the glabella, and we are strongly inclined to think it a different species from D. *pepinensis* Owen.

Formation and locality. In brown friable sandstone of the Potsdam period, at Hudson, Wisconsin.

Genus CREPICEPHALUS, Owen.

Crepicephalus onustus.

Plate I. Figs. 22 and 23.

Crepicephalus onustus — Whitfield; Ann. Rept. Geol. Surv. Wis. for 1877, p. 53.

Glabella of moderate size, highly convex, broadly conical and narrowly rounded at the summit, the width at the base equaling the height, exclusive of the occipital ring, which is short, less prominent than the glabella, and somewhat narrower; fixed cheeks, narrow, rounded and prominent; palpebral lobes, small and inconspicuous, situated opposite the middle of the glabella; frontal limb moderately long and regularly rounded on the margin between the facial-sutures, the front margin prominent and rounded; the space between it and the glabella deeply and regularly concave, and strongly arcuate laterally; ocular ridges faintly marked; dorsal furrows narrow, very deep and sharply marked; facial-suture directed gently outward in its course, from the eye-lobes to the anterior margin of the head, but recurving near the edge, and slightly rounding the antero-lateral angles of the frontal limb; behind the eye it is directed outward at an angle of about forty-five degrees, with a slight sigmoidal curvature to the posterior margin of the head, forming a short triangular lateral limb; posterior furrows narrow, and directed slightly forward in their passage from the dorsal furrow to the suture. Other parts of the organism unknown. Length of the head, half an inch; length of glabella from the occipital furrow, nine-sixteenths of an inch.

There seems to be an almost endless variety of this group of Trilobites preserved in the rocks of this period, differing principally in the combination of features as shown in the cephalic shield. The numerous species are readily recognized, however, by the form of the fixed cheeks and glabellas, even where no other part of the animal can be determined; and though it may appear incredible, entirely new forms are presented among the specimens obtained from each individual locality. The above species differs from any of the others described, in the short, conical form of the glabella, combined with the absence of glabellar furrows, the prominent, narrow cheeks, and long, concave frontal limb. In the short, conical form of the glabella, it is peculiar among the Wisconsin species, and is more nearly allied to those from the far west, described in the Geol. Rept. of the 40th parallel survey. The absence of glabellar furrows is a feature not usually seen in those from this region, but is common on those from the Canadian provinces, and was probably the reason for referring so many of these forms to the genus *Bathyurus*, by the author of that genus.

Formation and Locality. In rather compact yellow sandstone of the Potsdam period, at Ettrick and Eau Claire, Wisconsin.

Crepicephalus? gibbsi; n. sp.

Plate X. Figs. 12 and 13.

Conocephalites Gibbsi — Whitfield; Wis. Geol. Rept., Vol. II, 1873-1877, p. 67.

Species recognized only in movable cheeks and pygidia which occur in great numbers in a coarse brown sandstone as casts left by the removal of the substance of the fossils.

The movable cheeks are of moderate size, elongate triangular in form, depressed convex on the surface and rather oblique. Margin of the plate bordered by a rather wide, rounded, thickened rim, which increases in width posteriorly, and terminates in a thickened, slightly compressed spine of a length about equal to that of the cheek from the anterior margin to the origin of the spine. Inner area of the cheek distinctly convex and separated from the margin by a well defined sinus, and from the occipital ring by a deeper furrow. Ocular sinus rather small and surrounded by a slightly depressed furrow.

Pygidium proportionally large, transversly elliptical in form with subacute lateral extremities; posterior margin almost regularly rounded, and nearly twice as abruptly curved as the anterior border; plate strongly trilobed, the axial lobe forming considerably more than one-third of the entire width of the plate, somewhat strongly convex, and terminating a little within the posterior margin in a broad, obtusely rounded extremity, and marked by four strongly elevated rings exclusive of the terminal lobe. Lateral lobes marked by only three visible ribs, which are faintly developed.

In the general form of the cheek this species most nearly resembles *C. (Loganellus) centralis* Whitf., from the Potsdam sandstone of the Black Hills of Dakota (see Prelim. Rept. on the Pal. Black Hills, 1877, p. 10, and Pl. II, final Rept., fig. 24); it is, however, very much wider from the ocular sinus to the thickened margin, and also more oblique. It also resembles that of *C. (Loganellus) simulator* H. and W., Pal. Rept. 40th Parallel Surv., p. 218, Pl. II, figs. 16-18; but differs in the less curved or arcuate outer border; more distinctly rounded and wider marginal rim; smaller ocular sinus, and in the well marked groove surrounding the eye. The pygidium differs from any known form in the great proportional width of the axial lobe.

Formation and locality. In coarse brown and friable sandstone of the Potsdam group at Berlin, Green Lake county, Wisconsin.

Genus PTYCHASPIS, Hall.

Ptychaspis granulosa.

Plate I. Fig. 24.

Dikellocephalus granulosus— Owen; U. S. Geol. Surv. Wiscon. Iowa and Minnesota, p. 575. Pl. I. Fig. 7.

Not Ptychaspis granulosa—Hall; 16th Report State Cab. N. Y., p. 173. Pl. VI, figs. 33-40.

Glabella elongated, cylindrical or very slightly narrowing anteriorly, highly convex and divided transversly by three pairs of furrows, the two posterior ones being strongly marked and uniting in the middle, and directed forward at the outer extremities; the anterior pair being very short and faintly marked. Anterior extremity of the glabella rounded; dorsal furrows deep and well marked. Fixed cheeks, broad at the eye and widening behind, but in front of the eye are narrowed and rounded to the anterior margin of the head. Eye lobes small and situated opposite the extremity of the middle glabella furrow. In front of the eye-lobes and glabella the fixed-cheeks and frontal-limb are strongly curved downward to the anterior margin, the frontal-limbs being of medium width, but appearing narrow from fore-shortening, as seen in a vertical view.

Surface of the fixed cheeks and glabella covered with coarse elevated and transversly elongated pustules or granules, of proportionally large size, arranged in indistinct rows on the fixed cheeks, while on the glabella they are less regular and not so prominent.

This species is peculiar, among the Wisconsin forms, for its pustulose surface. The specimens in hand are all fragmentary, that figured being among the most perfect, but lacking the occipital ring and back portion of the fixed cheeks. The movable cheeks associated with the glabellas are also quite imperfect, but show the pustulose character very distinctly, and corresponding very well with those described and figured by Dr. Owen as above cited; but differing very materially from those indentified with that species by Prof. Hall, in having the surface strongly pustulose instead of lined or striated. I therefore, propose to recognize that species under the name *Ptychaspis striata*, from its striated surface features.

Locality. Hudson, Wisconsin.

PTYCHASPIS STRIATA; n. sp.

Ptychaspis granulosa — Hall; 16th Rept. State Cab. N. Y. p. 173. Pl. VI, figs. 33-40.
Not Dikellocephalus granulosus — Owen.

Differs from *Ptychaspis granulosa* Owen sp. in having the surface of the head strongly striated or marked with elevated ridges, which are more or less parallel to the margin.

PTYCHASPSIS MINUTA.

Plate I. Figs. 25 and 26.

Ptychaspsis minuta — Whitfield; An. Rept. Geol. Surv. Wis. for 1877, p. 55.

A minute species, known only from detached portions of the head, the length of which, as seen on the largest individuals observed, scarcely exceeds one-sixth of an inch, and mostly not more than an eighth of an inch from the anterior margin to the back of the occipital ring.

Glabella cylindrical, rounded and projecting in front, divided transversely by two pairs of deeply marked, oblique glabellar furrows, neither of which extend entirely across, and by a very faint third pair situated near the anterior end; occipital furrow also deep, the ring narrow and elevated. Fixed cheeks convex, more than half the width of the glabella and palpebral lobe, widening behind and narrowed in front. Frontal limb narrow and abruptly curved downward in front of the glabella, so as to be scarcely seen in a vertical view; dorsal furrow deeply marked. Eye-lobes proportionally long, but very narrow and but slightly elevated.

Movable cheeks elongate-triangular, convex on the surface, extended backwards at the genal angles into short obtuse spines; ocular sinus of moderate size. Surface coarsely striated near the margin parallel to the border. Thorax and pygidium unknown.

The small size of the species, with its deeply-lobed glabella and abruptly declining frontal limb in connection with its characteristic form, will readily distinguish the species.

Formation and locality. In soft, very friable, greenish-brown sandstone of the Potsdam formation, at Roberts' Store, St. Croix Co., Wisconsin.

Dikellocephalus minnesotensis.

Plate III. Fig. 1.

Dikellocephalus Minnesotensis — Owen; Geol. Rept., Wis., Ia. and Minn., p. 574. Tab. 1, figs. 1, 2, 10; and Tab. 1, A, figs. 3 and 6.

Dikellocephalus Minnesotensis — (Owen) Hall; 16th Rept., State Cab., p. 138. Pl. IX, figs. 5-10. Pl. X; and Pl. XI, figs. 1, 3 and 6.

Dikellocephalus Minnesotensis — of Authors.

Entire form of body unknown, being represented usually by detached portions of the head, separated thoracic segments, and by pygidia.

The head is broadly semi-elliptical, or semi-circular in form, with the posterior extremities of the cheeks projecting backward in the form of broad, flattened spines.

Glabella depressed convex, as long or longer than wide, from the occipital furrow to the anterior extremity; sides parallel, front rounded, surface marked by two pairs of glabellar furrows, the posterior of which extends entirely across, and is strongly bent backward in the middle; the anterior furrows extend only about one-third of the width from the dorsal furrow. Occipital furrow narrow, but well defined; and the ring broad and depressed convex, or often flattened. Fixed cheeks, rather narrow in front and behind the eyes. Frontal limb long and spreading, its surface generally flattened. Palpebral lobes large, and strongly grooved just within the margin. Postero-lateral limbs very long, but narrow, their lateral extent nearly equaling the width of the glabella, and the surface deeply grooved.

Movable cheeks large, but slightly convex, and triangular in outline; marked at their inner angle by a large ocular sinus; outer margin slightly thickened, and the intermediate surface concavo-convex; genal angles produced in the form of flattened spines.

Facial suture cutting the anterior border of the head nearly on a line with the outer portion of the eye, and is directed thence inwardly, with a light convex curvature to the front of the eye, behind which it turns abruptly outward, and runs parallel with the posterior margin of the head for about half the width of the movable cheek, where it is deflected backward.

Thoracic segments short and much flattened; the axial lobe is narrow, and the lateral lobes greatly extended, with the free extremities directed backward. The surface of the pleura is marked by a narrow but rather deep furrow extending nearly to the extremity, rising from near the front margin at the inner end, it passes rapidly backward for a short distance to behind the middle of the width, which position it retains for the remainder of its length.

Pygidium proportionally large and broad; once and a half, or more than once and a half as wide as long, with the axis narrow, very prominent, and extending about two-thirds of the length of the plate, marked by four distinct but flattened rings, exclusive of the terminal ones. Lateral lobes very broad, rounded on the anterior and posterior margins, and characterized by a short, flattened, triangular spine at each postero-lateral angle. The surface is marked by four double ribs on each side, exclusive of the anterior one; one division of each being wide at the inner end, and the other narrow, respectively; but becoming of nearly equal width in their outer extension. The surface of the shield is concavo-convex between the dorsal furrow and the outer margin, when preserved in its natural form, but is generally flattened, as seen on the surface of the layers of rock, owing to compression.

The species attains a very large size, some of the pygidia measuring nearly five inches in width. It appears to be characteristic of a certain horizon near the upper part of the Potsdam group, and consequently serves as an excellent guide in determining horizons, where found.

Formation and locality. In the upper part of the Potsdam group (Mendota beds), near Madison, at Mazomanie, and elsewhere in Wisconsin. It also occurs in Minnesota and Iowa at the same horizon.

Dikellocephalus Lodensis, n. sp.

Plate X. Fig. 14.

Several specimens of a pustulose cheek of a species of *Dikellocephalus* have been obtained from the Mendota beds at Lodi, by Mr. H. W. Eaton, which entirely differs from any hitherto noticed species; and which, from its marked peculiarity, will be readily recognized, should it be obtained at other localities. The form is much like those associated with, and usually referred to, *D. pepinensis* Owen, from the same horizon, but differs in its narrower border, shorter spine, somewhat larger ocular sinus, but most noticeably in the surface structure, which is strongly pustulose over the entire area within the thickened marginal rim, the pustules being largest and most regularly arranged near the ocular sinus, and decreasing in size toward the outer edge of the cheek. The occipital furrow across the cheek has been strong and deep.

The species resembles in its surface features the cheek of *Ptychaspis* *granulosus*, Owen's sp., but differs in its more erect form, much larger ocular sinus, narrower, thickened margin, and more slender posterior spine, and may be readily distinguished by these features. No other parts of the organism have yet been discovered, but from the occurrence of several movable cheeks among the collections obtained during a single short visit to the locality, there can be no doubt that the species will prove an abundant one in further collections, and from its peculiar features, will be readily identified.

GENUS AGRAULOS, Corda.

AGRAULOS (BATHYURUS?) WOOSTERI.

Plate I. Figs. 19-21.

Agraulos (Bathyurus ?) Woosteri—Whitf. An. Rept. Geol. Surv. Wis. for 1877, p. 56.

Head and moveable cheeks, when united, semicircular or short-paraboloid in form, rather strongly convex, and bordered by a narrow, rounded and elevated rim, which is wider in front than on the sides; genal angles obtusely rounded and destitute of spines, glabella round-conical in outline, prominent and convex, two-thirds as wide at the base as the length, including the occipital ring, the surface smooth and destitute of transverse furrows. Dorsal furrows faintly marked, occipital furrows not strongly marked. Fixed cheeks less than half as wide at the eye as the middle of the glabella, frontal limb, from the glabella to the anterior margin of the head, half as long as the glabella and occipital ring, and rapidly sloping from the glabella to the marginal rim. Eyes prominent, proportionally large, reniform and the visual surface strongly convex. Facial suture strongly diverging from the eyes to the anterior marginal rim, through which it passes with a strong inward curvature to the front; the width of the frontal limb being equal to the entire length of the head. Behind the eye the suture passes backward and outward to the posterior margin at an angle of not more than fifteen to twenty degrees with the vertical axis of the head.

Thoracic segments not fully determined, but those associated on the same sandstones with the glabellas, cheeks and pygidiæ, are narrow, in an antero-posterior direction, and have long, slender and pointed pleura.

Pygidium paraboloid on the outer margin, the anterior margin forming from three to four times as flat a curve as the posterior margin. Axis highly convex, two-thirds as long as the shield and not more than one-fourth as wide at its greatest width, marked by four transverse rings exclusive of the terminal ones; lateral lobes convex, destitute of any thickened border, marked by three furrows on each side exclusive of the anterior one; ribs simple, and nearly reaching to the border. Marginal selvage of the under surface wide and much thickened.

I know of no species sufficiently resembling this one to be readily confounded with it.

Formation and locality. In yellow sandstone of the Potsdam period (middle), at Ettrick and Eau Claire, Wisconsin.

Arionellus convexus.

Plate I. Fig. 17.

Arionellus (Agraulos) convexus — Whitf. An. Rept. Geol. Surv. Wis., for 1877, p. 57.

Glabella and fixed cheeks when united, strongly convex, and somewhat paraboloid in form, length and width nearly equal; anterior margin of the head, between the suture lines, regularly and somewhat sharply arcuate; palpebral lobes small, not very prominent, situated posterior to the middle of the head. Glabella rather less than two-thirds of the entire length of the shield, round-conical in form, and somewhat abruptly tapering, scarcely defined at the margins by the dorsal furrows, and apparently very indistinctly marked by three pairs of oblique furrows; occipital ring narrower than the base of the glabella, and more prominent, and also extending beyond the posterior limits of the fixed cheeks; occipital furrow very shallow and faintly marked, the ring short in the middle, and reduced to its minimum width at its junction with the dorsal furrows. Fixed cheeks half as wide as the glabella; frontal limb as long in the middle as the width of the fixed cheek, and slightly increasing toward the lateral angles. Facial suture passing nearly direct from the eye to the anterior margin of the head, its course posterior to the eye not determined.

The largest example of the glabella and fixed cheeks observed measures about three-fourths of an inch in length by nearly seven-eighths of an inch in width at the base. No other parts of the organism have been observed.

Formation and locality. In brown sandstone of the Potsdam formation, at Ironton, Sauk Co., Wisconsin.

GENUS ELLIPSOCEPHALUS, Zenker.

ELLIPSOCEPHALUS CURTUS.

Plate I. Fig. 18.

Ellipsocephalus curtus — Whitf.; An. Rept. Geol. Surv. Wis., for 1877. p. 58.

The species is known only by several detached portions of the cephalic shield, which occur in sandstone associated with *Orthis pepina*, *Ptychaspis miniscaensis*, and fragments of other trilobites crowded together, rendering it impossible to satisfactorily determine portions of other parts of the organism. The fragments observed consist of the glabella and fixed cheeks, which, when united, are sub-semicircular in form; the glabella is but slightly elevated, once and a half as long as wide, measuring from the back of the occipital ring, and somewhat quadrangular in shape; the front being almost regularly rounded, the sides parallel and the width slightly less across the middle than in front; a very slight angularity exists along the middle, and a single furrow crosses it near the base, distinct in the middle but becoming obsolete before reaching the sides.* Frontal limb very short in the middle, gradually and rapidly widening laterally. Fixed cheeks wide, but little less at the palpebral lobes than the width of the glabella, but rapidly contracting behind to about two-thirds of that width; their general surface flattened or somewhat depressed between the eye and the glabella. Occipital ring narrow; posterior cheek furrow very narrow. Dorsal furrow not impressed below the general level of the fixed cheek. Facial suture curved inward in front of the eye to the anterior border, and behind directed outward nearly at right angles to the axis, to a distance equal to one-third the width of the cheek, and then abruptly deflected to the posterior border of the head. Palpebral lobes proportionally large, simple in its structure, elevated on the margin and semi-lunate in form, situated very near to the posterior margin of the head.

The species closely resembles *E. Hoffi*, Schlot., from the Primordial rocks of Europe, but differs in having the glabella less angular; in its being rounded instead of obtusely angular in front, and in the wider fixed cheeks. In its general features, however, it is very similar.

Formation and locality. In friable, brown sandstone of the Potsdam period, at Hudson, Wisconsin.

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*It is possible this may be the occipital furrow, as the ring is imperfect in all the specimens, but this. being placed in advance of the furrow of the fixed cheek, has been considered as a glabellar furrow.

Genus AGLASPIS, Hall.

Aglaspis eatoni; n. sp.

Plate X. Fig. 11.

Body small and longitudinally oval in form, the length being equal to once and a half the width, which is at nearly the middle of the length. Surface moderately convex and distinctly longitudinally trilobed. Cephalic shield semicircular, about half as long as wide, rounded on the margin, and possibly slightly emarginate or notched in the middle of the anterior border, having the genal angles slightly produced, forming obtuse points. Surface of the plate trilobed, the central portion (glabella?) narrow, nearly two-thirds as long as the plate, conical in form, and obscurely marked by transverse furrows. Occipital furrow distinct, both on the central lobe and across the base of the cheek or lateral portion, to near the margin, where it passes into an obscure submarginal furrow, leaving the central portions of the cheek prominently convex. Eyes prominent, elongate elliptical in form, situated within the anterior half of the length of the shield, and at a distance equal to about their own length from each other, their anterior ends directed slightly inward, giving them an oblique direction to the axis.

Thorax distinctly but not prominently trilobed, but with obscure dorsal furrows, and consisting of eight segments or articulations. Axial lobe fully one-third of the entire width, the greatest width being at the third segment; the form is slightly narrowed anteriorly, and gradually contracting behind to the pygidial plate. Segments arching forward on the axial lobe and distinctly backward in their course across the lateral lobes, the deflection increasing posteriorly to the last one, which is abruptly arched or bent. General surface of the segments flattened, with the middle slightly depressed, forming a broad furrow, which extends nearly to the extremity and embraces almost the entire width of the segment, leaving the anterior margin sharply raised, and the posterior border rounded. Extremities of the free pleura wider than their inner ends, rounded on the front side, and slightly mucronate on the posterior edge, the extremity being directed slightly backward. The rounded posterior margin of the thoracic segments and the occipital margin of the cephalic shield are marked by a series of minute pointed nodes, numbering from eight to ten on the axial lobe, and about an equal number on each of the lateral portions of the principal segment.

Pygidial plate small, apparently triangular, and terminating in a slender triangular spine, of a length more than equaling half that of the thorax, and is apparently grooved on its under surface. Surface of the crust of the body minutely granulose.

This species differs from *A. Barrandi* Hall, as represented by the original specimens, in its minute size; that one attaining a transverse diameter of two and three-fourth inches across the base of the head, while this one is scarcely more than half an inch. It also differs in the greater proportional length of the cephalic shield, and the more distinct glabella-like central portion, and more distant eye-tubercles. The thoracic segments differ in being distinctly furrowed or channeled, and in the presence of the lines of nodes along their posterior borders and on that of the cephalic shield; which feature would naturally be one of adult age, rather than of a young stage of growth. With the other parts of the body of *A. Barrandi*, there is yet no means of comparing it, other than that furnished by the few fragments of that species originally figured, loc. cit.; but there is evidence in one of them, that at least some of the thoracic segments were continued at their extremities into long, recurving points (see 16th Rept. State Cab., Pl. II, fig. 14), which is not the case in this species. It might possibly be considered as the young of that species, were it not for its perfection of features, and the evidence of adult characters in its ornamentation, which, with the difference in structure and the proportion of parts, would tend to show its specific difference. This species would seem to be somewhat more closely related to the true Trilobites than *A. Barrandi* was at first supposed to be judging from remarks made by the author of the genus. The distinctly trilobed character of the thorax, and the glabellar-like central lobe of the head, with its transverse furrows, are strong trilobitic characters. No evidence, however, of facial sutures can be detected on the superior surface of the head, nor any lobation of the pygidial plate.

Formation and locality. In the upper part of the Potsdam group (Mendota beds) at Lodi, Wisconsin. The species is named in honor of its discoverer, Mr. Harlow W. Eaton, late of Lodi, Wis.

SPECIES FROM THE LOWER MAGNESIAN LIMESTONES.

The following group of species (except *Euomphalus Strongi*) is of peculiar interest, as coming from a bed of Lower Magnesian limestone occurring within the area occupied by the Huronian quartzites of the Devil's Lake region, at a quarry owned by Mr. Eikie, about seven miles east of Baraboo.

The bed in which they occur is underlain by a sandstone of the Potsdam period, containing an abundance of *Arenicolites* borings, apparently of the same age, and probably of nearly the same horizon, as the sandstone a few miles distant, nearer the lake, from which the fossils described by Prof. A. Winchell in the Am. Jour. Sci. and Arts, March, 1864, were obtained. The outcrop rests within the curve of a quartzite hill, near the eastern end of the range, and at a level considerably below that of the top of the quartzites; while at a short distance to the N. E. there is an outcrop of sandstone, at a considerable higher level than these magnesian beds. If this outcrop, referred to, is of the same age as those near the base of the hill underlying the magnesian beds, it would seem to indicate that the elevation of the sandstone as well as of the quartzite, had taken place prior to, and was perhaps still in progress during the deposition of the magnesian beds, and that considerable degradation had taken place over the area occupied by these beds before they were deposited.

The fossils are all new, except the *Leptæna*, of which there was but one specimen obtained, and are of peculiar types. Some of the Trilobites are similar to those described by Mr. Billings, Pal. Foss. Can. Vol. I, p. 409, under the generic name of *Bathyurus*, but are of different species, and are, we think, clearly referable to the genus *Dikellocephalus*, rather than to *Bathyurus*, as exemplified by the type of the genus, *B. extans*, Hall's sp. The occurrence of a species of the genus *Illænurus* shows the intimate relations which existed between the fauna of this and of the preceding Potsdam period of the neighboring counties. The existence of several species of *Metoptoma* of peculiar character, and also of the new and remarkable genus *Scævogyra*, adds a very marked feature, and gives a peculiar interest to the fauna of this very limited deposit. The rather remarkable fact that all the spiral shells found at this locality are sinistrally coiled, and that two at least of the capuloid forms show a tendency toward a backward curving at the apex, is a somewhat remarkable feature, and makes it particularly desirable that these beds should be more thoroughly explored. Beyond the species here described, a single specimen of a rather peculiar species of *Stromatopora* was found loose, near the top of the quarry; but showing marks of abrasion to such an extent as to suggest that it might have been derived from some other locality; although the lithological features would indicate it as belonging here. Still, with this uncertainty, we have not considered it safe to refer it to this horizon, although of an undescribed species.

BRACHIOPODA.

Genus LEPTÆNA, Dalman.

Leptæna Barabuensis.

Plate III. Fig. 6.

For citations and description of the species, see the same under the Potsdam sandstone, p. 171.

A single specimen of a ventral valve only was obtained. The shell is half as wide again as high, with a narrow, linear, nearly straight hinge line and area, not quite as long as the shell below, in the specimen; the extremities being rounded, and forming, with the front line, nearly two-thirds of an oval figure. Surface of the valve convex, with a distinct median sulcus, somewhat angular in the bottom and passing from beak to base. The surface also gives indications of having been marked by faint radiating striæ.

The specimen under consideration differs from those obtained from the sandstones below, in being less angular in the sinus, and less extended along the hinge line; but these differences are not sufficiently marked to be considered of specific importance, when seen only on a single individual valve.

GASTEROPODA.

Metoptoma Barabuensis.

Plate III. Figs. 16 and 17.

Metoptoma Barabuensis — *Whitf.;* Ann. Rept. Geol. Surv. Wis. for 1877, p. 60.

Shell, rather large, ovate in general outline on the margin; apex highly elevated, pointed and directed forward, even beyond the limits of the anterior margin of the aperture, attenuate in the upper part, and on one specimen, having the appearance of being slightly recurved at the tip; elevation of the apex equal to or greater than half the length of the shell, measured along the base. Anterior slope vertical, slightly concave or somewhat overhanging; sometimes with a slight angularity along the median line from the apex to the margin; lateral slope slightly convex; posterior slope most strongly rounded. Surface of the shell marked by concentric lines of growth, and on the posterior and lateral slopes, very faint indications of fine radiating lines are observable.

This species is most nearly related to *M. nycteis* Bill. (Pal. Foss. Canada, Vol. I, p. 37, fig. 39) than to any other described species, but differs materially in the more erect form and greater elevation of the apex.

METOPTOMA RECURVA.

Plate III. Figs. 14 and 15.

Metoptoma recurva —Whitf.; Ann. Rep. Geol. Surv. Wis. for 1877, p. 61.

Shell rather large, ovate in general outline; apex highly elevated, with a strongly backward curvature throughout its length; anterior slope very abrupt and slightly convex, subangular along the median line from beak to base; posterior slope broadly concave, and the lateral slopes nearly direct. Apical portion of the shell unknown, the specimen being imperfect in this part. In the earlier stages of growth, the shell has been very moderately expanding at the margin, but increased rapidly in height; and afterwards became more rapidly expanding, especially around the posterior margin, giving a long, concave posterior slope, broadly curved, and almost flattened near the posterior margin, while the anterior portion retains its vertical character. Surface marked by concentric lines of growth, strongest when crossing the angularity of the anterior end; also by faint evidences of obscure radiating lines.

This species differs from all others described, and is peculiar for the strong recurving apical portion, the convex anterior slope and broadly concave posterior slope.

METOPTOMA SIMILIS.

Plate III. Figs. 12 and 13.

Metoptoma similis —Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 61.

Shell of medium size or smaller, elongate-oval or slightly elliptical in outline; two-thirds as wide as long, depressed-convex on the top, the umbo slightly elevated and the beak depressed almost to the level of the anterior basal margin; greatest convexity at the anterior third of the length, and not exceeding one-half of the width of the shell. Anterior end very short, angular along the median line, and the slope concave; apex and anterior half of the dorsal slope angular or subcarinate in the middle, becoming more regularly rounded posteriorly; antero-lateral slopes slightly concave. Surface unknown.

The form of the shell being symmetrical, it consequently resembles in its general features many other species of the genus, still we know of none from near this horizon combining the same characters.

METOPTOMA RETRORSA; n. sp.

Plate III. Fig. 18.

Shell above a medium size, and highly elevated, the basal margin or aperature is very broadly ovate in outline, being longer than wide, the relative diameters are as eleven to thirteen, and the greatest transverse diameter at about one-third of the length from the anterior margin. Apex highly elevated and somewhat attenuate above, projecting beyond or overhanging the anterior margin of the aperture, and the upper part laterally compressed and reflexed or curved backwards, as in the Cretaceous genus *Anisomyon* Meek. Anterior slope of the shell concave below the reflexed portion, lateral slopes slightly convex, and the posterior slope more strongly convex, the back in the upper half of the length obtusely angular. Surface marked only by concentric lines of growth.

The specimen is mostly an internal cast, and there are some indications of muscular impressions on the left side figured, which unfortunately were not observed until the figures were in the hands of the lithographer; they are, however, too indistinct for positive determination. There is one elongated or elliptical area of considerable size, apparent about the middle of the length on the left side, and a line of small isolated areas extend from this one around and across the posterior slope of the shell. Similar indications are also seen in front of the apex, on the anterior slope. Along the right side of the shell no traces of scars are observable, and it is probable they were interrupted at this point, as in many genera of this group of shells.

It is somewhat remarkable. and also interesting, to find a group of shells at this low geological horizon, so closely resembling forms pertaining to the Cretaceous rocks, these reflexed forms differing in general appearance and structure, so far as determined, from *Anisomyon* only in wanting the few radiating grooves characterizing most of the species of that genus.

GENUS SCÆVOGYRA, Whitf.

Ann. Rept. Geol. Surv., Wis., for 1877, p. 61.

Thin, univalve shells, sinistrally coiled, with a more or less elevated spire composed of rounded volutions, and characterized on the lower side by a broad, open umbilicus, entirely destitute of callus; peristome entire, uniting with the preceding volution on the inner side, and more or less spreading or trumpet-shaped externally. Types, *S. Swezyei* and *S. elevata.*

The marked peculiarity of the shells for which the above genus was proposed, consists in their sinistral character and open umbilicus. We had at first supposed the former species could be classed under the genus *Maclurea;* but the rounded, *naticoid* character of the spire was an objection, and when, on developing the second species from the matrix, the greater elevation of the spire was observed, it was seen at once to indicate an entirely distinct genus. The genus differs from *Maclurea* in the elevation of the spire, rounded volutions and expanded aperture. The appearance is that of a *naticoid* shell of the type of *Gyrodes*, Conrad. They also resemble some forms of *Platyostoma*, Conrad, except in the wide umbilicus and sinistral curvature. We are inclined to think from the character of the shells that they may have been *Heteropodous* rather than *Gasteropodous.*

SCÆVOGYRA SWEZEYI.

Plate III. Figs. 7–9.

Scævogyra Swezeyi — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 62.

Shell of moderate size, depressed-convex on the upper side, the spire rather low and composed of about three rounded, rapidly enlarging, sinistrally coiled volutions, the last one more rapidly expanding and becoming distinctly trumpet-shaped at the margin of the aperture on the upper side; suture lines distinct in the casts; umbilicus wide and open, subangular at the margin, and the depression abrupt. Aperture oblique, strongly receding below; section of the volution obovate, widest above and angular below, somewhat modified at the inner upper portion by the preceding volution; surface marked by distinct concentric lines of growth, and in some cases by slight undulations of the shell parallel to the margin of the aperture.

The shell is peculiar for its distinctly naticoid appearance in all respects except the sinistral curvature of the spire.

Scævogyra elevata.

Plate III. Fig. 11.

Scævogyra elevata—Whitf.; Ann. Rept., Geol. Surv. Wis. for 1877, p. 62.

Shell of medium size, the largest specimen observed measuring a little more than an inch in height, spire proportionally elevated, the apical angle being about thirty-eight to forty degrees each side of the vertical axis. Volutions, sinistral, about three in number, moderately increasing in size, and strongly rounded on the surface; suture line distinct; umbilicus only moderately wide, less than half the diameter of the volution; aperture semilunate in form, straightened on the inner side, and slightly modified above by the preceding volution; outer lip slightly expanded at the margin on the outer portion; surface of the shell, so far as can be observed in the matrix, destitute of markings.

The great elevation of the spire of this species, and the small umbilicus, are distinguishing features.

Scævogyra obliqua.

Plate III. Fig. 10.

Scævogyra obliqua—Whitf.; Ann. Rept. Geol. Surv. for 1877, p. 63.

Shell small, sinistral, very oblique; consisting of about two volutions, the outer one forming nearly the entire bulk of the shell, rapidly descending in its curvature and somewhat compressed on the outer surface; section of the volution elongate-ovate, somewhat constricted on the inner side, and very slightly modified at the upper inner angle, by the preceding volution; aperture very much elongated, somewhat rounded below; umbilicus small; suture line indistinct; surface of the shell unknown.

The species is readily distinguished from the others by the proportionally large body volutions, the upper one being only apical. A single specimen only was obtained, having been discovered and presented by Mr. Jos. Miller, of the class of '77, Beloit College, Beloit, Wisconsin.

GENUS EUOMPHALUS, Sowerby.

EUOMPHALUS STRONGI.

Plate IV. Figs. 1, 2.

Euomphalus Strongi—Whitf.; Ann. Rep't Geol. Surv., for 1877, p. 66.

Shell somewhat larger than medium size, subdiscoidal, and coiled nearly in the same plane, the depression of the spire being nearly as great as the depth of the umbilical opening. Volutions, three or more, rapidly increasing in size and very slightly overlapping each other on the upper surface, strongly convex on the sides, becoming obtusely subangular just within the middle of their width, and sloping rapidly in each direction from this point; dorsum rather more decidedly subangular than the sides, giving a somewhat subquadrangular form to the volution when seen in a transverse section. Surface of the shell indistinctly marked by broad, faint undulations parallel to the margin of the aperture, and having a strong backward curvature from the ventral to the dorsal angle, indicating a deep, angular notch-like feature of the margin.

This is a very neat and pretty species, presenting, in its almost symmetrically coiled volutions, much the character of a large species of *Cyrtolites*, but on close examination it is seen to be spirally coiled, although but very slightly off the plain of the volutions. The diameter of the largest individual is nearly two and one-fourth inches, with a transverse diameter of the volution at the aperture of about three-fourths of an inch.

Formation and locality. In cherty layers of the Lower Magnesian limestone, Richland county, Wisconsin. Named in honor of the discoverer, Moses Strong, Esq.

CRUSTACEA.

GENUS DIKELLOCEPHALUS, Owen.

The two following species of Dikellocephalus are of great interest from the fact that they preserve the true form and convexity of the carapace, showing them to be quite convex and rotund. Nearly all the species of this group of Trilobites hitherto described have been obtained either from soft, compressible sandstone, from sandy shales, or from shaly rocks where the objects have been subjected to much distortion or change in form by vertical compression, flattening or spreading out the crust so as to present broad, flattened objects of but slight convexity; but in the present case, the matrix is a hard and very unyielding magnesian limestone, which has preserved them in their true proportions, although, as in nearly all other cases with species of this genus, they are preserved only as detached fragments or parts.

DIKELLOCEPHALUS BARABUENSIS.

Plate IV. Figs. 6–9.

Dikellocephalus Barabuensis—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 63.

Entire form of body unknown, the species being recognized by the glabella and fixed cheeks united, by detached movable cheeks and isolated pygidia. The species has attained to a medium size, the heads sometimes measuring one inch or more in length from the anterior border to the base of the occipital ring. Glabella strongly arcuate, longitudinally, and somewhat less so transversely, separated from the fixed cheeks by well marked dorsal furrows, which are continued in front; sides of the glabella very gradually converging anteriorly; anterior end rounded; surface marked by two pairs of very faint furrows, the anterior pair often obsolete, and the posterior seldom extending to more than one-third of the distance from the dorsal furrow, and recurved at the inner end. Occipital furrow broad and distinct, but not deep; occipital ring large and strong, widening in the middle, posteriorly. Fixed cheeks, very narrow; palpebral lobes small, obtusely angular in the middle, moderately prominent, and situated opposite the middle of the length of the glabella. Frontal limb wide and short, bordered by a distinctly elevated, flattened, narrow, anterior rim; posterior lateral limbs narrow longitudinally, but as long laterally as the width across the middle of the glabella and deeply and broadly furrowed. Sutures cutting the anterior border nearly on a line with the outside of the eye-lobe, which they reach with a slightly outward curvature, and behind are directed strongly outward, at a low angle with the line of the base of the head.

Movable cheeks proportionally large, depressed convex on the surface, and nearly semi-circular in outline, margined by a moderately wide, thickened, slightly elevated rim, which is prolonged in an acute spur on the anterior extremity, and incurved at the genal angles; not prolonged in the form of spines.

Pygidium referred to the species, subelliptical in outline, the marginal curve forming nearly one-third of a circle, while the anterior border is much less strongly arched, length and breadth as three to five, and the lateral angle slightly rounded; axis st rong, forming fully one-third of the entire width, strongly elevated and a little less than two-thirds of the entire length of the plate, marked by three rings exclusive of the anterior one. Lateral lobes convex, destitute of a thickened border, and marked by three very obscure ribs on each side, not observable on all the specimens.

The species somewhat closely resembles *Bathyurus capax* Bill (Pal. Foss. Canada, Vol. I, p. 409, fig. 389), but is more convex, has narrower fixed cheeks and more distinct glabèlla furrows, that one being described as destitute of them.

DIKELLOCEPHALUS EATONI.

Plate IV. Figs. 11-17, and Plate X. Figs. 4 and 5.

Dikellocephalus Eatoni—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 65.

Entire form unknown. Glabella and fixed cheeks, when united, quadrangular in form and very convex, as seen uncompressed in the limestone, entire length of the head equalling the breadth across the palpebral lobes. Glabella quadrangular, widest at the base, gently narrowing to the front, slightly rounded at the antero-lateral angles, and squarely truncate on the anterior border, where it is rather more than two-thirds as wide as at the occipital furrow, separated from the fixed cheeks by shallow dorsal furrows as well as by its greater convexity. Surface of the glabella marked by a broad and very shallow, but poorly defined posterior furrow, which is strongly directed backward on the outer portions, but nearly straight in the middle, and on a single example, by a very faint pair just in front of the eye lobe. Fixed cheeks narrow, not at all prominent. Eye lobes moderately large, prominent on the anterior end, and much less so posteriorly. Frontal border wide, measuring on the most perfect specimen about three-eighths of an inch between the front of the glabella and the anterior margin, strongly striated transversely with coarse, distinct striæ. Suture line, as shown by the outline of the fixed cheeks, directed slightly outward in front of the eye and rounding inward in crossing the anterior border; posterior to the eye its course has not been determined. Posterior lateral limb unknown, but from the position of the eye, has evidently been narrow, and from the form of the movable cheek, quite extended laterally.

Movable cheeks large, strong, subtriangular in outline, strongly convex, with a large ocular sinus and a wide, thickened, and strongly striate marginal border, which gradually narrows posteriorly to the genal angle. The anterior margin is prolonged in a spine-like projection, corresponding to the rounding of the antero-lateral angle of the frontal limb.

A large, semi-circular or elliptical caudal plate, which may be the pygidium of this species, was discovered among the specimens obtained at the quarry, after reaching home. The length is less than half the width, the surface regularly convex, with a short, and proportionally small axial lobe, about half as long as the shield, and with indications of three faint rings, besides the posterior terminal one.

The posterior margin is regularly and symmetrically rounded throughout, and the curvature considerably shorter than that of the anterior margin. It is possible this may be the caudal shield of the above species, although from the character of the head, and its great resemblance to *D. Minnesotensis* Owen, we had expected a somewhat different shaped plate.

The species bears considerable resemblance to *Bathyurus capax* Billings (Pal. Foss. Canada, Vol. I, p. 409, fig. 389), but the sides of the glabella are more nearly parallel and the whole more square, while the anterior thickened margin is broad and flattened, instead of narrow and rounded, as in that one. We know of no other described species with which it has close relations.

Genus ILLÆNURUS, Hall.

Illænurus convexus.

Plate IV. Figs. 3–5.

Illænurus convexus—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 66.

Glabella and fixed cheeks, as seen united, round-conical in outline, half as wide again at the base as in front of the eyes; surface almost regularly and equally convex, and destitute of either dorsal, glabella, or occipital furrows, except as the former are represented very faintly near the posterior margin by slight indentations, and by the constriction of the posterior margin of the head. Posterior margin of the glabella strongly rounded backward beyond the line of the lateral limbs; ocular lobes inconspicuous, and situated near the middle of the length of the head; lateral limbs short-triangular; anterior border of the frontal limb rounded between the suture lines, as if the movable cheeks had united in front. Facial suture rounding inward in front of the eye, and behind the eye is directed backward and slightly outward, with a gently sigmoid curvature, to the occipital border, at a distance from the dorsal furrow equal to one-fourth the width of the glabella.

Movable cheeks not definitely determined. There is, however, a single example of a cheek, in the collection, which may possibly belong to this species (see fig. 5, plate III), although the thickened, rounded border would seem to be an objection to this view. The suture line of the specimen, as shown on its border, corresponds nearly to that of the above described head, when held in a corresponding position. The specimen is rather strongly convex with a thickened, rounded margin of moderate width, the anterior prolongation of which has been broken, while the posterior angle is prolonged into a short, curving spine having a downward direction.

Pygidium elliptical, twice as wide as long, strongly convex on the surface, pointed at the lateral angles and less arched on the anterior than on the posterior margin, with slight constrictions at the place of the dorsal furrows.

This species appears to have been the most abundant form of life at this locality, the remains being quite common but so inconspicuous, owing to their small size and absence of marked features, that it is readily overlooked. It differs from *I. quadratus* H., of the Potsdam sandstone, in the round-conical form of the glabella, that one being quadrangular, or wider on the anterior border than at the eyes.

SPECIES FROM THE TRENTON LIMESTONE.

LAMELLIBRANCHIATA.

Genus AMBONYCHIA, Hall.

Ambonychia lamellosa.

Plate V. Fig. 5.

Ambonychia lamellosa — Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 31 (by error, *A. cancellosa*).

Ambonychia lamellosa — Geol. Rept. Surv. Wis., 1862, Vol. I, p. 437.

Shell very oblique, subovate or subquadrangular in outline; valves depressed convex, most ventricose below the beaks and near the anterior margin, and more compressed near the extremity of the hinge line; beaks small, pointed, directed forward and not projecting above the line of the hinge. Hinge line straight, but shorter than the length of the shell below; anterior margin forming an angle of about eighty degrees to the hinge, and the anterior slope vertical or slightly impressed in the upper part, not always showing evidence of a byssal opening; basal margin sharply rounded from its junction with the anterior end, and more broadly rounded posteriorly, the margin of the shell above the middle of the posterior end regularly arching forward to the extremity of the cardinal border. Surface of the shell marked by numerous concentric lines of growth, which present the appearance, even on the casts, of having been the margins of lamellar expansions, and in the matrix are decidedly of this character. No indications of radiating striæ exist either on the cast or in the matrix.

The form of the shell is somewhat variable in different specimens, being, in some examples, much more oblique than in others; they also vary in their proportional height and length, as well as in the convexity of the valves, but generally present evidence of the lamellose surface structure. In the example figured, there is evidence of a flattened and longitudinally striated cardinal or ligamental area of considerable width, extending nearly the entire length of the cardinal border. None of the specimens examined show traces of the hinge-teeth, either cardinal or lateral.

Formation and locality. In the buff limestones of the Trenton group, at the various localities near Beloit, Wisconsin.

AMBONYCHIA ATTENUATA.

Plate V. Fig. 6.

Ambonychia attenuata — Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 33; Vol. I, 1862, p. 437.

Shell of medium size, oblique, elongate-ovate in form, widest posteriorly; the width across the shell, from the buccal border to the postero-cardinal border, equal to two-thirds the length, as measured from the beaks to the postero-basal margin. Beaks attenuated, pointed, directed anteriorly, projecting above the cardinal line, and not incurved; valves regularly round-ventricose, most prominent just above the middle of the valve; hinge-line very short, not more than half as long as the width of the shell from the buccal-border to the posterior margin, and about one-third as great as the length of the shell when measured from the beaks to the postero-basal angle; posterior cardinal slopes very abrupt; anterior slope impressed; basal line short, very abruptly rounded, and the posteror border long and broadly rounded to near the cardinal line, where it is more sharply rounded to the hinge extremity. No surface features have been observed except concentric lamellose lines.

On a single example the muscular scars are shown very distinctly, and are situated somewhat differently from those of most species of the genus. They are situated near the anterior border of the valve, instead of subcentral as in the typical species, and are distinctly two in each valve, the lower one being large and nearly circular; the other quite small, much nearer the apex of the valve, but still more than one-third of the entire length of the shell from the beak, and is of a narrow triangular form, with a space of an eighth of an inch between the two impressions. The direction of the pallial line is not distinctly traceable, but appears to be obliquely across the valve, from above the middle of the larger scar to the anterior side of the pointed beak. The species resembles somewhat in form *A. bellistriata* Hall, from the Trenton limestones of New York, but is more sharply rounded and shorter on the basal line; has a much shorter hinge-line than that species, as shown on a much more perfect example than any of those figured in Vol. I, Pal. N. Y., the cardinal line being distinctly preserved to an extent equal to the greatest length of the shell below; while here the posterior margin is strongly rounded forward to reach the extremity of the short hinge.

Formation and locality. The specimens collected and examined were from the upper layers of the buff limestones of the Trenton group, at Hanchett's quarries, near Beloit, Wisconsin.

GENUS TELLINOMYA, Hall.

TELLINOMYA NASUTA.

Plate V. Fig. 12.

Tellinomya nasuta — Hall; Pal. N. Y., Vol. I, p. 34. Pl. XXXIV, fig. 3.
" " " 10th Rept. State Cab., p. 143, figs. 1–3.
" " " Geol. Rept. Wis., Vol. I, 1862, p. 38, figs. 1–2, and p. 438.
Ctenodonta nasuta — (Hall's sp.) Salter: Can. Org. Rem., Dec. 1, p. 35. Pl. VII, fig. 12.
" " *C. Logani — Salter;* British Assoc. Rept., 1851, Trans. Sect., p. 63.
" " *Isoarca Logani — Woodward;* Manual of Recent and Fossil Shells, p. 269, as cited by Salter.

Shell occurring of various sizes, from less than one inch in length to more than twice that size; form subovate, or narrowly subovate, with ventricose valves. Anterior end broadly rounded, once and a half to nearly twice as wide as the posterior extremity, the greatest length above the middle, and more narrowly rounded above this point than below. Posterior to the beak, the shell is narrowed on the cardinal line, and rapidly contracted on the base; posterior extremity sharply curved and somewhat compressed. Beaks small, proportionally broad, incurved and not conspicuous, situated much nearer to the anterior than to the posterior extremity of the valve. Hinge-plate narrow, marked by a variable number of small, curved teeth, according to the age of the shell. On a specimen measuring one and three-fourths of an inch in length, there are about fourteen on the anterior sides of the center, but the number on the opposite side cannot be counted. On the internal casts, the condition in which the Wisconsin specimens occur, the muscular scars are large and distinct; the anterior scar being situated close to the hinge-plate and well forward, and is large and subquadrate in form, the posterior scar being smaller, but more distinct and subtriangular in form. Pallial line entire, and frequently composed, on the casts, of a series of pustulose markings. Surface of the shell, as shown by the matrix, smooth, or marked only by fine concentric lines of growth.

Formation and locality. The species is quite a common one in the buff limestones of the Trenton group, and is quite characteristic. I have collected them from nearly all the horizons of the formations near Beloit, and they occur, also, at Janesville and elsewhere in the formation. In New York, the species is known in the Black river limestones, not uncommon about two miles above Watertown, associated with several forms of CYPRICARDITES with *Lituites undatus, Ormoceras tenuifilum* and other fossils of the same horizon; it also occurs in the higher Trenton at several localities.

GENUS CYPRICARDITES, Conrad.

CYPRICARDITES ROTUNDATUS.

Plate V. Fig. 11.

Cypricardites rotundatus—Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 29.
" " " Geol. Rept. Wis., Vol. I, p. 38, fig. 7, and p. 437, 1862.

Shell small, subcircular in outline and subglobose in form, the height and length being subequal, the valves full and ventricose. Beaks proportionally large, prominent, scarcely incurved, strongly projecting above the cardinal line and directed obliquely forward. Cardinal line strongly arcuate, and the hinge-plate marked on the anterior end by three or four small, oblique cardinal teeth, and by one or two oblique lateral teeth on the posterior extremity. Muscular scars, on the casts, moderately distinct; the anterior one small and situated close to the hinge-plate; the posterior larger but less distinctly marked. Surface of the shell, as shown in the matrix, marked by concentric lines of growth.

This species is smaller than any of those with which it is associated, being recognized in specimens from three-eighths of an inch in diameter to those of more than an inch, and is much the most common of the genus. It is readily recognized by its round form and the prominent and often pointed beaks, as well as the almost regularly curving margin; the anterior, basal and posterior margins being blended into each other without perceptible angle. The cardinal line is also almost as arcuate as the other parts of the outline.

Formation and locality. In the buff and blue limestones of the Trenton group at Beloit, Janesville and elsewhere in Wisconsin.

CYPRICARDITES NIOTA.

Plate V. Fig. 10.

Cypricardites niota—Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 20.
" " " Geol. Rep. Wis., 1862, p. 38, Fig. 8, and p. 438.

Shell of medium size, broadly subovate or subquadrangular in outline, with a suberect form, very ventricose valves, and large, strong, somewhat tumid beaks, which are but slightly incurved, are prominent above the hinge, have an anterior inclination, and are situated very near the anterior end of the shell; cardinal line nearly straight, rather shorter than the shell below; anterior margin nearly at right angles to the cardinal line in the upper part, but rounding into the base below; posterior extremity round and nearly equal to the anterior; basal margin regularly arcuate; valves most ventricose at the anterior third of the shell and a little above the middle of the width; muscular scars, on the cast, distinct; the anterior scar small and situated partly between the filling of the beaks; posterior scar large, subquadrangular, situated near the posterior margin, and close to the edge of the hinge plate; pallial line strongly marked, especially on the anterior part of its extension; surface of the shell, as seen in the matrix, marked only by concentric lines of growth.

The species is much less common than *C. rotundatus* or *C. megambonus*, and is readily distinguished from them, as well as from all others associated in the same horizon, by the quadrangular outline coupled with the erect form and anterior position of the beaks. The anterior margin forms nearly a right angle with the hinge line, a feature pertaining to no other species in this association. The valves are often quite ventricose, in fact inflated, and on the casts the anterior umbonal ridge is angular, and the beaks thin and compressed, apparently from the thickening of the shell in the upper portions of the valve, but the inflation of the valves is never so extreme as in *C. megambonus*, nor are the umbonal ridges ever so sharply rounded or so oblique as in that species.

Formation and locality. In the middle and upper parts of the buff limestones of the Trenton group, at Beloit, Wisconsin, at Carpenter's and Hess' quarries.

Cypricardites ventricosus.

Plate V. Fig. 9.

Edmondia ventricosa — Hall; Pal. N. Y., Vol. I, p. 155, Pl. XXXV, Fig. 1.
Palæarca ventricosa — Hall; 12th Rept. State Cab., p. 10, Figs. 1-3, and pp. 68 and 95; also Pal. N. Y., Vol. III, p. 271, Fig. 1-3.
Cypricardites ventricosa — Hall; Geol. Rept. Wis., Vol. I, p. 438, 1862.

Shell transverse, very obliquely ovate, broadest posterior to the middle; valves ventricose, prominent on the umbo; beaks large, ventricose, projecting above the cardinal line, and incurved. Hinge-line nearly two-thirds the length of the shell, slightly arcuate, marked by two or three small cardinal teeth beneath the beaks, and one or two long, slightly curved lateral teeth. Anterior end short, sharply curved; posterior margin broadly curved from the extremity of the hinge to the postero-basal angle; basal line, in the anterior portion, straight, and forming an angle of about fifty-five degrees to the line of the hinge, umbonal slope subangular. Surface marked only by concentric lines of growth.

Among the specimens of this species recognized in the Buff limestones of Southern Wisconsin, there is considerable variation in form. The generality of the examples have much the shape of those from the Trenton limestone of New York, and few have the narrowed and very oblique character of those figured by Prof. Hall in the 10th Report State Cab., above cited, from St. Joseph island. There is also considerable difference in the ventricosity of the valves, but this may result in part from accidental compression. The specimen figured is one of the broader forms, the distance across the valve, from the cardinal teeth to the antero-basal border, being more than in the majority of specimens noticed. It is not as common at most localities as *C. rotundatus*, and we do not remember to have seen it in the higher beds.

Formation and locality. In the lower buff limestones of the Trenton group, near Beloit, Janesville, etc., Wisconsin.

Cypricardites megambonus.

Plate V. Figs. 7 and 8.

Cypricardites megambonus — *Whitf.;* Ann. Rept. Geol. Surv. Wis. for 1877, p. 73.

Shell of medium size, very oblique, ovate in outline and very ventricose in profile, with large, tumid, obliquely enrolled beaks, situated a little anterior to the center of the hinge, and strongly projecting above the cardinal line. Valves very deep, and very ventricose along the prominent and obtusely rounded umbonal ridge, with a broad, abrupt and slightly concave cardinal slope, and convex, but rapidly declining antero-basal surface; anterior end rapidly sloping backwards, uniting imperceptibly with the basal curve; posterior margin extending obliquely backwards from the extremity of the short hinge-line to the postero-basal angle. Surface marked by irregular concentric lines of growth. Hinge-plate marked by two or three short, oblique, cardinal teeth, and by two long, curved, posterior teeth in the right valve, as shown by the internal cast; muscular imprints rather faint; ligamental area rather small.

This species approaches most nearly to *C. niota* Hall, with which it is associated, but may be readily distinguished by the obliquity of the shell to the hinge, that one being nearly erect; and also by the ventricose and more prominent umbonal ridge, which, with the great obliquity, gives to the shells an entirely different aspect when placed side by side.

Formation and locality. In the Buff limestone of the Trenton group, in the upper part of Carpenter's quarry, and also more abundantly at Hess' quarry, near Beloit, Wisconsin.

GASTEROPODA.

Genus METOPTOMA, Phillips.

Metoptoma perovalis.

Plate V. Figs. 13 and 14.

Metoptoma perovalis — Whitf.; Ann. Rept. Geol. Surv. Wis., for 1877, p. 74.

Shell of medium size, oval or elongate-oval in outline, a little more than half as wide as long, and about one-third as high as the greatest width. General surface, depressed convex; anterior end very slightly truncate from below the apex to the anterior margin, giving a slightly flattened and concave anterior slope. Apex small, situated very near the anterior end, and slightly overhanging the anterior slope. Surface of the shell smooth, so far as can be determined from the specimens in hand.

On the internal cast, the muscular scar is seen as a narrow, scarcely elevated band, passing just below the apex on the anterior side, and extending back to near the middle of the length, where it widens and forms a broader band around the posterior half of the cast, at about midway between the apex and the posterior margin. Length of the largest specimen, nearly one and one-fourth inches.

Formation and locality. In the lower bluish limestone of the Trenton group, below Carpenter's quarry, Beloit, Wisconsin.

Genus CYCLONEMA, Hall.

Cyclonema percarinatum.

Plate V. Fig. 15.

Murchisonia percarinata — Hall; Pal. N. Y., Vol. 1, p. 177, Pl. XXXVIII, Fig. 4.

Shell of medium size, broadly conical, the apical angle being a little less than ninety degrees. Volutions three, or from three to four;

strongly convex and rapidly increasing in size, being very broadly ovate in transverse section, narrowest at the upper angle and rounded below. Surface of the volutions marked by several distinct revolving carina, varying in strength and in their distance from each other, the spaces between being more or less concave. The principal carina occurs just above the center of the volution, and one or sometimes two above it, near the suture line; below the principal one there are two others, at nearly equal distances, the position of which give the periphery of the volution a somewhat vertical form; while below this, the surface is rapidly rounded and marked by one or two very faint carinations. There appears to have been a small open umbilicus, as in the cast there occurs a small core, which has filled the opening. On the surface of the cast are slight indications of nearly vertical striæ of growth, but too faintly marked to be satisfactorily determined.

The species is apparently somewhat rare, as only one satisfactory specimen was obtained, although several other fragments were detected. The type specimen of the species is from the Trenton limestones at Watertown, N. Y., and as it is the only one seen, so far as we are aware, it must have been equally rare at that locality. Although originally described as a MURCHISONIA, the specimen shows no evidence of a slit in the aperture, but seems to possess all the essential features of CYCLONEMA, unless the presence of a small umbilicus should prove objectionable, although some of the typical species, *C. bilix*, seems to have been open when only partially grown. The form of the aperture, however, and the existence of so many cariniæ would at once distinguish it from MURCHISONIA.

Formation and locality. In the Buff limestones of the Trenton group, at Hess' quarry, near Beloit, Wisconsin.

GENUS TROCHONEMA, Hall.

TROCHONEMA BELOITENSE.

Plate VI. Figs. 7 and 8.

Trochonema Beloitensis—Whitf.; Ann. Rept. Geol. Surv. Wis., for 1877, p. 74.

Shell moderately large, with a rather low spire, the entire height of the specimen being somewhat less than the diameter across the base; volutions about three in number, ventricose, about as high as wide, the outer one increasing in size more rapidly than the preceding, obscurely flattened on the periphery, slightly concave above and rounded below and on the inner and basal surfaces; suture line very distinct and well marked; base of the shell gradually rounding into, and forming a deep umbilical cavity, with a rather small central perforation; aperture subcircular and very oblique, not modified by the preceding volution, but apparently having the outer lip slightly expanded; surface of the cast marked by obscure transverse lines, indicating stronger lines of growth, parallel to the margin of the aperture.

The shell resembles *Trochonema ambigua* and *T. umbilicata* Hall, of the Trenton limestone of New York, but is more round and ventricose even than the former, with an equally elevated spire, but more rapidly increasing volutions.

Formation and locality. In the Buff limestone of the Trenton group, at Hess' quarry, near Deloit, Wisconsin.

Trochonema Beachi, n. sp.

Plate VI. Fig. 6.

Shell of medium size, broadly conical, with a low, conical spire consisting of about three volutions, which increase very rapidly in size with subsequent age, and are closely coiled, the entire height of the shell being rather less than the transverse diameter. Volutions having a general quadrangular aspect in a transverse section, with truncated corners, the top, the dorsal and lower sides representing the sides of the quadrangle; periphery vertical, forming a broad, flattened, vertical band; top of the volution also flattened, and the space between slightly concave; under surface gently rounded, and representing a depth rather less than that of the vertical band; inner volutions projecting above the outer ones equal to about two-thirds of their entire depth, or to the base of the vertical portion. Aperture subquadrangular, the margin somewhat expanded in adult shells, especially on the lower side. Umbilicus small and abrupt. Surface, as shown by the matrix, marked by transverse striæ of growth, which have a general backward direction in passing from the upper to the under surface of the volution.

The shell has the general aspect of *T. umbilicata* Hall, but is rather smaller, and is more compactly coiled, with a proportionally higher spire, very much more rapidly increasing volutions, which are more decidedly quadrangular, less spreading and of greater proportional height. These features combine to give the shell a very much smaller umbilical opening. We were at first inclined to refer this species to Hall's *Pleurotomaria ambigua*, Pal. N. Y., Vol. I, p. 176, Pl. XXXVIII, fig. 3; but on examining the type specimen it proves to be quite distinct, as that shell has no flattening on the upper surface of the volution, but is distinctly convex from the margin of the vertical band on the periphery to the base of the preceding volution, and is also destitute of an umbilical opening; the columella is straight, and slightly prolonged at the base. On the specimen we can detect no evidence whatever of the vertical striæ shown in the figure.

Formation and locality. In the Buff beds of the lower part of the Trenton group, below Carpenter's quarry, near Beloit, and at the railroad quarries three miles above Beloit; also at Janesville and other places in southern Wisconsin.

Genus RAPHISTOMA, Hall.

Raphistoma lenticularis.

Plate VI. Figs. 4 and 5.

Trochus lenticularis — *Sowerly;* Sil. Researches, 1839, Vol. I, p. 642. Pl. XIX, Fig. 11.
Pleurotomaria lenticularis — *Conrad* in MS. Em. Geol. Rept. 3d Dist. N. Y., 1842, p. 392, fig. 2; p. 393, figs. 2 and 3; and p. 101, fig. 2.
" " *(Sow.) Hall;* Pal. N. Y., Vol. 1, p. 172. Pl. XXXVII, fig. 6.
" " " *Owen,* 1844, Geol. Iowa, Wis. and Minn., p. 86. Pl. XVIII, Fig. 6.
Raphistoma lenticularis — *Salter;* Can. Org. Rem., Dec. 1, 1859, p. 12.
" " *Hall;* 12th Rept. State Cab. Catalogue of Vol. 1. Pal. N. Y. and Geol. Rept. Wis., 1862, p. 39; fig. 4, and p. 440.
" " *(Con. Sp.)* M. and W. Geol. Ill., Vol. 3, p. 316. Pl. III, fig. 7.

Form discoidal as seen from above, and lenticular in a side view; the portion below the periphery of the outer volution equal to or a little more than one-half of the entire height of the shell, and the entire height equal to about one-half the diameter. Volutions about four, angular on the edge and nearly three times as deep below the angle as above, very gradually increasing in size with increased growth; the upper surface flattened in the direction of the spire, so that the outer edge of one volution is even with the inner edge of the next succeeding one. Suture between the volutions, in the cast distinct, but not conspicuous, and in the matrix scarcely visible. Lower side of the volution rounded from the angle to the margin of the broad, open umbilicus. Aperture subtriangular, obliquely flattened above, rounded below and on the inner side; the lip being thin and sharp, and regularly and rapidly receding from its junction with the preceding whorl to the outer angle on the upper side; and on the lower side is again projected forward in a lingulate extension between the periphery and the margin of the umbilicus, leaving a deep, narrow cleft in the margin at the angle of the volution. Within the umbilicus, the lip appears to have been nearly vertical. Surface of the shell marked only by fine striæ of growth, parallel to the margin of the aperture.

The depressed lenticular form of the shell, and the angular periphery, are distinguishing features of the species. Although there are several other species which are very closely allied in form found in the Trenton group at various places, there are none in Wisconsin, so far as at present known, which approaches nearer to this than *R. Nasoni* Hall, with which it is associated, but which may be readily distinguished from this one by the greater elevation of its spire, the volutions of which are scaliform or step-like, while on this one they are smooth and even, from the apex to the outer margin of the shell. In *R. Nasoni* the volutions are also deeper and more ventricose, and the umbilicus is proportionally wider, while the notch in the aperture gives rise to a round elevated ridge along the edge of the outer whorl; whereas on this one it produces no feature whatever.

The species is a somewhat common one, and as it is not known to occur at any other horizon, notwithstanding its almost world-wide distribution in the same formation, it is a very safe guide in determining the age of strata wherever it occurs.

Formation and locality. In the Buff limestones of the Trenton group at most of the localities where they occur, and in the Trenton limestone in Iowa, Minnesota, New York and Canada; and also in rocks of the same age in Europe.

Raphistoma Nasoni.

Plate VI. Figs. 2 and 3.

Pleurotomaria (Raphistoma) Nasoni — Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 34; Ibid, Vol. 1, p. 39, Fig. —.

Shell rather above a medium size, very depressed, conical, the height of the spire being less than two-thirds as great as the greatest width across the base of the shell, and consisting of from four to five volutions, which increase in size very gradually with increased age, and are each elevated above the succeeding one, about two-thirds of their depth. Volutions round in the younger stages of growth, but becoming flattened or sloping on the top, and angular on the periphery, in the more advanced stages, with a nearly vertical dorsal margin, and strongly rounded lower side. Upper surface of the outer volution marked by a broad, shallow depression or furrow, just within the margin, which gives a slight convexity to the surface between the furrow and the suture line, and also has a tendency to elevate the obtusely angular periphery. Under surface of the volutions broadly rounded, often a little more depressed on the base than on the sides. Umbilicus broad and open, exposing to view each of the inner whorls. Volutions subquadrangular in section, flattened above, round on the sides and below, and somewhat impressed on the upper inner side by the preceding volution. Aperture strongly and deeply notched at the outer angle, the lower lip extending as far, or even farther forward, below the notch on the vertical portion, than on the upper side, but sharply receding below and on the inner side of the volution. Surface of the shell marked only by concentric striæ, parallel to the margin of the aperture; and the extreme form of the aperture developed only in adult individuals.

Formation and locality. The species is a well marked and very characteristic one of the upper Buff beds of the Trenton group, at Hess' quarry, near Beloit, Wisconsin; not occurring, so far as we have observed, in the lower layers at any of the localities. There is a species described by Dr. D. D. Owen in his report on a Geol. Recon. Wis., Iowa and Minnesota, p. —, Pl. XI, Figs. 12 and 13, as *Straparollus (Euomphalus) Minnesotensis,* which very closely resembles this one, and which, were it not for his reference of the specimen to the Lower Magnesian limestone, we should suppose to be identical with it.

Genus PLEUROTOMARIA, Defrance.

Pleurotomaria subconica.

Plate VI. Fig. 1.

Pleurotomaria subconica — Hall; Pal. N. Y., Vol. I, p. 174; Pl. XXXVII, Fig. 8, and p. 304; Pl. LXXXIII, Fig. 3.

Shell moderately large, with a short, conical spire, consisting of four and a half or five volutions when fully grown; apical angle about seventy or seventy-five degrees; transverse diameter across the body of the last volution equal to the entire height of the shell, and the height of the last volution equals a little more than half the entire length. Volutions obliquely flattened on the upper surface in the direction of the slope of the spire; and the last one marked on the periphery by a flattened and somewhat elevated band, marking the place of the slit in the margin of the aperture. Under side of the last volution rounded or depressed convex; umbilical depression small and deep; axis perforate, but not strongly so. Surface of the shell marked by transverse striæ of growth, parallel to the aperture, which are generally grouped in fascicles and form broad undulations on the surface, their direction being strongly retral in passing from the suture to the periphery, and equally forward from below the band to the umbilical cavity.

In the cast, the condition in which they usually occur within the state, the suture line is strongly marked, owing to the removal of the substance of the shell, and the impressions of the surface marking are very often preserved even in this condition, so as to be readily traceable.

Formation and locality. The species is quite abundant in the Buff limestones of the Trenton group, at most of the quarries near Beloit, Wisconsin; and also at many other places within the state.

GENUS MURCHISONIA, D'Arch. & Vern.

MURCHISONIA GRACILIS?

Plate V. Fig. 19.

Murchisonia gracilis—*Hall;* Pal. N. Y., Vol. 1, pp. 181 and 303; Pl. XXXIX, Fig. 4, and Pl. LXXXIII, Fig. 1.
M. " *Salter;* Can. Org. Rem., Dec. 1, Pl. V, Fig 1, p. 22.

Shell of medium size and slender, spire elevated and composed of about ten volutions in a specimen of a little less than an inch in extreme length; volutions round or showing but very little tendency to angularity on the periphery; suture very distinct and deep; apical angle very acute, the diameter of the last volution, on the specimen above referred to, being nearly one-fourth of an inch, or about one-fourth as great as the length of the shell. Aperture extended below, the columella being straight and the axis imperforate. Surface, so far as can be ascertained from any of several specimens shown by the matrix, destitute of any marking.

Some of the typical specimens of the species, as figured in Vol. 1, Pal. N. Y., show considerable angularity of the volutions, with fine striæ crossing them; while others, probably partially or entirely internal casts, have them more regularly rounded. The examples under consideration show, even in the matrix, no evidence of either band or vertical markings, and the evidence of angularity is so slight as to leave one in doubt whether it is really a feature pertaining to the shell or an illusion. From the absence of the above-mentioned features in these western specimens, we are prepared to see them prove a distinct species when better material shall be obtained, and believe they may prove to belong to some other genus than *Murchisonia;* probably to *Holopella* McCoy.

Formation and locality. Although the species is common at many places in the state in the Trenton group, the specimens used and figured are from the bluish limestones near the base of the Trenton, below Carpenter's quarry, and at the railroad quarries near Beloit, Wisconsin.

MURCHISONIA (EUNEMA?) PAGODA.

Plate V. Fig. 20.

Eunema? pagoda—Salter; Can. Org. Rem., Dec. 1, p. 30, Pl. VII, Fig. 5.

Shell small and slender, with an extremely elongated and attenuated spire, composed of very prominent and distinct volutions, sixteen of which may be counted on a specimen of a little less than an inch in length, the nine upper ones occupying one-fourth of the space; diameter of the last volution, three-sixteenths of an inch; volutions angular and marked by a proportionally wide revolving band near the middle, which is bordered by an elevated carina on each edge, the space between being concave; a third carina occurs on the base of the volution, but is seen only on the last one, being covered on the others by the succeeding whorls; surface of the volution above the revolving band regularly sloping to the deep suture above; faint indications of vertical striæ are seen crossing the volution, but too indistinct for satisfactory determination, owing to a coating of very minute crystals over the surface of the matrix; form of the aperture not determined.

Specimens of the species are not common in the rocks of Wisconsin, but those seen have so much the appearance of a slender form of *Murchisonia*, and the revolving band is so distinct and so similar, that I should have had no hesitation in referring it to that genus, were it not for the reference originally made by the author of the species, from observations made on what appears to have been better material than that I have in hand. The western examples are somewhat more slender than the Canadian, but the general aspect is the same in all other respects.

Formation and locality. In the bluish-buff layers of the Trenton group, below Carpenter's quarry, near Beloit, Wisconsin.

MURCHISONIA VENTRICOSA.

Plate V. Fig. 18.

Murchisonia ventricosa—Hall; Pal. N. Y., Vol. I, p. 41, Pl. X, Fig. 3.

Shell of medium size, broadly conical in form above the periphery of the last volution; spire consisting of about three to three and a half volutions, which increase somewhat rapidly in size with increased growth, and present a decidedly scaliform appearance, being flattened or only moderately sloping on the upper surface; decidedly angular on the periphery; nearly vertical just below, and rounded on the lower side; suture very strongly marked; apical angle about ninety degrees; umbilicus deep, of rather small size and round on the margin; aperture subquadrangular in form, rounded below, flattened on the upper side, and strongly modified at the upper inner portion by the protrusion of the preceding volution; surface, as shown on the internal casts, apparently smooth; still, there is the slightest indication of a simple revolving ridge about midway between the edge and the suture, on the upper flattened portion of the volution, and of another a short distance below the angulation, which may have marked slight ridges on the surface; the surface striæ, as indicated by wavy lines on the cast, have been receding on the upper surface in passing from the suture to the periphery, and directed gently forward below the angle to near the base of the volution, then passing nearly direct into the umbilical cavity.

The species is not a common one, a very few individuals only having been noticed. It seems to be, without doubt, identical with the New York species, but I can detect no appearance of the regular striæ on the top of the volutions, resembling those of a *Loxonema*, as described by Prof. Hall on that one; still, the western examples, being only internal casts, might not have preserved them, although existing on the perfect shell.

Formation and locality. In the buff limestones, near the middle of the Trenton group, at Carpenter's quarry, near Beloit, Wisconsin. The New York specimen from which the original description of the species was taken, is from the Birdseye limestone in the Mohawk Valley, just below, and where graduating into the Trenton. I also obtained a much larger individual, apparently of the same species, in the Birdseye at Watertown, N. Y.

MURCHISONIA TRICARINATA.

Plate V. Fig. 16.

Murchisonia tricarinata—Hall; Pal. N. Y., Vol. 1, p. 178, Pl. XXXVIII, Fig. 6.

Shell of medium or rather large size, with an elevated and turreted spire, composed of four or five volutions, which are angular and closely coiled in the upper part of the shell, but often become disconnected near the aperture in old specimens. The middle of the volutions is marked by a strong, angular ridge or carina, and a second, less distinct one, occurs just below the suture, leaving the space between the two distinctly concave. Below the central one, and at a distance equal to that between the others, a third ridge exists, but less prominent than either of the former, while the space between is equally concave. Below this point the surface is rounded and ventricose. Aperture slightly elongated, ovate, rounded below and on the inner side, but slightly angular above and in the middle of the outer lip, the margin of which has been broadly and deeply notched. Axis apparently minutely perforated. Surface marked by sharp, transverse striæ, parallel to the margin of the aperture, and as shown in the matrix are strongly bent backward in passing from the suture to the central carination, and below are again directed forward, the bending of the striæ being most abrupt on the sides of the central carina.

The species is very common in some layers of limestone in Southern Wisconsin, associated with the forms known as *M. helicteres* Salter, between which and this one the characters seem to blend by imperceptible steps, so that the species are only distinguished by the size of the shell and the disunited volutions of the larger forms. The original specimens from which the description of this species was drawn, were from the Trenton beds at Mineral Point, Wisconsin, and were in a rather poor state of preservation. The larger specimen of those figured, as above cited, shows a tendency, so far as one can determine from the figure, to have the whorls disunited, showing the existence of the principal feature upon which the *M. helicteres* was established.

Many of the individuals of this species, as well as of that one, present evidence of the existence of a very thin, broad, flange-like expansion, projecting from the crest of the central carina, and which has been serrated on the edge, the serrations corresponding to the striæ of the surface of the volution. This feature is one that does not pertain to the true *Murchisonias*, and when considered in connection with the form of the volution and of the aperture, may prove of generic importance, but the material now in hand is not sufficient to furnish a complete diagnosis.

Formation and locality. In the buff and blue layers of the Trenton Group, at Beloit, Janesville and elsewhere in Southern Wisconsin.

Murchisonia helicteres.

Plate V. Fig. 17.

Murchisonia helicteres — Salter; Can. Org. Rem., Dec. I, p. 21, Pl. IV, Fig. 17.
Comp. M. tricarinata — Hall; Pal. N. Y., Vol. I, p. 178, Pl. XXXVIII, Fig. 6.

Shell moderately large, spire elevated, turreted, and consisting of from four to six volutions, which are rather sharply angular and carinate on the periphery, and also marked by two less distinct carinæ, one above and the other below, and at about equal distances from the central one; the upper one being much nearer to the suture than to the central carina. Spaces between the carina concave, and below the lower one, convex. Volutions closely coiled in the upper part of the spire, but in old or fully grown individuals the last volution is often widely separated from the preceding one. Apical angle about forty or forty-five degrees. Aperture rounded on the inner side and below, and angular on the outer margin at the carina; sometimes the former is slightly effuse below. Surface marked by strong, roughened, transverse striæ, as shown by the matrix, which have a strong backward direction in passing from the suture to the central carina, and are again directed forward below it.

There can be no reasonable doubt of the specific identity of this shell with those described from Canada by Mr. Salter, as above cited, although they differ in some few particulars. The central band is not wide, nor is it flattened on any of the many individuals which we have examined, but instead, it is in some instances, as shown by the matrix, furnished with a thin, sharp expansion or flange-like keel, nearly an eighth of an inch in width, while on others it is very obtusely rounded. This feature is also quite variable in the Canadian specimens, as may be seen quite readily on figure 3 of the plate and work above cited. Where the specimens are uncoiled, the additional ridge bordering the suture is distinctly shown on the casts, and all other features shown on the Canadian specimens are clearly traceable.

There is so close a resemblance between the specimens of this species and specimens of *M. tricarinata* Hall, that it is practically impossible, among the casts, as seen in the limestones of Wisconsin, to distinguish between them. So all small, closely coiled specimens are usually referred to the latter species, and the older individuals showing the uncoiled condition are separated under Mr. Salter's designation of *M. helicteres.* It is our belief, however, that they are forms of the one species, the difference being only those of age, and the example of *M. tricarinata*, represented by figure 6 *a* of the plate cited, appears to have been loosely coiled, showing their similarity.

Formation and locality. In the buff limestones below Carpenter's quarry, and at that owned by Mr. Hess, near Beloit, Wisconsin.

GENUS CLISOSPIRA, Billings.

CLISOSPIRA OCCIDENTALIS.

Plate V. Fig. 21.

Clisospira occidentalis — Whitf.; Ann. Rept. Geol. Surv. Wis., for 1877, p. 75.

Shell small, synestrally coiled, spire conical, the apical angle being nearly ninety degrees; volutions from two to two and half, obliquely flattened on the back in the direction of the apical angle, or very slightly convex between the suture lines, and sharply angular on the periphery. Suture distinct on the internal cast, the only condition in which the species has been observed. Base of the shell concave; base of the volution, between the edge of the shell and the axis, very slightly convex, and the axis in the cast minutely perforate; but probably solid in the perfect state. Surface of the cast marked with indistinct undulations, representing lines of growth, which pass rapidly backward, with a broad, gentle curvature, from the suture to the basal angle; traversing about one-third of the volution between the two points and indicating a very oblique aperture.

The shell has the general appearance of a synestral form of *Infundibulum.* It differs from *C. curiosum* Billings, Pal. Foss. Can., pp. 186 and 420, in being more rapidly expanding, but without the spreading dorsal edge to the last volution, and in being destitute of surface marking beyond the ordinary lines of growth.

Formation and locality. In the Buff limestone of the Trenton group, at Carpenter's quarry, Beloit, Wisconsin.

GENUS MACLUREA, Leseuer.

MACLUREA BIGSBYI.

Plate VI. Figs. 17 and 18.

Shell of moderate size, consisting of about four closely coiled volutions; flattened surface showing to be slightly depressed in the center, as seen in the matrix, with the surface of each volution slightly convex between their outer and inner margins; outer margin obtusely rounded on the periphery. Convex side strongly elevated, the depth of the volution equalling its greatest transverse diameter; central depression broad, rather more than one-fourth of the diameter of the shell, the margin abruptly rounded; transverse section of the volution subtriangular, with the inner angle on the flat side strongly modified by contact with the preceding volution. Surface of the shell, as seen in the matrix, marked on the periphery and convex surface by strong revolving striæ.

This species, as seen in internal casts, is somewhat more elevated on the convex surface than *M. magna* of the Chazy limestones of New York, and also differs in the possession of revolving surface lines; and from *M. Logani*, of the Canadian rocks, it differs also in having a more slender tube.

Formation and locality. In the lower part of the Buff limestones of the Trenton group, at Beloit, Janesville, and other localities in southern Wisconsin.

Genus BELLEROPHON, Montf.

Bellerophon Wisconsensis.

Plate VI. Figs. 15 and 16.

Bellerophon Wisconsensis — Whitf.; Ann. Rept. Geol. Surv. Wis., for 1877, p. 76.

Shell of medium size, rather closely coiled; globular in form when young, but becoming strongly bilobed, and the lip laterally expanded in the adult form; anterior margin of the aperture broadly and deeply sinuate, and more deeply notched in the middle; periphery of the outer volution marked by a broad, somewhat elevated, and flattened or slightly convex revolving band, extending along the sides of the deep notch in the aperture. Umbilicus small, but in the cast showing of medium size, from the removal of the substance forming the axis. Surface of the shell apparently marked by concentric lines of growth, parallel to the border of the aperture.

The species closely resembles the figures 8 *e* and *f*, of *Bucania bidorsata* Hall (Pal. N. Y., Vol. I, Pl. XL); but not the others of that species. This shell is, however, a true *Bellerophon*, as is readily seen by the closed or nearly closed umbilicus; while that of *Bucania* is broad and open. It may be readily distinguished from *B. bilobatus* Sow., with which it is associated, by the flattening of the periphery and the laterally expanding lip.

Formation and locality. In the blue beds of the Trenton lime stone, below Carpenter's quarry, near Beloit, Wisconsin.

Genus BUCANIA, Hall, 1847.

Bucania (Tremanotus?) Buelli.

Plate VI. Figs. 12-14.

Bucania Buelli— *Whitf.;* Ann. Rept. Geol. Surv. Wis., for 1877, p. 76.

Shell of moderate size, composed of from three to three and a half closely coiled, appressed volutions, the last one of which is somewhat more ventricose than the preceding, and broadly expanded or trumpet-shaped at the aperture. Transverse section of the volutions broadly elliptical or reniform, the lateral margins obtuse or subangular, and the ventral surface slightly concave from close contact with the inner coils; the lateral diameter varies from once and a half to nearly twice the dorso-ventral diameter in different parts of the shell. Umbilical openings broad and deep, exposing all the inner coils; suture between the volutions sharply marked. Aperture circular or subcircular, slightly notched in front and moderately elevated along the middle on the exterior; the posterior side slightly modified by the intrusion of the preceding volution. Dorsal surface of the last volution marked by a long, narrow slit or opening, extending along the outer half of the whorl, and reaching to within about half an inch, more or less, of the margin of the aperture, the edges of the slit being slightly elevated above the surrounding parts of the volution.

Surface of the outer volution marked by raised revolving lines, which originate in fine striæ on the smaller parts of the volution, and rapidly increase in strength toward the aperture, where they become strongly developed and distinctly alternate in size. There are also finer concentric striæ crossing and cancellating the revolving lines.

This species differs from *B. expansa* Hall, from the Trenton limestone of New York, in the more compressed form of the volution, and in wanting the subtriangular form, as seen in a transverse section of that species. On some of the examples of this species examined, there are indications of the slit having been closed at intervals, forming a series of perforations, supposed to be characteristic of the genus *Tremanotus*. This feature is also seen in *B. expansa*, and we have lately examined some very fine specimens of *Bucania profunda*, from the Pentamerus limestones of Schoharie, in the cabinet of Mr. W. D. Gebhard, which preserve the impression of the expanded aperture with its strong alternating revolving lines. On one of them may be counted eight distinct elongated nodes on the dorsal portion of the outer volution, and indistinct remains of two others, showing that this also possessed the features of *Tremanotus*. From these facts, we have been led to believe that all the group were characterized by this peculiarity, though as yet we have not been able to trace it on either the typical species of Bucania (*B. sulcatina* Emmons), nor on any of the species pertaining to the group typified by *B. bidorsata*. This latter group, however, is not known to have the expanded aperture characteristic of *B. expansa*, and its congeners, nor do any of the species of *B. sulcatina* known, show any such feature, so that it is possible we shall have to refer all those possessing this feature to the genus *Tremanotus*. Their family affinities will be with *Porcellia* rather than with the *Bellerophontidæ*.

Formation and locality. In the upper Buff limestones of the Trenton group, at Hess' quarry, near Beloit, Wisconsin.

PTEROPODA.

Genus HYOLITHES, Eichwald.

Hyolithes Baconi.

Plate VI. Figs. 9–11.

Hyolithes Baconi—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 77.

Shell of moderate size, measuring from one to one and a half inches in length, with a diameter at the aperture equaling from one-fourth to one-third of the length; dorsal side of the shell depressed convex, more abruptly rounded near the margins and on the edges, the surface marked by transverse striæ, which arch gently forward and are parallel to the margin of the dorsal extension; dorsal projection regularly rounded and one-third as long as the width of the aperture; ventral surface about twice as deep as the dorsal, strongly subangular along the middle and the surface marked by transverse striæ, which are directed nearly straight across the shell; transverse section of the tube subtriangular or triangularly elliptical.

Formation and locality. In the harder bluish-buff layers of the Trenton group, below Carpenter's quarry, near Beloit, Wisconsin.

CEPHALOPODA.

GENUS ORTHOCERAS, Breynius.

ORTHOCERAS (ACTINOCERAS) BELOITENSE.

Plate VIII. Fig. 1, and Pl. X. Figs. 9 and 10.

Orthoceras (Actinoceras) Beloitense—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 97.

Shell large and robust, subfusiform, moderately expanding to the diameter of about four inches, then more gradually decreasing in size to the aperture. Section oval in all the examples noticed, and usually a little more flattened on one side than on the other, with the siphuncle submarginal on the flattened side. Septa shallow and not often symmetrically arranged, from seven to eight chambers occupy a length equal to the diameter of the largest of the number measured; toward the outer portion of the shell the septa become more crowded, and just below the outer chamber are sometimes less than half the usual length. Siphuncle large, strongly beaded within the chambers, with an inner core, in the casts, having radiating filaments extending to the center of the bead in each chamber. Surface of the shell unknown.

This species belongs to the group separated by Brown under the name *Actinoceras*, on account of the radiating character of the inner part of the siphuncle; and in some of the examples seen, offers a beautiful illustration of that peculiar feature. The true siphuncle is very large, and owing to its subcentral position in the shell, causes the septa, which are apparently always symmetrically situated on the siphuncle, to be strongly eccentric at their junction with the outer shell or sheath. In its size and general form this species resembles *Orthoceras fusiforme* Hall, from the Black River limestone of N. Y., but differs in the more numerous septa, oval section, and beaded character of the siphuncle.

Formation and locality. In the Trenton limestone (buff beds), at Hess' quarry, near Beloit, Wisconsin.

ORTHOCERAS ANELLUM.

Plate VII. Fig. 13.

Orthoceras anellum — Conrad; Proc. Acad. Nat. Sci., Phila., 1843, p. 334.
" " *(Con.) Hall;* Pal. N. Y., Vol. I, p. 202, Pl. XLIII. Fig. 6.
Geol. Rept. Wis., 1862, Vol. I, p. 422.

Shell of small dimensions, the diameter of the tube seldom seen to exceed five-eighths of an inch, and usually not more than half an inch; rate of increase very gradual, the expansion in the specimen figured being only an eighth of an inch in a length of one and three-fourths of an inch, beyond which point it again as rapidly decreases in diameter. In the rock, the matrix was seen for a length of nearly four inches below the part preserved, showing the diameter to be nearly uniform. Tube cylindrical and strongly annulated by encircling rings, which are narrow and rounded on the crest, the spaces between being somewhat wider and regularly concave. Annulations slightly varying in distance in different portions of the tube; on the specimen referred to, there may be counted eight in the upper part and nine in the lower part in the space of an inch. Septa very moderately concave, arranged one to each annulation, uniting with the external shell at the bottom of the depressions. Siphuncle small and subcentral. Surface of the shell only known by the impression in the matrix, where it has the appearance of having been smooth.

This species is somewhat variable in its characters, some individuals noticed being so nearly uniform in their diameters that it is difficult to determine the increase; while in others the rate of increase is much more rapid, though these latter are usually of smaller size than the others, some being noticed of less than an eighth of an inch in diameter. The individual figured has the peculiarity of decreasing in size toward the upper extremity, as well as of having the annulations proportionally more distant in the upper part, though as this portion of the tube is without septa, it might be inferred that it was an adult individual, and that these were features of maturity. The specimen is also somewhat curved throughout its entire length, but as other individuals noticed appear straight, it is to be inferred that this is probably an accidental condition. The New York specimens, on which the species was founded, have the surface marked by fine, even, longitudinal striæ, which are separated by flattened spaces of four or five times the width of the striæ. This feature has not been noticed on the Wisconsin specimens, but the state of preservation is such that features of this kind might not be preserved. Except for the want of this feature, they are so nearly alike that there is no reasonable question of their specific identity.

Formation and locality. In the buff limestones of the Trenton group, at Beloit, Janesville, and other localities in southern Wisconsin, occurring at nearly all horizons in the formation.

Orthoceras planoconvexum.

Plate VII. Fig. 14.

Orthoceras planoconvexum—*Hall;* Rept. Prog. Geol. Surv. Wis., 1861, p. 47, and Geol. Rept. 1862, Vol. I, p. 442.

Shell of medium size, somewhat rapidly expanding from the apex to the upper end; a fragment measuring about three inches in length and having a transverse diameter of half an inch at the smaller end, increases to one and one-fourth inches at the larger end; transverse section planoconvex, or nearly so; one side being very depressed convex and the other having the curvature three or four times as sharp, and the short diameter of the tube a little less than half that of the other diameter. The most convex surface often presents a slight angularity along the middle. Lateral margins rounded. Septa closely arranged, six of the chambers just below the outer one, in the example figured, measuring half an inch, and showing no perceptible increase in distance in different parts of the tube, so far as can be determined by the examination of this and several other individuals. The septa appear rather deeply concave, as seen from edge to edge of the tube, but not perceptibly so in a dorso-ventral direction. Siphuncle quite small, centrally situated on the flattened side, and close to the outer shell, but not in contact. Surface of the shell marked only by concentric undulations, indicating striæ of growth.

This species is not uncommon, but is peculiar in the distinctly planoconvex character of the transverse section; in this feature differing from all others of the same geological formation. There are other Cephalopods occurring in the same formation and locality, having this feature to a limited extent, but none so decidedly unequal as this one. It is possible the shell should be referred to the genus *Cyrtoceras*, rather than to *Orthoceras;* but none of the individuals examined show the slightest curvature; still the lateral position of the siphuncle would indicate its close relationship to the slightly curved forms herein described, and shown to be unequal sided.

Formation and locality. In the hard layers of the bluish buff limestones of the Trenton group, below Carpenter's quarry, near Beloit; and also at Janesville, Wisconsin.

Endoceras Hall; Cameroceras and Diploceras Conrad.

The two genera, *Endoceras* Hall and *Cameroceras* Conrad, appear to be very closely allied, if not identical forms; *Cameroceras* being founded upon a species *(C. Trentonensis)* possessing an inner sheath or tube which is permanently attached to the septa in precisely the same manner as that of *Endoceras*, and differing simply in its lateral position, beaded form, and more gradual expansion. The permanent inner sheath or tube of *Endoceras* is not always central; is permanently attached or anculosed to the septa through which it passes, and if slightly expanded in the chambers, would present the annulated or beaded character shown in *Cameroceras* (see Pal. N. Y.,Vol. I, Pl. —, fig. 1, which is not a septate inner tube, but only annulated by expansions within the chambers, as the specimen shows). There is a difference, however, in the more rapid expansion of the tube in *Endoceras*, and in the occurrence of one or more additional and apparently free tubes within the first or permanent tube; a feature, so far, not observed in any example of *Cameroceras*. This, then, would appear to be the only essential difference, and one only occasionally occurring, as by far the greater number of individuals of *Endoceras* possess only the first or permanent inner tube. So the difference between the two genera would thus be reduced to the lateral position of the permanent tube or siphuncle, and an occasional occurrence of additional free tubes (or young) within the permanent one.

In 1842, Mr. Conrad proposed the genus *Diploceras* for a shell *(D. Vanuxemi)* obtained from the Trenton limestone, which, according to his outline figure, given on Plate XVI, fig. 2, Vol. 8, Jour. Acad. Nat. Sciences, Phila., 1842, appears to have possessed an inner tube of large size, surrounded by septa and an outer tube, the inner one being near one side of the outer one. The specimen from which this outline figure was made must have possessed all the essential features of *Endoceras*, and is probably identical with *E. proteiforme*.

Mr. Conrad's description, both generic and specific, is very obscure and unsatisfactory, but he undoubtedly had before him a specimen of *E. proteiforme* which had been broken or worn away to below the center, exposing its internal structure. Mr. Conrad's description is as follows:

"Straight; siphuncle not central nor adjoining the margin; a longitudinal arched septum starting from the margin and dividing the transverse septa.

"This genus occurs in the same limestone with the last *(Cameroceras Trentonensis)*, and is very distinct. The following species was found by Mr. Vanuxem at Trenton Falls.

"DIPLOCERAS VANUXEMI, Pl. XVI, fig. 2. Siphuncle large; septa numerous; exterior smooth."

The following species possesses features which allies it to both *Endoceras* and *Cameroceras.*

ENDOCERAS (CAMEROCERAS) SUBANNULATUM; n. sp.

Plate VII. Figs. 15 and 16.

Shell of moderate or large size, and moderately expanding from the apex to the outer chamber, the rate of increase being about three-eighths of an inch in a length of four inches, or less than one-eighth of the increase in length in a slightly compressed specimen. Section oval, the relative diameters being as three to four. Surface of the shell marked by closely arranged concentric undulations which encircle the tube and are arched upward in crossing the narrower sides of the shell. The undulations form low, rounded ridges with concave interspaces and count about six in the length of one inch. There are also indications of finer lines of growth of which four or five occur on each annulation. Septa deeply concave, arching upward on the sides of the shell, corresponding in this feature, and also in their distance from each other to the undulations of the surface. Inner tube (or siphuncle) proportionally large, fully equaling one-half the shorter diameter of the outer tube, situated on one of the flattened sides of the shell and almost in contact with the outer tube; its surface straight or destitute of any expansion between the septa, but marked by oblique lines or slight ridges where the septa have been broken from around it, their obliquity corresponding to the concavity of the septa.

This species somewhat resembles *Endoceras annulatum,* Hall (Pal. N. Y., Vol. I, p. 207; Pl. 44, Fig. 1); but differs in the strength of the annulations, which are only about half as large, and in a corresponding difference in the distance of the septa. The transverse section of that species is round, while this is oval, and this latter feature in our species is a natural one, as is very distinctly shown by the arching upward of the septa on the sides of the shell, which if the form was due to compression, would not occur.

Formation and locality. In the upper part of the buff limestone of the Trenton group, at Hess' quarry, near Beloit, Wisconsin.

GENUS CYRTOCERAS, Goldfuss.

CYRTOCERAS PLANODORSATUM; n. sp.

Plate VII. Figs. 10–12.

Among the collections made from the lower buff or bluish-buff limestones near Beloit, there exist several specimens of a *Cyrtoceras*, presenting features so unlike any previously described species that it is readily distinguished, and as it has been noticed as yet only in the lower beds, it may prove a characteristic species of that horizon. The form is but slightly curving, the degree of arcuation being not more than one-sixteenth of the length; or, the curvature being one-sixteenth of an inch in a length of one inch. The tube is but slightly expanding, and is unequal sided; the dorsal side being very depressed convex to near the edges, then more abruptly curving, while the ventral or inner side of the tube is very convex, forming a segment of a broadly oval figure, the transverse section appearing as an oval with one side pressed nearly flat, the short diameter being a little more than two-thirds as great as the larger. Among the specimens noticed, there are but few septa preserved, the lower portion being represented only by the cavity in the rock; where any are preserved, they are closely arranged, moderately concave, and very regular in their distance. Siphuncle minute, nearly marginal at the middle of the flattened side. Surface marked only by concentric striæ of growth, which indicate a broad, shallow sinus in the outer margin, on the flattened side of the shell.

The unequal sided form, nearly straight tube with slightly increasing diameter, are distinguishing characteristics.

Formation and locality. In the lower part of the buff limestones of the Trenton group, below Carpenter's quarry, and at the railroad quarries, three miles above Beloit, Wisconsin.

CYRTOCERAS CAMURUM.

Plate VII. Figs. 7 and 8.

Cyrtoceras camurum—*Hall;* Pal. N. Y., Vol. I, p. 196, Pl. XLII, fig. 6.

Shell of moderate size, and of only a moderate degree of curvature, the outer circumference of the coil, at least of the outer three inches, forming an arc of two and a quarter inches radius; or of a circle of four and a half inches diameter. The increase in size is also very gradual, being only three-sixteenths of an inch in a length of two inches. Transverse section of the tube nearly elliptical, or very slightly ovate; the narrowest part of the ovate figure being at the dorsum; the greatest diameter being in a dorso-ventral direction, and the two diameters being as a little more than four is to five, in the upper part of the shell; but the diameters appear to change somewhat below, the difference being a little greater. Septa very slightly concave, more deeply so in a dorso-ventral than in the opposite direction; strongly curving upward for the outer third of their length, being more abruptly bent a little outside of a central line; rather compact in their arrangement, six of the chambers occupying a space, when measured along the dorsum, equal to the greatest diameter of the upper one counted. Outer chamber as long or longer than its greatest diameter, and very slightly constricted a little below the outer border. Siphuncle rather large, situated close against the dorsal surface of the shell, generally showing along the back of the internal casts, and slightly expanded within the chambers.

Surface of the shell smooth, so far as can be detected, either on the cast or in the matrix, no markings except a few lines of growth being apparent.

The specimens found at the west closely resemble those of the species from New York, both in the moderate degree of expansion and the slight curvature, as well as in the smooth surface of the shell. The species is readily distinguished from others found associated with it by these characters; differing from them all in the slight curvature; nearly equal sized tube, and in the elliptical section.

Formation and locality. In the Buff limestone of the Trenton group, at Hess' quarry, near Beloit, Wisconsin, where it is quite abundant, being more frequently met with than any other form of cephalopod, so far as I have observed.

GENUS ONCOCERAS, Hall.

ONCOCERAS MUMIAFORME; n. sp.

Plate VII. Figs. 3–5.

Shell of small size, the largest individual observed scarcely exceeding half an inch in its greatest diameter, and with a length of probably two inches. Form gradually expanding from the apex to the base of the outer chamber, above which it rapidly contracts, until within a distance of the last septum, much less than its diameter, it is only about two-thirds of the greatest diameter, and is then again expanded to the aperture. Shell slightly curving throughout, appearing more strongly arched on the outside near the upper part, or just below the constriction of the outer chamber, owing to the contraction being more on the outer surface than on the inner side. Transverse section nearly circular, the inner side being just perceptibly less convex than the outer surface. Septa shallow or but slightly concave, arching upward on the inner side, and broadly sinuate on the back; distantly arranged in the lower part of the tube, becoming more crowded in the upper portion, at least for the three or four upper chambers. In the lower part of the tube, four chambers occupy a space equal to the diameter of the upper portion of the outer one measured. Siphuncle central, minute. Surface smooth, so far as can be determined by the specimens, which are all internal casts or impressions of the exterior.

The species has somewhat the character of *O. constrictum* Hall, from the Trenton limestones of New York; but is much less rapidly expanding, proportionally more slender, and much less strongly arcuate.

Formation and locality. In the Lower Buff limestone of the Trenton group, below Carpenter's quarry, near Beloit, Wisconsin.

Oncoceras pandion.

Plate VII. Fig. 6.

Oncoceras pandion—Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 45, and Geol. Rept. Wis., Vol. I, pp. 41 and 441.

Comp. O. abruptum—Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 44.

Shell of medium size, of rather robust habit, strongly curved, and rather rapidly expanding from below, upwards, to near the base of the outer chamber, which is very gradually converging to near the aperture, when it is suddenly contracted. The rate of increase in the diameter, in the specimen figured, is equal to two-thirds of the diameter of the smaller end of a section measured, in a length of one inch along the back of the shell; transverse diameter of the tube broadly ovate, the greatest diameter being in a dorso-ventral direction; dorsum narrowly subangular, and the inner face broadly rounded; the greatest transverse diameter is on the inner side of a central line drawn along the side of the shell, and the two diameters of the section are as five and six; septa moderately distant, strongly arching forward on the dorsum and moderately concave; from seven to ten of the septa may be counted in the space of one inch on the back of the shell near the upper part, but they gradually decrease in distance below; this feature varies somewhat in different individuals; siphuncle rather large, situated just within the shell on the back, and slightly expanded within the chambers. The surface of the cast is marked by indistinct longitudinal ridges, arranged at pretty equal distances from each other, but gradually diverge with the increased diameter of the tube; in the lower part of the specimen figured, there are about four in the space of one-fourth of an inch; these ridges do not appear to pertain to the exterior surface features of the shell, but are probably the result of the muscular attachment of the animal to the shell; for although they mark the filling of all the chambers below, they are not apparent on that of the outer chamber, except at its lower margin; a similar marking is often observed surrounding the base of the outer chamber of other species of this and allied genera, more especially on those of *Gomphoceras* and *Phragmoceras*, which can only be the result of muscular attachment.

This species is most readily recognized by its abruptly expanding form and curvature, coupled with the form of its transverse section; the longitudinal ridges are not always present, as may be seen on the example figured by Prof. Hall, Geol. Rept. Wis., Vol. I, p. 44. From comparison with the type specimens of *O. abruptum* of the same author, we are inclined to consider them as of the one species, the longitudinal ridges on that one being the only point of difference between them. This feature of ridges, arising from the recession of the scars of muscular attachment, is one that would readily vary in different individuals, as the scar would be deep only on specimens where the shell was thickened by excessive deposit; while others, having thinner shells, would not possess them sufficiently deep to leave the thickened ridge on the inside of the shell.

Formation and locality. In the buff limestone of the Trenton group; at Carpenter's quarry, Beloit, Wisconsin.

Oncoceras brevicurvatum; n. sp.

Plate VII. Fig. 2.

Shell of rather small size, very sharply curved throughout its length, and very abruptly expanding from the apex to the aperture; the rate of increase being about as one to four, as compared with the length; the diameter doubling in a length equal to four times the diameter of the part measured, the length measured on the outer curve. Transverse section nearly circular, the dorso-ventral diameter only perceptibly smaller than the lateral diameter, and the ventral surface a little more flattened than the dorsum; the latter being very slightly angular. Septa moderately concave, not arching upward on the back; about six chambers occupying a length equal to the diameter of the outer one of those counted. Siphuncle small, situated just within the dorsal surface. Surface smooth.

This species in many respects resembles *Oncoceras abruptum* Hall, Rept. Prog. Geol. Surv. Wis., 1861, p. 44 (=? *O. pandion*), but differs in the abruptly curved form, and in the nearly circular section of the shell; the variation of diameters, although very slight, being in the opposite direction to what it is in that species. The specimens show no evidence of contraction of the outer chamber near the aperture, but may possibly be immature.

Formation and locality. In the upper part of the buff limestones of the Trenton group, at Hess' quarry, near Beloit, Wisconsin.

Genus GYROCERAS, D'Konnick.

Gyroceras duplicostatum.

Plate VII. Fig. 1.

Gyroceras duplicostatum — Whitf.; Ann. Rep. Geol. Surv. Wis. for 1877, p. 78.

Shell rather small, seldom exceeding two and a half inches across the coil; consisting of one and a half to two or more slender, moderately increasing, loosely coiled volutions, which are not in contact, and gradually increase in distance with the increased growth of the shell. Section of the shell circular, and from half an inch to five-eighths of an inch in diameter, at the end of one and a half volutions. Surface of the shell marked by closely arranged, sharply elevated, rounded, encircling costa, separated by wider interspaces, which are mostly occupied on the dorsal half of the shell by smaller additional or intercalated costa, which do not extend beyond the middle of the side. Costa bending slightly backward in crossing the side of the volution from the inner to the outer surface, and strongly arching forward in crossing the dorsum.

Formation and locality. In the Trenton limestone, at Bristol, Dane county, and in the bluish-buff beds below Carpenter's quarry, near Beloit, Wisconsin.

CRUSTACEA.

Genus ASAPHUS, Brong.

Asaphus Susæ.

Plate V. Fig. 3, and Pl. X. Fig. 8.

Asaphus Susæ — S. Calvin; in MS.

Body, when entire, more or less oval, the anterior and posterior extremities almost alike in form, the anterior border a little more sharply rounded than the other, and the sides of the body along the edges of the thorax straight. In profile, the body rises gradually from the middle of the caudal plate, along the thorax, and to the anterior border of the eyes; in front of which it abruptly declines to the front margin of the head. Proportional width and length about as ten and twelve. In the specimen figured, the breadth is apparently somewhat greater, being as nine is to twelve, owing to the partial overlapping of two of the thoracic segments.

Cephalic shield crescent-form; the occipital line having a much longer curvature than the outer border, and the length, along the median line, equal to two-fifths of the transverse diameter, the sides of the head extending backward some distance behind the central portion, and the genal angles rounded. Surface very convex in the middle, and nearly level on the top between the eyes, which are very distant, large and exceedingly prominent, strongly reniform, situated less than their length from the occipital border, and their visual surfaces highly convex. Facial sutures rounding outward in front of the eye for half the distance, then rounding rapidly inward and uniting in the middle just above or on the margin, in a very obtuse point. Behind the eye they are directed backward and outward, reaching the posterior border at a point about one-third the width of the lateral lobe from the dorsal furrow; the posterior lateral limbs being about twice as long as wide.

Thorax short, strongly lobed longitudinally, and consisting of eight short articulations, which are nearly flat on their exposed surfaces from front to back, and their free extremities rounded. Axis convex, about once and a half as wide as the lateral lobes, and very slightly narrowed posteriorly. Lateral lobes horizontal for a short distance outside of the dorsal furrow, the flattening scarcely visible on the anterior segment, but gradually increasing in length to the sixth segment, when it again diminishes posteriorly. Beyond the horizontal part, the segments are abruptly bent downward, and the articulating face of the free pleura extends almost the entire width of the rib.

Pygidium depressed convex, transversely subelliptical, the length a little more than half the width, posterior margin almost regularly arcuate, and more strongly curved than the anterior border; so that a line drawn across the plate from the two outer angles would cross at about the anterior third of the length. Lobation very indistinct, the dorsal furrows being scarcely perceptible except near the anterior margin, and the articulation only faintly traceable. A perceptibly depressed furrow extends along the sides just within the margin.

Formation and locality. In the limestones of the Trenton group. The example figured was obtained at Apple River, just across the Illinois line.

Asaphus homalonotoides.

Plate V. Fig. 4.

Asaphus homalonotoides — *Walcott;* 31st Rep. State Cab. N. Y., p. 71.

Species known only by the pygidium, which is almost equilaterally triangular in outline, the breadth across the anterior margin exceeding, by a very little, the length of the side from the antero-lateral angle to the posterior extremity; anterior margin arcuate; posterior extremity obtusely pointed, and the lateral margins nearly straight or a little rounded in the upper part; surface of the plate moderately convex, the lateral lobes rather flattened on the inner half, outside of which they slope rapidly and are again recurved near the outer border, leaving a concavity just within the margin; axial lobe very depressed convex, two-thirds the length of the plate, and comparatively narrow; wide on the anterior margin, but rapidly contracting to the middle of its length, and less rapidly behind; the extremity obtusely rounded; anterior extremity marked by a scarcely perceptible ring, beyond which it is smooth; lateral lobes marked only by a single broad, distinct and deep furrow near the front margin, on the inner part; but which becomes obsolete before reaching the margin; articular slopes of the antero-lateral angles wide and very oblique, truncating the outer angles.

The species is peculiar for its triangular caudal shield; differing in this respect from any heretofore described species.

Formation and locality. In the blue limestone of the Trenton group, in the bed of the creek on Sec. 5, T. 5, R. 5 W., Grant county, Wisconsin.

Genus ILLÆNUS, Dalman.

Illænus ovatus.

Plate V. Figs. 1 and 2.

Thalliops ovatus — Conrad; Acad. Nat. Sci., Phil., Vol. I, p. 332, 1843.
Thalliops (Illænus) ovatus — (Conrad) Hall; Pal. N. Y., Vol. I, p. 259. Pl. 67, fig. 6.

Body small, broadly obovate, widest across the base of the cephalic shield, distinctly but not strongly trilobed. Cephalic shield semi-ovate or somewhat paraboloid in form, very highly convex, rounded in front, and half as long as wide, exclusive of the very small movable cheeks, the genal angles of which are produced laterally into short, blunt, or obtuse spines, extending beyond the limits of the throax to a distance equal to about one-third of the width of the axial lobe. Eyes sub-pedunculated. Dorsal furrows distinct on the posterior third of the head, but obsolete forward of that joint. Glabella between the dorsal furrows convex, equaling more than one-third, but less than one-half of the width of the head. Occipital furrow and ring very faintly marked even on the larger specimens, the ring rounding backward beyond the posterior line of the head.

Throax wider than long, composed of ten short, smooth; slightly convex articulations; axial lobe depressed convex, regularly tapering posteriorly, narrower than the lateral lobes, and the segments strongly arching forward in the middle; lateral lobes flat for more than half their width from the axis, and then rather sharply bent downward, at an angle of more than fifty degrees, and the segments also strongly curved backward.

Pygidium short and broad, twice as wide as long; axis convex, very little more than half the length of the shield, obtusely rounded and prominent at the extremity; rings usually very obscure; margins of the plate smooth and abruptly declining.

Surface of the head covered on nearly all parts except near the front margin, by small, deep punctures; that of the throax and pygidium being entirely smooth.

The specimens of the species noticed from Wisconsin are of the usually small size, the largest head observed measuring about one inch between the extremities of the eyes, the peduncles of which project laterally and horizontally, and are about one-sixteenth of an inch in length.

Formation and locality. The detached heads and caudal plates are not uncommon in the buff and blue limestones of the Trenton group, at most of the quarries near Beloit, Wisconsin; and a single entire individual was obtained at the quarry of Mr. Hess, near that place.

SPECIES MORE PARTICULARLY CHARACTERIZING THE GALENA LIMESTONE.

Genus RECEPTACULITES, De France.

Receptaculites Oweni.

Plate X. Fig. 7.

Receptaculites Oweni — Hall; Rept. Prog. Geol. Surv. Wis., 1851, p. 13; Geol. Rept. Wis., 1862, p. 46, Fig. 2, and p. 429.
Coscinopora sulcata — Owen (not of Goldfuss); Rept. Geol. Expl. of Iowa, Wis. and Ill., 1844, p. 40, Pl. VII., Fig. 5.
Receptaculites Oweni — (Hall); M. and W. Geol. Rept. Ill., Vol. III, p. 302, Pl. II, Fig. 3.
Comp. Receptaculites occidentalis — Salter; Can. Org. Rem. Dec. I.

Body, as preserved fossil throughout the Lead Region, consisting of broad expanding discs, varying in size from those of a few inches in diameter to others of twenty or more inches. Discs thin in substance, increasing in thickness from an eighth of an inch near the center, to almost an inch near the margin of large individuals; circular in form, flattened or more or less undulating, but usually marked in the center or at the initial point by a small, somewhat deeply funnel-formed depression, which appears to have originated in a point of attachment during the earlier stages of growth; after which the body became more expanding and undulating, as well as thicker in substance. The substance of the fossil is filled with circular cell-like perforations, placed perpendicular to the plane of the disc, and arranged in curved or concentric lines or rows, which radiate or diverge from the central point, and the cells gradually increase in dimensions as they approach the margin of the disc; but with frequent intercalated rows. The cells are so arranged as to form circular and often direct radiating lines, as well as the concentrically curved lines above mentioned. Cell apertures on the lower side, nearly as large as the body of the cell within, with the margins excavated or flaring, forming sharply angular surfaces on the partition walls; but on the upper surface they are contracted to about half the diameter of the tube within, and the aperture is rhombic or quadrangular, with walls, which are variously ornamented according to the condition of preservation and the compactness of the arrangement. The walls on the outer portion of large individuals, where they are much thickened and well preserved, show peculiar markings resembling radii, but which are probably the impressions of the stolon-like branches or ramifications, described by Mr. Billings in his excellent observations on the genus, published in the Palæozoic Foss. of Canada, Vol. I, p. 282, as arising from the contracted portion of the cell and passing along the inner surface of exterior crust or wall of the disc; and not true rays, like those of a coral. It should be remembered, in examining these bodies as they occur in the dolomitic limestones of the west, that they are only internal casts of the organism, and not the substance itself; that the substance now occupying the spaces between the cylindrical cavities is only the filling of spaces that existed between the true cells, which were themselves, in all probability, hollow cylinders opening on the exterior surface of the body. Taking this view of them the corrugations or constrictions occurring within the present tubes would not represent transverse septa, as surmised by Messrs. Meek & Worthen, loc. cit., dividing them into chambers like those of *Favosites*, but merely currugations or wrinkles, on the exterior of a tube, formed by the excess of deposit or irregularity of growth, and the apparent rays, referred to by Prof. Hall, surrounding or marking the rhombic apertures are only the impression of ridges on the inner surface of the exterior crust of the body.

The exterior surface of the shell of the organism has probably been smooth, or nearly so, as indicated by the surface of fragments of rock adhering to some of the specimens examined. This feature, however, might be readily determined by an examination of the matrix of some of the larger individuals where well preserved.

Mr. Billings has suggested, in his remarks, that the true form of all these bodies was more or less globular, with an internal cavity in all, into which the waters of the surrounding seas were admitted through a central aperture; and that these discoid remains, so commonly found, were only the basal portions of the organism from which the upper part had been broken. This could hardly have been the case in these forms, since if it were, some of them would probably have been found preserving some portion of the upper walls. Besides, some of the globular forms have been seen, in which the cell cavities reached nearly if not quite to the center of the mass; thereby indicating that the central cavity was very small, if it was not entirely obsolete.

Formation and locality. In the limestone of the uppermost Trenton (Galena limestone), throughout almost the entire extent of its distribution; not only in the lead-

bearing portions, but at the same horizon further north, near Green Bay, where they occur of very large size, in thin bedded, shaly white limestones.

RADIATA.

Genus HALYSITES, Fischer.

Halysites catenulatus.

Plate X. Fig. 6.

Tubipora catenulata — Linne; Catenipora escharoides — Lam. and others. Halysites catenulatus — Fischer and *later authors.*

Corallum forming irregularly hemispherical or explanate masses of various sizes, composed of an aggregation of slender tubular corallites, united by their sides so as to form laterally extended rows or ranges of cells in a single series; but the rows so united to each other as to form, by their intersection, open intercellular spaces or meshes of various sizes. Corallites slightly oval in the direction of the ranges, and divided internally by transverse partitions at varying distances. Outer surface of the ranges marked by a strong, roughened epitheca, marked horizontally by strong lines, indicating the growth of the cells. Openings of the cells on the surface, when the substance of the coral is preserved, presenting an appearance resembling the links of a chain along the ranges. Longitudinal rays obsolete.

Fragments of two individuals of this species have been found in the limestones marking the Upper Buff horizon of the Trenton group at Rockton, Illinois. The specimens differ from the ordinary form of the species, as it occurs in the Niagara group, in its lax and irregular mode of growth. The expansions formed by the united corallites do not appear to have formed the regularly arranged intercellular meshes, but to have been formed of two, three or many corallites, which have sometimes been connected with those adjoining; or to have grown free, and to have formed folds, or grown winding, flexuose and contorted, as if for the want of support. I have noticed a similar mode of growth existing on Niagara group specimens sometimes, near the margins of a corallum, where some deposit of earthy matter or other accident has interfered with the regular growth, causing a small portion to become separated from the surrounding parts, growing up without their support, and resulting in this irregular and distorted form. In the specimens found in the Galena limestone, the substance of the coral has been removed, leaving only the impression of the fronds; but aside from the irregular growth, they present the features usually seen in similarly preserved specimens from the Niagara group.

BRACHIOPODA.

GENUS LINGULELLA, Salter.

LINGULELLA IOWENSIS.

Plate IX. Fig. 1.

Lingula Iowensis — Owen; Geol. Rept. Iowa, Wis. and Ill., 1844, Pl. XV, Fig. 1.
Lingula quadrata ?— Owen; Geol. Rept. Iowa, Wis. and Minn., Pl. II B, Fig. 8.
Lingula quadrata — (Eich.) Hall; Geol. Rept. Wis., Vol. I, p. 46, Fig. 1, and p. 435.
" " *(Eich.)* M. and W. Geol. Rept. Ill., Vol. III, p. 305, Pl. II, Fig. 4.
Comp. Lingula quadrata — Eichwald, and other authors.

Shell large, broadly ovate, elliptical or subquadrate in outline, generally a little narrower above the middle of the length than below; upper end very obtusely angular, the cardinal slopes forming an angle with each other of about one hundred and twenty degrees; sides of the shell gently rounded, and the basal line more sharply rounded but never truncate. Valves convex, the ventral valve most strongly so, and generally subangular along the middle. Ventral beak projecting a short distance beyond the dorsal, and more pointed. The cardinal margins of the ventral valve are infolded, along their border, forming an imperfect cardinal area of a very perceptible width on well preserved specimens.

Surface of the shell marked by strong, irregular lines of growth at irregular distances, the outer margins of which are slightly raised and free, presenting a strongly lamellose appearance under a magnifier; the spaces between being smooth and often polished. On exfoliated specimens, and more distinctly on internal casts, the surface is very strongly radiated by fine, flattened, but irregular striæ for from one-third to one-half the length of the shell, and on nearly the entire width along the basal line; but a little higher on the sides they lose their regularity and become broken and wrinkled as well as more strongly divergent. The striæ are apparently confined entirely to the internal surface of the shell, and are not at all visible on the shell itself. On the internal casts of the more thickened shells, there is a deep groove of considerable width, extending from a little below the beak for one-third, or more th n one third, the length of the shell, representing an elevated, thickened, median rib on the inside of the shell; indicating relations to the genus *Dignomia* Hall.

This species has usually been referred to *Lingula quadrata* of Eichwald, a Russian species, and it is possible that it may be identical; but in the absence of true specimens of that species for comparison, and the possession of some peculiar hinge features existing on this one, we should prefer to retain Dr. Owen's original name of *L. Iowensis*, with a change to the genus *Lingulella*.

Formation and locality. The species appears to be confined entirely to the lead bearing or Galena limestones, at the top of the Trenton, and is quite abundant at that horizon throughout the greater part of the lead bearing portions of the formation.

Genus HEMIPRONITES, Pander.

Hemipronites Americanus.

Plate X. Figs. 15–17.

Hemipronites Americanus — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 72.

Shell of medium size, subparaboloid or subquarangular in outline, hinge-line straight, and as long as the width of the shell below, the sides of the shell somewhat straightened, and the front rounded or round-truncate. When viewed in profile, the form is plano-pyramidal, the dorsal side flat or even depressed along the middle, with a narrow or linear area. Ventral valve pyramidal, half as high as long, and having a small, pointed and slightly incurved beak. Area high, with a large, closed deltidium. Surface of the shell marked by fine, radiating striæ, which are crossed by strong, concentric lines of growth at irregular intervals.

This species resembles, to some extent, the forms referred by Mr. Billings to *Orthisina Verneuili* Crip., but wants the large area on the dorsal valve of the typical forms of that genus. It however corresponds closely to the form known as *Orthis hemipronites*, which possesses only a small horizontal area on the dorsal valve, and which possesses internal septa in the ventral valve entirely different from those of *Orthis anomala*.

Formation and locality. In the upper portion of the Trenton group (Galena horizon), at Oshkosh, Wisconsin.

GASTEROPODA.

GENUS MURCHISONIA, D'Arch. & Vern.

MURCHISONIA MAJOR.

Plate IX. Fig. 4.

Murchisonia major—Hall; Foster & Whitney's Lake Sup., p. 209, Pl. XXVI, Fig. 1.
Comp. M. bellicincta—Hall; Pal. N. Y., Vol. I, p. 179, Pl. XXXIX, Fig. 1.

Shell large, strong and robust, gradually and rapidly tapering throughout; spire elevated, consisting of six or eight strong, very ventricose and compactly coiled volutions; which are separated by deep, well marked suture lines. Apical angle about thirty degrees in the more slender specimens, but often much greater. Aperture round-ovate, inner lip straight for a short distance, slightly prolonged below; its exact form not ascertained. Axis imperforate. Surface of the shell unknown, but no markings are preserved on the casts. Length sometimes as great as four and a half inches, by a diameter across the body volution of nearly two and a quarter inches.

The species is a very variable one in some of its characters, especially in the proportional length and width of the shell, as well as in the number of its volutions within a given length. Specimens referred to the species often occur, of not more than two inches in length, possessing as many volutions as others of nearly four inches in length, and this variation not arising from the preservation of the smaller volutions in one case and not in the other, as may readily be seen by the difference in the rate of increase between the two individuals examined. The same variations occur among the New York specimens referred to *M. bellicincta*, and it is possible there is more than one species represented in each locality; although, from the fact of the same varieties occurring at both places, I have been inclined to consider them as all pertaining to the one, and to class them under the specific name, *bellicincta*. I am also of the opinion that none of these forms are true *Murchisonias*, as, so far as I have observed, none of them show any evidence of having been marked by a revolving band; but as no specimens showing the surface of the shell in a very satisfactory manner have been observed, I am unable to fully determine their generic relations.

Formation and locality. In the upper part of the Trenton group (Galena limestone), at Whitewater, Fond du Lac, Pensaukee, Oshkosh, Neenah and at most of the localities where this bed has been detected. It is somewhat peculiar that it has not been detected in the lower or true Trenton, at any point within the state, although many other species with which it is associated in New York occur abundantly.

GENUS FUSISPIRA, Hall.

FUSISPIRA VENTRICOSA.

Plate IX. Fig. 2.

Fusispira ventricosa — Hall; 24th Rept. State Cab., p. 229. Pl. VIII, Fig. 6.

Shell elongate-ovate or elliptical in general form, the point of greatest diameter being nearly in the middle of the length, and the last volution forming fully two-thirds of the entire length. Volutions ventricose, and rapidly increasing in size, from four to five in number, with a strong, distinctly marked suture line. Body volution extended below, forming a moderately long, slightly twisted or rimate columella or beak, which is truncate at the lower extremity. Aperture obovate in form, broadest below the middle, and acutely pointed at the upper end. Outer lip thin and sharp.

Surface of the shell marked only by fine lines of growth, parallel to the margin of the aperture.

This species is distinguished from all others of the genus yet described, by the short ventricose form and nearly equal lengths above and below the middle of the body volution.

Formation and locality. In the upper part of the Trenton group (Galena limestone), at Waupun, Wisconsin.

FUSISPIRA ELONGATA.

Plate IX. Fig. 3.

Fusispira elongata — Hall; 24th Rept. State Cab., p. 229. Pl. VIII, Fig. 5.

Shell elongate-fusiform, spire slender and much elevated, consisting of six or more volutions which are long and only moderately convex on the surface, and gradually decreasing from the body whorl upward. Apical angle about twenty, or between twenty and twenty-five degrees. Suture strongly marked, appearing almost as if it had been channeled. Body volution rounded below more sharply than on the surface, and the columella prolonged to form a somewhat twisted, beak-like extension in front, imperfect in the specimen. Aperture obliquely elongate-ovate, pointed at the upper end and broad below; the length, exclusive of the anterior canal-like extension, being more than once and a half as long as the greatest width. Surface of the shell apparently smooth, or marked only by fine lines of growth, parallel to the margin of the aperture.

This species differs from *F. ventricosa*, in its greater length in proportion to the diameter. The beak, at the anterior extremity, is imperfect, as is also the upper end of the spire, but the type specimen figured by Prof. Hall, loc. cit., shows it to be nearly as long as the expanded part of the volution, and very slightly twisted.

Formation and locality. In the upper part of the Trenton (Galena limestone), at Whitewater, Wisconsin.

Genus MACLUREA, Lesueur.

Maclurea cuneata.

Plate XX. Figs. 5 and 6.

Maclurea cuneata—*Whitf.;* Ann. Rept. Geol. Surv. Wis. for 1877, p. 75.

Shell of medium size, attaining a diameter of three inches, and consisting of two or more volutions which increase very rapidly in size; lower (?) side of the shell flat, or very slightly concave between the suture lines; the opposite side being depressed-conical between the outer margin and the central depression, with a very slight convexity of the intermediate surface; outer margin of the volution slightly cuneate; central depression very small in the casts, leaving but little more space than would be occupied by the thickness of the shell. Transverse section of the volution triangular.

The species very closely resembles *M. acuminata* Billings, from the Quebec group (Pal. Foss. Can., Vol. I, p. 240, fig. 225), but is not so sharply angular on the periphery, with a less number of volutions and is also a much larger shell.

Formation and locality. In the upper portion of the Trenton group (Galena limestone), at Whitewater, Wisconsin. I have also seen a similar specimen from the same horizon, at Dubuque, Iowa.

Maclurea subrotunda.

Plate IX. Figs. 7 and 8.

Maclurea subrotunda— *Whitf.;* Ann. Rept. Geol. Sur. Wis. for 1877, p. 75.

Shell rather below the medium size, attaining a diameter of only about one and a half inches, and composed of two very rapidly increasing volutions which are almost twice as high as wide; the outer one being nearly vertical on the periphery, as it approaches the aperture, and then rapidly rounding on the base and to the very small central depression. Lower (?) surface of the volutions flattened, the two volutions being on the same plane. Surface of the shell not determined.

This species very closely resembles *M. rotundata* Billings, of the Quebec group, of Newfoundland (Pal. Foss. Can., Vol. I, p. 245, fig. 231), but differs in the smaller umbilical opening, and in not having the inner volution projecting above the outer one on the flattened surface.

Formation and locality. In the upper portion of the Trenton group (Galena limestone), at Whitewater, Wisconsin.

SPECIES FROM THE SHALES OF THE HUDSON RIVER GROUP.

RADIATA.

Genus CHÆTETES, Fischer.

Chætetes fusiformis.

Plate XI. Figs. 13 and 14.

Chœtetes fusiformis—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 70.

Corallum forming small, solid, irregularly fusiform or subcylindrical bodies, which are generally slightly curved, and vary from one-fourth of an inch to one inch in length, and attain a diameter of nearly an eighth of an inch at the thickest part in the larger individuals; extremities usually pointed, generally acute, when perfect; surface covered by very minute, round or slightly oval cell pores, which are separated by intercellular spaces of from less than one-third to nearly or quite two-thirds of their own diameter; intercellular spaces, marked by a few scattered intercellular pits, or a depressed groove, or oftentimes by an elevated line along the middle, which becomes ridge-like, leaving the cell apertures spreading or excavated at the top.

The species is peculiar only in its mode of growth; the cells being similar in form to those of many other finely-marked species of the genus, and are quite variable in character, even on the same specimen. The cells are directed slightly upward in their course from the axis, the stems appearing to be quite solid, although probably originally commencing their growth on some foreign substance. They show no cicatrix or point of attachment at the extremities, or evidence of having been rooted, and, except in a solitary instance, present no appearance of bifurcation.

Formation and locality. In shales of the Hudson river formation of New York, at Iron Ridge, Wisconsin.

GENUS MONTICULIPORA, D'Orb.

MONTICULIPORA RECTANGULARIS.

Plate XI. Figs. 11 and 12.

Monticulipora rectangularis—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 70.

Corallum compound and ramose, the stems cylindrical and solid, with distant bifurcations, and often attaining a diameter of three-eighths of an inch. Surface thickly covered with closely set, moderately elevated, rounded tubercles; cell-tubes of moderate size, from ten to fourteen occupying the space of an eighth of an inch; generally quadrangular in form, though commonly polygonal; usually arranged in concentrically curved rows, diverging from the center of a tubercle or forming segments of circles around them, on the upper side; cell walls very thin and sharp, not elevated to form spines at the angles.

The species closely resembles *M. multituberculata*, herein described, but differs in the quadrangular form of the cells, and in their mode of arrangement, and also in the absence of spines at the angles of the cells. In the form of the cells and in their arrangement, it is similar to *M. (Chætetes) quadrangularis* Nicholson, but differs conspicuously in the tuberculose surface, that species being said to be smooth. From *M. (Chætetes) quadrata* Rominger, it differs in the great strength and elevation of the tubercles, that one being smooth or having the tubercles only slightly developed. These differences in the strength of the surface tubercles, may be thought by some to be of but little specific value, still when coupled with other variations, and existing on large numbers of individuals at the same locality, they present a very marked and distinctive feature.

Formation and locality. In shales of the Hudson river group of New York, at Delafield, Wisconsin.

MONTICULIPORA PUNCTATA.

Plate XI. Figs. 3 and 4.

Monticulipora punctata—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 71.

Corallum forming comparatively strong, solid, bifurcating branches, varying from an eighth of an inch to more than half an inch in diameter, and attached by the base to foreign substances by a spreading, root-like expansion. The branches are densely covered by medium sized, moderately elevated, not confluent tubercles, which usually measure about a line, or a little more than a line, from center to center; or if measured in a direct series, numbering from ten to twelve in the space of an inch. The entire surface of the branch, except the top of the tubercles, is marked by fine rounded pits or pores of a nearly uniform size, divided by thickened walls, often slightly flattened on the edge; the pores number from six to twelve between the tubercles. The area on the top of the tubercles not occupied by pores, is irregular in form, about one-fourth or one-third of a line across, and is marked by fine, closely arranged puncta, which forms the distinctive character of the species.

The species somewhat resembles *Chætetes sub-pulchellus*, Nich. (Pal. Ohio, Vol. II, p. 196, Pl. XXI, fig. 6), but on comparison, will be found to differ in being composed of solid branches, with elevated tubercles, the centers of which are solid, the puncta not forming cells or tubuli, as said to be the case in that species. These maculæ are also uniformly much smaller in this one, never exceeding, so far as observed, more than a third of a line instead of a line in diameter. There is some faint indication of transverse partitions in some of the specimens, as seen in transverse sections, but altogether too obscure to render their existence certain.

Formation and locality. In soft shale of the Hudson River formation, at Delafield, and also at Iron Ridge, Wisconsin.

MONTICULIPORA MULTITUBERCULATA.

Plate XI. Figs. 9 and 10.

Monticulipora multituberculata—Whitf.; Ann. Rept. Geol. Surv. for 1877, p. 71.

Corallum growing in strong, solid, more or less flattened stems or branches, with frequent and irregular bifurcations. Surface of the stems covered with rather strong and prominent, rounded tubercles, with concave interspaces. Cells of medium size, polygonal in form, and numbering from ten to fourteen in the space of an eighth of an inch, those situated on the tubercles not differing materially from those on the interspaces. Cell-walls thin and sharp, without any appearance of intercellular pits or pores, and elevated at the angles of the cells to form low points. Cell tube divided by transverse partitions, which in the outer part are placed at distances about equal to the diameter of the tube.

This species resembles *Chætetes tuberculatus* Ed. & Haime, from Cincinnati, Ohio, but differs in the flattening of the stems; more distant and heavier tubercles, and in the character of the cells, which are much larger, with thinner walls, and always destitute of intercellular pits or pores. In general form, it very closely resembles *Tremato-*

pora tuberculata Hall, from the Niagara shales of New York, both in the mode of growth, flattening of the branches and form of tubercles, but differs in the character of the cells.

Formation and locality. In shales of the Hudson River formation of New York, at Delafield, Wisconsin.

MONTICULIPORA (?) ORTONI.

Plate XI. Figs. 7 and 8.

Chætetes Ortoni—Nicholson; Pal. Ohio, Vol. II, p. 211, Pl. XXII, Fig. 3.

Corallum parasitic on shell or other foreign bodies, forming thin incrustations over their surfaces, but from repeated growths, sometimes becoming moderately thickened. Surface of the corallum covered with fine polygonal pores, or cells, and also by rather distant, sharply elevated, transversely elongated, and often solid tubercles of varying size and form, on which the pores often become obsolete. The cells or pores measure about ten or twelve in the space of an eighth of an inch, and are separated by thin, sharp partition walls, which are elevated at the angles of the cells into short, obtuse, angular spines or projections, as seen in an oblique view.

We have no hesitation in referring the Wisconsin specimens to the above cited species, although we have not been able to detect the "miliary tubercles" which are said to crowd the walls of that one; but unless there are more than one species among the Cincinnati specimens, differing only in the presence or absence of these peculiar granulations, we feel certain that it is not a constant feature.

Formation and locality. In the soft shales of the Hudson River formation, at Delafield, Wisconsin.

GENUS ALVEOLITES, Lamarck.

ALVEOLITES IRREGULARIS.

Plate XI. Figs. 1 and 2.

Alveolites irregularis — Whitf.; Ann. Rep. Geol. Surv. Wis. for 1877, p. 72.

Corallum forming solid, flattened branches of irregular form, or incrusting other substances and partaking of the form of such bodies. Cells minute, from twelve to fifteen in the space of a tenth of an inch, more or less rhombic in form, moderately recumbent, and diverging from imaginary centers; the posterior lip slightly elevated and acutely angular. Surface often marked at irregular distances, usually of a tenth of an inch or more, with indistinct maculæ, composed of a few cells having thicker walls, and somewhat more elevated than the intermediate ones.

The species is very irregular in its mode of growth, and is generally found in detached fragments, having the appearance of flattened branches of a ramose frond. The cells are usually longest in an antero-posterior direction, but are extremely variable, often presenting examples that are much wider than long. They are not uncommonly arranged in oblique rows of from ten to fifteen or more cells, arranged in alternating series, so as to bring their walls in a direct line with each other. We have not been able to detect the transverse partitions in the tubes, owing to the crystalline character of the interior of the fragments.

Formation and locality. In greenish shales of the Hudson River group of New York, at Iron Ridge, Wisconsin.

BRYOZOA.

Genus FENESTELLA, Lonsdale.

Fenestella granulosa.

Plate XII. Figs. 1 and 2.

Fenestella granulosa—Whitf.; Ann. Rep. Geol. Surv. Wis. for 1877, p. 68.

Bryozoum growing in small, fan-shaped or funnel-formed fronds, which rise from a root-like base by which they have been attached to foreign substances. Longitudinal rays slender, rather closely arranged and frequently bifurcated, giving to the lower part of the frond a somewhat irregular mode of growth, but becoming more regular above. From three to four of the rays may be counted in the space of one millimeter, in the upper part, but seldom more than three in the lower. Fenestrules subquadrangular, longer than wide, but extremely variable in size and form, and about as wide as the diameter of the rays. Pores small, slightly oval, scarcely excert, generally four to each fenestrule, one of which is situated at the junction of the transverse dissepiments; rays carinate between the pores, dissepiments narrower than the rays. Nonporiferous surface of the rays convex, distinctly but very minutely granulose, the granules closely and irregularly arranged, sometimes numbering as many as six in the width of the ray opposite the fenestrule.

This is a very distinct and well marked species, although small as far as observed, and will be readily recognized by the finely granulose character of the back of the frond. The genus is not very abundant in this formation, so there are but few species with which to compare it. It differs from *F. nervata* Nicholson, from near Cincinnati, Ohio, in the absence of the thickened dorsal ray characteristic of that species.

Formation and locality. In shales of the Hudson river group of New York, at Delafield, Wisconsin.

Genus STICTOPORA, Hall.

Stictopora fragilis.

Plate XI. Fig. 24.

Ptilodictya fragilis — Billings; Cat. Sil. Foss. Anticosti, p. 9.

Bryozoum consisting of thin, slender, bifurcating stipes, with sharp edges and slightly convex surfaces, cellulose on both sides. Pores round-oval, longest in the direction of the stipe, and arranged in longitudinal rows, separated by thin, longitudinal, slightly elevated ribs. From two to four of the central rows are parallel to, and traverse the middle of the stipe; the others or marginal rows are oblique, and pass upward and outward to the margin.

The species has been recognized in many fragments, all of small size, but occurring at several localities. It differs from other described forms in the obliquity of the marginal ranges of pores, a feature which readily distinguishes it.

Formation and locality. In the soft shales of the Hudson River group, at Roberts' quarry, near Pewaukee Lake (Delafield?), and at Hartford and Iron Ridge, Wisconsin.

Genus TREMATOPORA, Hall.

Trematopora granulata.

Plate XI. Figs. 22 and 23.

Trematopora granulata — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 68.

Bryozoum growing in strong, solid, bifurcating branches, which are marked with low, rounded, and distant nodes, and the entire surface densely covered with small, rounded, elliptical or quadrangular cells, the apertures of which are slightly excavated and divided by proportionally thick partition walls; surface of the partition walls thickly set with small, rounded granules, sometimes arranged in a single and sometimes in a double series; from nine to twelve granules may be counted around a single cell, where they form only a single series, but where a double series exists they often alternate, so that the individual nodes are more distant; cells, where counted in a direct series, numbering from twelve to fourteen in the space of an eighth of an inch.

The growth of the cells is generally from the center outward, forming solid branches, with the cells opening at right angles to the axis; instances occur, however, where the upper end of a branch is hollow, the cells forming only a thin crust or tube; this, however, is not the usual mode of growth, but apparently the result of accident. In some of the cells thin, distant diaphragms can be seen. Intercellular substance apparently solid.

There is no species described from rocks of this age which sufficiently resembles this one to require comparison.

Formation and locality. In shales of the age of the Hudson river formation of New York, at Delafield, Wisconsin.

TREMATOPORA ANNULIFERA.

Plate XI. Figs. 15–17.

Trematopora annulifera—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 67.

Bryozoum forming slender, solid branches, with a diameter, in the larger specimens, of nearly a line, and marked by distant bifurcations. Branches characterized by numerous encircling annulations, which are arranged at about a sixteenth of an inch from each other, and are angular on the crest, with concave interspaces; cell pores very minute, elongate-polygonal in form, two-thirds as wide as long, and separated by intercellular spaces, somewhat narrower than the cells, and deeply grooved along the middle, leaving an elevated margin bordering the cell aperture, which is elevated at the base to form a short triangular node or spine.

The species is peculiar in its regular encircling annulations, placed at about the same distance from each other on specimens of all diameters. The cell pores vary considerably in size and form in different individuals, sometimes occurring nearly circular. The spine at the base of the cell aperture is not always developed, although generally present. The fragments seen vary from one-fourth to nearly one inch in length, and are seldom seen to bifurcate, although several have been noticed, showing this feature.

Formation and locality. In shales of the Hudson river formation of New York, at Delafield, Wisconsin.

GENUS FISTULIPORA, McCoy = *Callopora*, Hall.

FISTULIPORA SOLIDISSIMA.

Plate XI. Figs. 18 and 19.

Fistulipora solidissima—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 69.

Bryozoum forming strong, cylindrical, ramifying branches, which often attain a diameter of nearly one-fourth of an inch; general surface destitute of tubercles or tuberculiform elevations, but densely covered with minute, elongate-oval, or sometimes rounded cell pores, which are separated by intercellular spaces as wide or wider than the transverse diameter of the pores; intercellular spaces marked, usually, by a single series of very minute, slightly elongated, polygonal pits, which vary in size according to their positions, being largest in the angles formed by three adjacent cells, and smallest on the sides between two nearly opposite cells; occasionally there are two irregular lines of pits on the intercellular spaces, but this feature is not a common one; twelve to sixteen cell-pores may be counted in the space of an eighth of an inch, measured along the branch, and from three to five of the intercellular pits occur in the length of a cell.

The species is remarkable for the great density of its substance, and for the small size of the cell-pores, the surface appearing to the unassisted eye only as minutely granulose.

Formation and locality. In shales of the Hudson river formation of New York, at Roberts' quarry, Delafield, Wisconsin.

FISTULIPORA RUGOSA, n. sp.

Plate XI. Figs. 20 and 21.

Bryozoum forming solid, cylindrical, bifurcating branches; the bifurcations widely divergent, and the stems often slightly flattened at these points; general surface of the stems marked by distant, but rather indistinct pustules, which in some cases are grouped together, so as to form annulating ridges surrounding the stems; the stems are densely covered by minute rounded pores, with comparatively narrow interspaces; and these latter spaces are occupied by variously formed pits of small size, generally not exceeding one between any two cells, except at the angles between three adjoining cells, where they are frequently grouped into three or more to each group.

The principal point of difference between this and other forms of the genus is, in the general surface features of the stems or branches being pustulose or annulated.

Formation and locality. In the shales of the Hudson river group, at Delafield, Wisconsin.

FISTULIPORA LENS.

Plate XI. Figs. 5 and 6.

Fistulipora lens—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 69.

Corrallum growing in small, discoid or plano-convex, button-shaped bodies, which appear to have commenced their growth on a fragment of shell or other substance, and afterward become free; discs varying in size from one-fourth or less, to nearly three-fourths of an inch in diameter; under surface more or less concave, not usually possessing an epitheca, but presenting a fine, radiately striate surface, from the exposure of the cell tubes; cells radiating from an imaginary center, and forming on the upper surface of the disc extremely minute, rounded or polygonal apertures, with often a thin, sharp partition wall; but more frequently the wall has a thickness of nearly half the diameter of the cell, with one large intercellular pit occupying the space between the adjacent cells, and other smaller ones between the cells wherever the walls are thick enough to permit them; the walls near the angles between the cells bear small elevated points or nodes in many or most cases, as seen when looked at obliquely under a strong lens; four of the cells occupy the space of one millimeter.

The specimens have the appearance of the young individuals of *Chætetes lycoperdon*, but on examination, will be found to present the features of *Fistulipora.*

Formation and locality. In the shales of the Hudson river group of New York, at Roberts' quarry, Delafield, Wisconsin.

Genus CONSTELLARIA, Dana, 1846.

Constellaria polystomella.

Plate XII. Figs. 3 and 4.

Constellaria polystomella — Nicholson; Pal. Ohio, Vol. II, p. 215, Pl. XXII, Fig. 7.
Constellaria antheloidea — Ed. et Haime; Pal. Foss. Terr. Pal., Pl. XX, Fig. 7.
Constellaria antheloidea — Nicholson; Pal. Ohio, Vol. II, p. 214.
Not Stellopora antheloidea — Hall; Pal. N. Y., Vol. I, Pl. XXVI, Fig. 10.

Corallum composed of flattened ramifying branches or palmate fronds, which become branched by continued growth; surface of the fronds and branches poriferous and similar on all sides, and marked with somewhat crowded, elevated, star-like centers, which are composed of from six to fourteen or more elongate-elliptical tubercles or ridges, arranged in a radiating manner around the sides of a slightly convex elevation, leaving an open or plane space of variable size in the middle within their inner ends; stars circular to elliptical in form, and averaging about a tenth of an inch in diameter, separated from each other by narrow, depressed interspaces, which in older specimens sometimes become elevated along the center of the interspace, giving to the star an appearance as if occupying an hexagonal depression in the general surface; cell pores small, circular, and arranged principally along the sides of the elevated rays, but scattered more or less, also, over the interspaces, but never, so far as ascertained, occurring on the central areas of the stars; from three to seven of the cells occur on each side of the ray; the entire surface of the frond is covered with a minutely cellular structure, which appears as granular under an ordinary magnifier, but when more highly magnified, is seen to be composed of minute depressions, forming a cystose interstellar substance.

This species has usually been referred to *C. (Stellopora) antheloidea* Hall, from the Trenton limestone of New York, but, I think, wrongly, as that species is always parasitic, forming their incrustations on other substances, and I have sought in vain for true solid branches that were not parasitic; even specimens which present the appearance of very slender cylindrical stems reveal, when broken and carefully examined, a central axis of some other substance. This marked difference in the habit and mode of growth is, it appears to me, of sufficient importance to be considered as specific; but there are also differences in the character of the stellar elevations. I am not prepared, however, to recognize two species among those found at the west as founded on the characters described by the author of the name here adopted, as all the variations in the number of rays can be commonly found on the same fragment of a frond, and the feature of circumscribed stars by hexagonal borders is only one of age or condition, the same example frequently exhibiting both features in a very marked degree. Believing these western examples, however, to be entirely distinct from the New York forms, I have adopted the specific name, "*polystomella*," of Prof. Nicholson, for them.

Formation and locality. In soft shales of the Hudson river formation, at Delafield, Wisconsin.

BRACHIOPODA.

Genus ORTHIS, Dalman.

Orthis testudinaria.

Plate XII. Figs. 5–7.

Orthis testudinaria — Dalman; Kongl. velensk. Acad. Handl., 1827, and of subsequent authors.

Shell small, plano-convex, or nearly so, hinge line shorter than the entire width of the shell below, giving a transversely oval form to the outline. Ventral valve much the deepest, and somewhat carinate along the medium line, becoming compressed and thin near the lateral margins; beak small, slightly incurved, and extending slightly above that of the opposite valve; area small, and divided in the middle by a small, triangular fissure. Dorsal valve flattened, or but slightly convex, and marked along the median line by a shallow, subangular depression, corresponding to the carination of the ventral valve. Surface marked by moderately fine radiating striæ, which are distinctly recurved along the upper portion of the shell, so that many of them pass off on the hinge line; also by numerous concentric striæ, at irregular distances, marking stages of growth.

The shells of this species usually characterize the Trenton and Hudson river beds at nearly all their outcrops, being one of the most persistent, as well as most characteristic fossils of these layers. Still there are so many varieties of it that it is often difficult to refer it, without some hesitation, to its original place. Very many of these varieties have been described as distinct species, and others as varieties under varietal names, until collectors have almost lost sight of the original species. Some of these varieties seem to mark given horizons over limited areas, and others apparently characterize special localities; still I do not believe they are sufficiently distinct or persistent enough to rank as species, or to be worthy a varietal name, beyond the purpose of the locality where found, or for local preservation. The form under consideration, and figured, seems to be one of these local or restricted varieties, apparently characterizing the horizon over a very limited area, but is given for the purpose of representing a species so universally distributed. This particular variety closely resembles that figured and described by Mr. F. B. Meek, Pal. Ohio, Vol. I, p. 112, Pl. VIII, Figs. 3 *a* and *b*, as *O. emacerata* Hall; var. *multisecta* James; and has been by Mr. U. P. James considered as a species quite distinct from *O. testudinaria* Dalman. In the first place, it bears almost no resemblance to *O. emacerata* Hall, nor do any of the figures given on Pl. VIII, loc. cit. as of that species, except fig. 1 *a*, which is of a type given by Mr. James as *O. testudinaria* var. *jugosa*, the dorsal valve of which is flat, or slightly concave, with a sharp and somewhat angular depression along the median line, while the hinge line is quite long, more so, in fact, than that of any other variety of the species yet described. Considering the great variations undergone by the species at different horizons and localities, I can see no good reason for referring the present form to any other than the original name given by Dalman.

Formation and locality. In the soft shales of the Hudson river formation, at Delafield, and several other localities near that place, in Wisconsin.

Orthis pectinella.

Plate XII. Fig. 8.

Orthis callactis and *O. flabellum — Conrad;* Ann. Rept. Geol. Surv. N. Y., 1840, p. 201; and 1841, p. 27.

O. pectinella. Conrad in MS.—Emmons; Geol. Rept. 3d Dist. N. Y., 1843, p. 394; Illustrations 105, Fig. 2.

O. pectinella (Conrad)—Hall; Pal. N. Y., Vol. I, p. 123, Pl. XXXII, Fig. 10.

Shell of medium size, semiovate in form, the hinge line straight and shorter than the width of the shell below; the form of the shell being that of the large end of an ovate figure cut across, above the middle of its length. Ventral valve convex at the beak and on the ambo, but compressed at the sides and near the front; area moderately high, slightly overhanging and divided by a wide fissure. Dorsal valve flat or very little convex, slightly impressed along the median line; area linear. Surface marked by strong radiating striæ, which increase in size toward the margins of the valves, and are increased by implantation principally, although sometimes observed to bifurcate. There are also very fine concentric striæ crossing the radii, giving a roughened surface to the ridges, but miscroscopic in size; and also a few stronger ridges of growth.

This species, although not uncommon in the Trenton limestones of New York, at some localities, does not appear to be common in any of the western localities. It closely resembles *Orthis flabellulum* Sow., as it occurs in the Niagara group of New York, at Lockport and elsewhere, but may be distinguished by its increasing number of plications as the shell advances in size, and by the more convex ventral valve.

Formation and locality. In the soft shales of the Hudson river formation, at Delafield, and in the Trenton and altered Galena, at Neenah and Menasha, Wisconsin.

ORTHIS OCCIDENTALIS.

Plate XII. Fig. 17 and 18.

Orthis occidentalis — Hall; Pal. N. Y., Vol. 1, p. 127; Pl. XXXII, Fig. 2, and Pl. XXXII B, Fig. 1.
" " (*Hall*), Meek; Pal. Ohio, Vol. I, p. 96; Pl. IX, Fig. 3.
" *sinuata — Hall;* Pal. N. Y., Vol. 1, p. 128; Pl. XXXII B, Fig. 2.
" *subjugata — Hall;* Pal. N. Y., Vol. 1, p. 129; Pl. XXXII C, Fig. 1.

Shell large, resupinate, the dorsal valve being much deeper and larger than the ventral; strongly convex over the surface, with a large, tumid, enrolled beak, and a narrow horizontal area, with an open fissure. The surface of the valve being somewhat elevated along the median line, forms an almost imperceptible mesial elevation, more especially marked near the front margin. Ventral valve flattened or depressed convex, with a broad and moderately elevated beak; mesial line, on the front half of the shell, depressed, often deeply and angularly so near the margin on full grown individuals; cardinal area large, nearly vertical to the plane of the valve, and divided by a broad, open fissure.

Surface of the shell marked by strong, rounded, bifurcating, radiating striæ; which are crossed by very fine, corrugating lines, and stronger varices, marking stages of growth.

Nearly all the specimens of this species yet observed in the collections of the survey have been single valves, and most of them of large size. The example figured is a fair representative of the species and of a well marked form. The interior of the shell is quite characteristic, and will readily serve to distinguish the species, even where the exterior form cannot be clearly identified.

Formation and locality. In the shales of the Hudson River formation, at Roberts' quarry, near Delafield, and also at Iron Ridge, Wisconsin.

GENUS STREPTORHYNCHUS, King.

STREPTORHYNCHUS CARDINALE, n. sp.

Plate XII. Figs. 9 and 10.

Shell small, transversely subelliptical in outline, and plano-convex in profile; the length from beak to base, measured on the ventral valve, about two-thirds, or a little more than two-thirds, the width. Ventral valve flattened or very depressed convex, with a broad cardinal area, which, on a specimen measuring about seven-eighths of an inch in width, is fully one-sixth of an inch high in the middle, and is marked in the center by a broadly-triangular, covered deltidium, having a distinct round perforation or foramen at the apex of the valve; area striated longitudinally, and the cardinal borders sloping to the extremities of the hinge line. Dorsal valve very convex, often quite gibbous in the middle; hinge line straight, and the area obsolete. Surface of the valves marked by fine, sharp, radiating striæ, which are crossed by numerous strongly marked varices of growth, giving a roughened character to the shell. The radiating striæ are also crossed by very fine, closely-arranged, concentric rugæ; presenting, when seen under a glass, a sharp, file-like surface.

The species is somewhat of the type of *S. (Leptæna) plano-convexa* Hall, of the Cincinnati beds of Ohio, but differs in the greater rotundity of the dorsal valve and the largely developed cardinal area of the ventral valve.

Formation and locality. In the soft shales of the Hudson River group, at Delafield, Wis.

GENUS STROPHOMENA, Rafinesque.

STROPHOMENA KINGI.

Plate XII. Figs. 15 and 16.

Strophomena Kingi—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 72.

Shell larger than medium size, measuring two inches along the hinge in full grown specimens. Valves strongly concavo-convex, approaching sub-hemispherical on the ventral side, with a full, rounded umbo, length and breadth sub-equal, or often wider than long; hinge line as long or longer than the shell below, and generally somewhat pointed at the extremities. Area narrow on each valve, that of the convex valve the largest, and marked in the middle by a broadly triangular foramen. Valves rather strongly recurved or deflected near the hinge extremities, so as to give a strongly sinuous hinge-line, as seen in a cardinal view. Dorsal valve deeply concave, closely following the curvature of the ventral. Surface of both valves marked by very fine, even, thread-like or wiry striæ, without any indication of alternation. These are crossed by finer concentric rugose markings, invisible to the unassisted eye, and also by fine, indistinct and interrupted, concentric undulations on each valve.

The species rather closely resembles *S. profunda* Conrad, of the Clinton group, of New York, and still more closely the Niagara specimens of that species as it occurs in Wisconsin; it is, however, more convex than most specimens of that species, with a fuller and more prominent umbo on the ventral side.

Formation and locality. In shales of the Hudson river formation of New York, at Delafield, Wisconsin.

Strophomena unicostata.

Plate XII. Fig. 14.

Strophomena unicostata — M. & W.; Pal. Rept. Ill., Vol. III, p. 335, Pl. IV, Fig. 11.

Shell below a medium size, transversely semi-elliptical in outline, being sometimes about twice as wide along the hinge line, as the length from beak to base; hinge line straight on the dorsal, or concave valve, and very slightly arcuate on the ventral; extremities often mucronate. Ventral valve flat on the visceral area, and abruptly geniculate near the margin, the deflected portion seldom exceeding an eighth of an inch in width; beak minute; area narrow, usually less than a twelfth of an inch in its greatest width, and gradually decreasing toward the extremities; marked in the center by a very small covered deltidium. Dorsal valve concave, nearly following the curvature of the ventral; area linear or obsolete. Surface of the valves marked by extremely fine radiating striæ, which are rounded and somewhat flexuose in their direction; a single stronger rib marks the median line on the ventral valve, but so far as we have seen, does not characterize the dorsal side No concentric undulations mark the surface of either valves.

The species has the general form of *S. rhomboidalis* Wilck, and particularly resembles the variety of that form known as *S. tenuistriata* Hall, from this same horizon; but it differs very materially from that one, in being destitute of concentric wrinkles on the flattened portions of the valve, and also in the larger single rib on the median line of the ventral valve.

Formation and locality. In the shales of the Hudson river formation, at Delafield and Iron Ridge, Wisconsin.

Strophomena Wisconsensis, n. sp.

Plate XII. Figs. 11–13.

Shell of the type of, and much resembling *S. planumbona* Hall (Pal. N. Y., p. 112, Pl. XXXI B, Fig. 4), being half as wide again along the hinge, as the length from the hinge to the front of the shell; hinge-line straight, with submucronate extremities. Dorsal valve highly arcuate and gibbous in the middle, with an impressed umbonal region, and becoming strongly recurved at the hinge extremities. Ventral valve rather deeply concave, with a slightly rounded umbo and minute beak; cardinal extremities of the valve deflected. Area of the ventral valve moderately high in the center, gradually declining toward the extremities, and divided in the middle by a covered triangular deltidium; area of the dorsal valve linear. Surface of the shell marked by fine radiating striæ, and by a few strong concentric lines of growth.

The shell was at first considered as identical with *S. planumbona* Hall, but on critical examination, differs so extremely in the strongly gibbous character of the valves, and the much greater height of the ventral area, as well as in the more transverse outline, that it seems to be doing violence to strict classification to place it under the same name. I have therefore thought best to consider it as a distinct species.

Formation and locality. In the shales of the Hudson river group, at Delafield, Wisconsin.

Genus RHYNCHONELLA, Fischer.

Rhynchonella capax.

Plate XII. Figs. 26 and 27.

Atrypa capax — Conrad; Jour. Acad. Nat. Sci., Vol. VIII, p. 264, Pl. XIV, Fig. 21.
Atrypa increbescens — Hall; Pal. N. Y., Vol. I, p. 146, Pl. XXXIII, Fig. 13, W., X. and Y.
Rhynchonella increbescens — Hall; 12th Rept. State Cab., N. Y., p. 66, and 13th Rept., p. 66; Geol. Rept. Wis., Vol. I, pp. 55 and 436.
" *capax — Billings;* Pal. Foss., Vol. I, p. 142.
" " *(Conrad);* M. & W., Pal. Ohio, Vol. I, p. 123.

Shell attaining a large size, sometimes measuring considerably more than an inch in diameter, lenticular and appressed when young, and of a triangular form, but when fully grown it becomes extremely ventricose and gibbous, the depth of the united valves considerably exceeding the length or transverse diameter; ventral valve moderately deep, with a closely incurved beak, and a broad, deeply impressed mesial sinus, which is abruptly bent upward and prolonged in front; dorsal valve extremely ventricose, nearly twice the depth of the ventral; the beak large and closely enrolled beneath that of the other, and the middle elevated to form a strong mesial fold, which is excavated in front to correspond to the prolongation of the ventral valve; sides of the valves or cardinal slopes sunken and destitute of plications; surface of the shell marked by from sixteen to eighteen strong subangular plications, four of which are elevated to form the fold of the dorsal valve, and a corresponding number depressed in the sinus of the ventral. The entire surface is further marked by closely arranged, zigzaging, lamellose lines of growth, which are strongly arched backward in crossing the plications, and become very closely crowded on the front of the shell.

The species is readily distinguished, in the mature specimens, by its extreme ventricose form, and by the highly elevated, subquadrangular outline when viewed in front or from behind, and also by the great proportional depth of the dorsal valve. It is rather closely allied in character to *R. perlamellosa*, herein described, when seen in its younger stages of growth, but may be recognized in this condition by the narrower and more angular plications; deeper dorsal valve; more distinct mesial fold and sinus, and by the finer lamellose markings. I am not at all satisfied that the species has yet been found in the Trenton group in New York, nor that the forms referred to from the New York localities as *R. increbescens*, in Vol. I, Pal. N. Y., are identical with the western shell. There is a certainty, so far as I am aware, that none of the ventricose varieties so extremely abundant in Ohio and Kentucky, and less common in Wisconsin, have ever been observed in that state, and I think it quite advisable that the name, *R. increbescens* Hall, should be retained for the New York, Trenton and Hudson River group specimens; while that of *R. capax* Conrad, be restricted to the more highly ventricose western shells.

Formation and locality. In the shales of the Hudson river group, at Stockbridge and Iron Ridge, Wisconsin.

Rhynchonella perlamellosa.

Plate XII. Figs. 23–25.

Rhynchonella perlamellosa — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 73.

Shell of medium size, triangularly-orbicular or very broadly ovate in outline, and lenticular to ventricose in profile; beak small, flattened, and closely incurved; cardinal slopes convex and full, never depressed or excavated. Dorsal valve with a moderately elevated mesial fold, extending nearly to the beak, and the ventral with a corresponding sinus. Surface marked by strong, simple, subangular plications, four of which are elevated to form the fold and three depressed in the sinus, while from six to eight occur on each side of the shell; plications crossed by rather coarse, distant, strongly lamellose lines of growth, strongly arching backwards in crossing the plications and continuing across the cardinal slopes to the margin of the shell with but slight diminution in strength.

The species somewhat closely resembles the smaller lenticular specimens of *R. capax* Conrad, but may be readily distinguished by the stronger and less numerous plications, stronger and more distant, although more prominent, lamellose lines of growth, and also by the full cardinal slopes instead of depressed or concave slopes, as in that species; and also by the continuation of the plications over this part, which is not the case in that one, and the valves are also more nearly of equal depth.

Formation and locality. In soft shales of the age of the Hudson River group of New York, at Delafield, and also at Iron Ridge, Wisconsin.

Rhynchonella Neenah, n. sp.

Plate XII. Figs. 19–22.

Shell small, not exceeding five-eighths of an inch in its greatest diameter, and seldom more than half an inch; form varying from subtriangular to subquadrangular in a top view, subtriangular in profile and more or less irregularly quadrangular in a front view. Sides of the valves compressed and nearly vertical, and the depth of the shell, from the dorsal to the ventral surface, usually equalling or exceeding the length or width. Apex of the ventral valve small, narrowed or cuneate, projecting beyond that of the dorsal, and slightly curved upward, perforated at the extremity, and the fissure covered by deltidial plates of proportionally large size. Dorsal valve very deep rapidly rising from the beak to near the front margin along the middle of the valve, where the height is generally double that of the ventral valve; sides of the valve much less elevated and almost regularly arcuate from beak to base. Ventral valve straight along the base, with a deeply sunken triangular mesial depression and rapidly sloping sides; the front of the valve strongly and abruptly elevated, corresponding to the notch of the dorsal fold.

Surface of the shell marked by about ten angular plications on each valve in the larger individuals, two of which are abruptly elevated to form the mesial fold, and two depressed in the sinus. On some of the specimens there is an incipient plication on each side of the fold in the upper half of the shell, which becomes obsolete before reaching the front margin. The plications are marked by strongly lamellose concentric lines, which arch backward in crossing them.

The species resembles *R. Anticostensis* and *R. Janea* Billings, but differs in the great lateral compression, and in having only two plications forming the mesial fold. It also resembles the form generally known as *R. dentata* Hall, as it occurs abundantly at Frankfort, Kentucky, and elsewhere in the west, but differs very materially from the New York specimens of that species. From the Frankfort, Kentucky, specimens it differs in the laterally compact and compressed form, nearly vertical sides, narrower and more angular plications, narrower and stronger fold and sinus, and stronger lamellose markings, as well as in the deeper and more unequal valves, and more projecting beak.

Formation and locality. It occurs in the Trenton at Neenah, Menasha, Center, Ripon, Waterloo, Janesville and Beloit, and in the altered Galena beds near Oshkosh, Neenah, Menasha and Flintville, and in the shales of the Hudson river formation, at Delafield and Iron Ridge, Wisconsin.

SPECIES FROM THE LIMESTONES OF THE NIAGARA GROUP.

PROTOZOA.

GENUS CERIONITES, M. & W.

CERIONITES DACTYLOIDES.

Plate XIII. Figs. 1–3.

Lunulites? dactyloides—Owen; Rept. Geol. Expl. Iowa, Wis. and Ill., 1844, p. 69, Pl. XIII, Fig. 4.

Pasceolus? dactyloides—(Owen); M. & W. Geol. Rept. Ill., Vol. III, p. 345, Pl. V, Fig. 2.

Genus Cerionites; M. & W. loc. cit., p. 346.

Body plano-convex, circular or slightly oval in outline; lower surface flat, and the upper irregularly convex, or depressed convex; the periphery subangular, and thin in some parts, thickened and nearly vertical in others. Convex surface covered by numerous rows of hexagonal pits or depressions, which appear to center at a point near the middle of the disc, and pass outward to the margin in concentric circles; increasing in size toward the edge. The depressions are deeply concave and round at the bottom, but are crowded so as to present hexagonal borders, and are each marked at the bottom by a minute pore, which extends to considerable depth in the substance of the fossil. Near the periphery of the disc, where the edge is thickened, the cells have the appearance of being vertically compressed, and have a transversely rhombic outline, the longest axis horizontally placed. They are each marked at the lower middle angle by an elevated point, which is covered with minute crystals, probably coating a spine-like process at this point. The flattened basal surface is marked by obscure radiating lines, corresponding to the centers of the marginal cells.

The center or initial point of both surfaces is coated with hard, rocky material, which cannot be removed without material injury to the specimen, so that there is doubt whether there may be openings at these points or not.

The species has been variously referred by different authors without any apparently very satisfactory results, until finally Messrs. Meek & Worthen proposed the new genus CERIONITES for its reception (Geol. Rept. Ill., Vol. III., p. 346), expressing, at the same time, much doubt as to the correctness of the step taken. Up to that time, and even now, it is generally referred to the genus *Pasceolus* of Billings, but there appear to be many points of distinction between these bodies and those for which the latter name was proposed, and also many similarities. One principal difference consists in the arrangement of the pits in concentric circles, a point radically distinct from *Pasceolus*. The pits gradually increase in size, which is not the case with the plates of that genus; and as these fossils are the internal casts of the body, and present rounded depressions, they differ from that one, which is said to have the plates concave on the inside, and to give an internal cast marked with rounded tubercles.

In proposing the genus *Cerionites*, Mr. Meek appears to have been in doubt if the body he was describing was an internal cast or an external impression. That the specimen here figured is an internal cast there is positive proof, as the upper surface is obscured near the central point by crystalline matter filling the depressions in such a way as to show that it replaces the original integument of the body; and that on the upper or outer surface the plates have been nodose; or, in other words, that the present fossil has been covered with an integument of small plates filling the depressions which now remain, and which were on their outer surfaces strongly convex. Moreover, each of these plates, as they now exist, has the center filled with a small core of material similar to that of the fossil itself and the surrounding rock, showing that the plates were minutely perforated, which does not appear to be a feature of *Pasceolus*. This leads directly to another explanation. On probing the minute pores at the bottom of the rounded pits, I found them penetrating so far into the substance of the fossil that I concluded to break it; on doing which, I found them extending to a depth of a quarter of an inch near the periphery, and those of the sides and upper surface nearly to the basal floor, and also to be somewhat tapering inward. From a study of these minute cavities I infer that they were originally occupied by minute tubular foramina, connected with the plates of the integument, and penetrating the interior of the body cavity, as in the interior they appear not to have any definite destination or arrangement. The substance of the fossil, therefore, as we have it, seems to be the filling, either by infiltration or by silting, through the opening at the center, if such existed, of the interior cavity of a sac-like and probably more or less flexible subdiscoid body, formed of an integument of small, hexagonal plates, arranged in concentric curves, originating at a central or initial point, and terminating at the periphery in plates of a different form, composing a floor-like integument of attachment, the plates of the upper surface being biconvex, and penetrated by a minute pore, the walls of which were prolonged on the inside in the form of minute tubular spine of undetermined length.

The bodies, of which this is a representative, have been closely related to *Receptaculites*, as is shown by the concentric arrangements of the plates, and more particularly so by the form of the cells on the thickened vertical edge of the disc, where the pits assume the rhombic form possessed by those cells similarly situated on several of the elevated or globular forms of that genus, such as *R. globulare* and *R. hemispherica* Hall. Among the collections of Niagara group fossils from the western states, I have seen specimens which appeared to be the impression of the exterior surface of convex bodies, composed of smooth, tuberculose or highly convex, hexagonal plates, arranged in similar concentric curves, and have no doubt they were the impressions of the exterior of specimens of this same species.

Formation and locality. In the Niagara group, at Waukesha, Wis.

Genus RECEPTACULITES, De France.

Receptaculites hemisphericum.

Plate XIII. Fig. 4.

Receptaculites hemisphericum — Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 16; Geol. Rept. Wis., 1862, p. 429.

Body small, hemispherical or rather more than hemispherical in form, sometimes approaching a globular shape with a more or less truncated base. Surface convex, the cells originating from a subcentral point and spreading outward in curved radiating lines. Cells minute near the point of origin, but rapidly increasing in size over the upper surface, and again decreasing as they descend the sides of the body, so that where the form exceeds that of a hemisphere, they are again quite minute and crowded in the lower part. From a point corresponding to a horizontal center of the sphere and below, the cells are so arranged as to present horizontal lines as well as the curved radiating lines above mentioned.

The specimens are often less than hemispherical in form, as seen in collections, and sometimes, as in the example figured, form more than a half globe. The base when perfect is flattened, and appears as if the body had grown attached to a flattened foreign substance, and in the examples examined, presents no appearance of radiating lines.

Formation and locality. The specimen figured is from the Niagara limestone, at Waukesha, Wisconsin, probably from the Racine limestone at that place. It also occurs at Racine, Wis.

RADIATA.

GENUS ASTROCERIUM, Hall.

ASTROCERIUM VENUSTUM.

Pl. XIII. Figs. 8-10.

Astrocerium venustum — Hall; Pal. N. Y., Vol. 2, p. 120, Pl. XXXIV, Fig. 1.
" *venustum and Favosites of many authors.*

Among the many Favosite corals which characterize the Niagara group of Wisconsin, and the neighboring states, this species *(A. venustum)* holds a prominent position; and among the silicified specimens found in the drift of the same region it is also quite common. The specimens are generally easily recognized by the comparatively small size of the cell tubes, and when silicified and weathered, often show the peculiar feature of the species, and on which the genus was founded, in the most beautiful manner.

The cell tubes, in characteristic specimens, vary from a twentieth of an inch in diameter to those of about one-fourteenth of an inch; and in many individuals the larger cells are quite abundant, being distributed through the mass at nearly equal distances. They are usually more nearly round than the smaller tubes, and have from eight to nine, or even ten smaller ones bordering them, and are, apparently, those from which the new cells take their origin. All the tubes are divided transversely by their horizontal plates at irregular distances, usually at distances equal to the diameter of the tube, or less. The plates quite commonly extend only partially across the tube, and are usually, when perfect, bent downward at the angles. Between the plates there are numerous slender, spine-like processes, extending into the tubes from the walls, generally placed one above each mural pore, and when viewed on the surface of the corallum, give a stellate feature to the cell, which at once distinguishes it from any other coral of the group in the Niagara rocks.

The walls of the cells are perforated at somewhat regular distances by ranges of minute mural pores, generally a single range to each face of the tube; but occasionally, on wide faces, there will occur two ranges.

Formation and locality. In the Niagara group, quite generally distributed. It has been noticed in the lower coral beds at Cato; in the upper coral beds at Cato and Sturgeon Bay; in the Waukesna beds at Pewaukee; in the Racine beds at Waukesha, Wauwatosa and Milwaukee, and doubtfully in the Guelph beds at Saukville and Sheboygan, Wisconsin.

Genus HALYSITES, Fisher.

Halysites catenulatus, Linn.

Plate XIII. Figs. 5–7.

Among the corals of the Niagara group of Wisconsin, specimens of the genus Halysites are quite numerous, and among them we find three grades of form, differing from each other in the size of the meshes or intercellular spaces, and also to a corresponding degree in the size of the individual polyp-cells or corallites. It is also noticed that the specimens of the three varieties do not usually occur at the same locality; or if so, that some one of the varieties will greatly predominate, either at the locality or in a certain horizon, while the others are present only in limited numbers.

In making lists of the species constituting the fauna of the several localities or supposed horizons, it became necessary to distinguish these different forms, and for this purpose I used the varietal names *macropora* and *micropora* as indicating the two extremes, the medium between these two most closely resembling the form usually known as *H. catenulatus* Linn. As it is frequently necessary still to designate these forms separately, I propose to retain the varietal name *micropora* to designate the minute form, and to adopt the name *labyrinthicus* for the large meshed variety; that being the name proposed for it by Goldfuss, when separating it as a distinct species from the *H. catenulatus*.

The characters of these varieties will be recognized from the following descriptions of the two extremes, and they will be found convenient for reference, although they may not be considered as of strictly specific importance. Still I am much inclined to the opinion, that in life, there were differences sufficiently great marking them, which would have made them more distinct from each other than many of the living corals now recognized as good species.

Halysites catenulatus var. labyrinthicus.

Plate XIII. Fig. 7.

Catenipora labyrinthica — Goldfuss; Petr. Germ., Vol. I, p. 71, Pl. XXV, Fig. 5.

Corallum having the general characteristics of the species *catenulatus*, but with cell tubes of large size, measuring about an eighth of an inch, or, when measured in a direct line, averaging from six to eight in the space of an inch. Intercellular opening very large, often an inch and a half in length by from one-fourth to one-half an inch in width, and of very irregular form. Epitheca strong and rugose.

Halysites catenulatus var. microporus, new var.

Plate XIII. Fig. 6.

Corallum similar to the ordinary form except in the size of the cells, which are very small or minute, equal to from one-eighteenth to one-twentieth of an inch; there being that number of cells within the space of an inch, as counted in a line across the face of the corallum. Intercellular spaces small, varying from one-twelfth to nearly one-fourth of an inch in their longest diameter, and usually nearly equal in length and breadth, presenting a nearly quadrilateral form. Epitheca thinner and less rugose than on those of the ordinary size and form, and still more so than on the *H. labyrinthicus.*

Genus SYRINGOPORA, Goldf.

Syringopora verticillata.

Plate XIV. Fig. 6.

Syringopora verticillata — Goldf.; Petr. Germ., Vol. I, p. 71, Pl. XXV, Fig. 6.
" " " Bill. Rept. Geol. Can., 1867, p, 00; Extract, p. 8.

Corallum forming hemispherical masses of slender, slightly diverging tubes, varying from a line to one and a half lines in diameter, and connected at irregular distances by numerous small, transverse filaments; which are arranged around the tubes in circles, "like the spokes of a wheel," several of them being situated at the same level, often forming by the coalescence of their bases, an encircling plate around the corallite. Interior of the tubes divided by numerous transverse plates or diaphragms, closely arranged, and deeply funnel-formed; apparently perforated in the center, so as to form a continuous tube along the middle of the corallite.

The individuals of this species, as I have observed them in Wisconsin, are extremely variable in the size of the corallites and in the closeness of the connecting filaments. The tubes are often of not more than one line in diameter, and seldom exceed a line and a half; the connecting filaments are usually very closely arranged and often crowded, with the epitheca of the corallite rough and marked with rings of growth. In other cases the filaments are distant and not so distinctly verticillating as in the smaller tubed varieties. The individual figured by Goldfuss, loc. cit., has very large and distant corallites, with widely separated connecting filaments; and Mr. Billings describes specimens from Lake Temiscaming, Canada, having corallites "about two lines in diameter." It is possible that all these extreme varieties may be of the same species, but I strongly suspect that if studied together, with ample collections from the several localities, they would prove to embrace more than a single species.

Formation and locality. In the coral beds of the Niagara group, near Rockville, Manitowoc county, and in the Racine beds at Wauwatosa and Kewaunee, Wisconsin. It has also been obtained from the drift near Beloit, in a beautiful state of preservation. The specimens described by Goldfuss were from Drummond's Island, in Lake Huron.

Genus CYSTOSTYLUS, new genus.

Corallum compound, composed of parallel, cylindrical tubes or corallites, either wholly or in part in contact, and united to each other by transverse filaments. Increase by bifurcation. Internal structure composed of small cystose chambers or cavities, formed by more or less imperfect transverse plates, arranged in circular funnel-formed order as in cystiphyllum. Radiating septa and transverse plates, obsolete.

The corals for which the above genus is proposed are in all respects compound *Cystiphyllia*, having all the internal features of specimens strictly referred to that genus. They differ, however, in being compound bodies, composed of a large number of corallites united by transverse branches, as in *Syringopora*, *Eridophyllum*, and others of that character, and are increased by a form of budding resulting in a bifurcation of a corallite. The cystose plates are arranged exactly as in *Cystiphyllum*, and form by their union, a deeply funnel-formed cup at the upper end of the stem. The species at present known are both from the Niagara group, and are very distinct in their specific features, and characterize two different portions of the group. In the second species referred to this genus, it resembles *Syringopora* Goldf. to some extent, but differs in that the plates or tabulæ do not extend entirely across the tube, but are only partial, in some cases requiring three or four of the partial plates to complete the diameter of the tube.

CYSTOSTYLUS TYPICUS, n. sp.

Plate XIV. Fig. 8–9.

Corallum growing in large compound masses, composed of numerous subparallel or slightly diverging tubes or corallites, which vary from one-fourth to one-half of an inch in diameter; attain a length of several inches, and are placed at distances from each other equal to from one-fourth to more than one-half their diameter. Connecting filaments distant. Interior composed of small cysts, or blister-like chambers, arranged in from three to six indistinct circles, as shown in a transverse section of the tubes.

The specimens of the species vary greatly in the size, and in the distance between the corallites. Those examined consist mostly of fragments of larger masses, and are themselves several inches in diameter. They are preserved in limestone, which fills the spaces between the corallites, and on the fractured surfaces they reveal the systose character of the tubes very beautifully, although the plates themselves are usually coated with minute crystals. Some of the specimens preserve only the perforations in the rock where the corallites have been removed by solution, in which case they show only the size and form of the exterior surface of the corallite without retaining any of the internal features of the coral. In this case it is quite difficult to distinguish them from species of *Eridophyllum* or *Diphiphyllum.*

Formation and locality. In the Lower Coral beds of the Niagara, at Cato, Monitowoc County, and in the Upper Coral beds, at Sturgeon Bay, Wis.

CYSTOSTYLUS INFUNDIBULUS.

Plate XIV. Fig. 7.

Syringopora infundibula—Whitf.; Ann. Rept. Geol. Surv. Wis., 1877, p. 79.

Corallites growing in large or medium-sized masses of variable form, but generally irregularly subhemispherical; individual polyps slender, subflexuose, and measuring from one to nearly two lines in diameter, arranged at distances of from one to three times their own diameter; transverse diaphragms represented only by deeply funnel-formed, imperfect plates or cysts, appearing on the broken surface as a series of deep inverted cones or funnels, placed one within the other so closely as to produce by their united tubes an almost or quite continuous columella along the center of the corallite; the cystose plates are never continuous around the whole circumference, but are usually from one-third to two-thirds entire, and are so closely arranged that from two to four may be counted in a length equal to the diameter of the tube; external surface of the corallites not observed; increase by budding from the side of a perfect corallite, the separation being at first small and nearly horizontal, but suddenly turning upward parallel to the parent stem.

The species differs from *C. typicus* in the smaller size and more flexuose corallites. It was at first supposed to belong to the genus *Syringopora*, and so classed in the annual report, but on reexamination, it proves to possess all the requisites of the genus *Cystostylus* and to differ in the form of the plates very materially from *Syringopora*. As it is so far found in the solid limestone only, with the fractured surface showing the deeply funnel-formed plates only partially extending across the tubes, readily determine its true relations.

Formation and locality. In the upper part of the Niagara group (Racine limestone) at several points in the vicinity of Wauwatosa and Milwaukee, Wisconsin.

Genus STROMBODES, Schweigg.

Strombodes pentagonus.

Plate XV. Fig. 5.

Strombodes pentagonus — *Goldf.;* Petr. Germ., Vol. I, p. 58, Pl. XX, Fig. 2.
" " *Rominger;* Geol. Rept. Mich., Vol. III, Pt. II, p. 131, Pl. XLVIII, Figs. 1 and 2.
Strombodes pentagonus — *Of authors.*
" *striatus* — *D'Orb.*

Coral forming large depressed-convex, or low-hemispherical masses of considerable size, the surface of which is covered by polygonal depressions, formed by the calyces of the closely aggregated polyps, the depressions varying from less than a fourth of an inch to three-fourths or more in diameter, and having a depth of from an eighth to about three-eighths of an inch below the top of the partition walls; divisions between the calyces carinate, often sharply crested; central part of the calyces more abruptly depressed than the intermediate space, and the center rising up in form of a slight columella, not always apparent; surface of the calyces marked by extremely fine, hair-like rays, varying in number according to the size of the cell. When seen in a vertical section, the mass appears to be made up of a number of vertical columns, each of which is composed of a series of funnel-formed plates, superimposed one upon the other in an irregular manner, leaving open spaces of different sizes and great irregularity of form between them.

The examples of this species present in the collection are thoroughly silicified, and to such an extent as to nearly obliterate the more minute generic and specific characters of the coral. Individuals from other localities show the vertical rays to be very numerous, the cells to be abruptly deepened in the center, with a slight columella, and the transverse diaphragms to be numerous and cystose in structure.

The species varies much in the size of the corallites in different individuals, and the general appearance of the specimens, when seen under different states of preservation, varies so greatly that they are not readily recognized as of the same species. When the upper coating or surface of a specimen of this genus is removed by breaking or by weathering, as is often the case with the silicified examples, the exposed layer below is seen to be composed of calyces covered or formed by numerous blister-like elevations, resembling those forming the internal structure of the genus *Cystiphyllum*, and the surfaces of the blisters are marked by the remains of the radii. In this condition they correspond to the genus *Vesicularia* Rominger, Geol. Rept. Mich., Vol. III, part 2, Pl. XLIX; and if the view is upon the under surface of such weathered specimens, the cells appear as if raised and the center depressed as in *Astrea mamillaris* Owen (=*S. mamillatus* Rominger), and *Vesicularia varilosa* Rominger. This feature is also often produced in silicified and weathered specimens of *Cyathophyllum rugosum* Hall, from the upper Helderberg group at the falls of the Ohio, which are often thought to represent a species of a different genus from those of the perfect coral.

Formation and locality. In the coral beds of the Niagara group at Red River, Kewaunee county, and in T. 24, R. 24, Sec. 28; also at Forrestville and Bailey's Harbor, and in the Racine limestone at Wauwatosa. It has also been recognized in the Guelph limestone. It occurs also in the drift near Beloit, Wisconsin, and in Michigan, and in the Niagara limestone on Drummond's Island, and in Ohio.

GENUS ZAPHRENTIS, Rafinesque.

ZAPHRENTIS RACINENSIS, n. sp.

Plate XIV. Figs. 1 and 2.

Corallum forming a short, rapidly-expanding, cup-shaped or turbinate body, nearly as wide as high, and strongly curved; calyx occupying nearly the entire depth of the body; the floor, in a specimen measuring one and one-quarter inches in diameter, not exceeding three-eighths of an inch in width; longitudinal or vertical lamellæ moderately well developed, but very thin and distinctly alternating in size, increasing in number only along the primaries dividing the dorsal and lateral sections; those of the two sections on the inner side of the curvature are more numerous than the others, counting ten in each division, while those of the outer divisions are only eight on each side, making, to the entire cup, thirty-six primary lamellæ on the specimen figured; fosset deep, situated on the outer side of the curvature, very narrow, and having only one primary lamella depressed within the cavity.

The examples of the species observed are all internal casts of the cup, but are well marked and quite numerous. They present evidence of the outer surface having been transversely wrinkled, which, owing to the thinness of the substance, have shown in the cup, and been preserved on the cast of the interior. The substance of the coral itself having been entirely removed from the rock by solution, it is impossible to ascertain the characters below the cup, but as the species is common, and seems to characterize the Racine beds, it has been thought best that it should be noticed.

Formation and locality. In the Racine beds of the Niagara group, at Racine, and at Schoonmacker's quarry, near Wauwatosa, Wisconsin.

GENUS CYATHAXONIA, Milne Edwards.

CYATHAXONIA WISCONSENSIS.

Plate XIV. Figs. 3–5.

Cyathaxonia Wisconsinensis — Whitf.; Geol. Rept. Wis. for 1877, p. 79.

Among the many cyathophylloid corals of the upper Niagara formation, represented only by casts of the interior of the cup, is one having a deep elliptical cavity near the center, which has been formed by the removal of a thin, transversely elliptical and highly elevated, solid and subcentral axis, as in the genera *Cyathaxonia* and *Lophophyllum*, presenting a feature entirely new, so far as we are aware, among the corals of the middle silurian rocks of this country. The coral must have attained a length of three inches or more, by a transverse diameter of one and one-fourth inches, judging from the size of the casts of the cup observed. The vertical lamellæ have been strong and arranged in pairs, the secondary rays being quite subordinate to the primaries; a large, deep fosset marks the bottom of the cup on the convex side, and the upper transverse plate, forming the bottom of the cup, has been smooth and nearly half as wide as the coral opposite the base of the cup.

The external features of the coral are not known, but as casts of the interior of the cup are not uncommon at many localities, and seem to mark a certain horizon, it has been thought worthy of notice and a name. The features given will serve to distinguish it from any of the associated forms, and should it be detected at other localities where the substance of the coral itself is preserved, the elevated columella will then be a distinguishing feature.

Formation and locality. In the upper part of the Niagara group (Racine limestone), at Racine and elsewhere in Wisconsin.

Genus AMPLEXUS, Sowerby.

Amplexus fenestratus.

Plate XV. Figs. 1–3.

Amplexus fenestratus — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 80.

Corallum forming strong, simple, irregularly turbinate columns, often attaining a diameter of two and a half to three inches, and apparently twelve or more inches in length, with distant, strongly projecting, periodic, lip-like varices, above each of which the coral is again contracted; cup deep; margin thick, except near the periodic varices, where it becomes much thinner than at other points; longitudinal rays well developed, very closely arranged, and apparently subequal; transverse plates large and strong, closely arranged, and extending to about one-half the diameter of the body; interlamellar cystose divisions well developed and very numerous; exterior of the coral covered, when perfect, by a thin epitheca, marked longitudinally by the rays, and, transversely by small elevations at the junction of the walls of the interlamellar cysts with the epitheca, which is generally worn through, or originally left imperfect, the spaces appearing as minute transverse or elliptical perforations in the epitheca, giving a peculiarly roughened exterior surface, which will readily be distinguished.

Formation and locality. In the lower coral beds of the Niagara group, at Cato, at Cato's Falls, and at the rapids below Clark's Mills and vicinity, Wisconsin.

GENUS OMPHYMA, Rafinesque.

OMPHYMA STOKESI.

Plate XIV. Fig. 10. Plate XV. Fig. 4.

Coral — Stokes; Geol. Trans. 2d series, t. 1, p. 129, fig. 1.
Pachyphyllum Stokesi — Edwards & Haime; Polyp. Foss. Paleoz., p. 407.
Omphyma Stokesi (Ed. R. H.) — *Rominger;* Geol. Mich., p. 119, Pl. 44, Figs. 1-4.

Remains of a large species of coral, apparently of the genus *Omphyma*, is quite abundant among the Niagara fossils from the Sheboygan river and elsewhere in the state. They consist only of the casts of the interior of the calyx, which has often attained a diameter of two and a half inches at the top; the primary rays, as shown on these casts, appear to have been forty or more in number, and to have been pretty strongly developed, excepting near the top of the cup; while the secondary rays are but very faintly developed, scarcely showing in the lower part of the calyx, and only slightly indicated above. The floor of the calyx has been very broad, usually forming more than one-half, and often more than three-fourths, of the entire diameter of the coral; it has been strongly marked on its surface by the rays, which extend to the center, and in some cases form an elevation in the middle; the fosset has not been strongly developed, not showing distinctly in any of the examples studied.

The generic reference of this species is by no means certain, and the specific features to be btained from the casts are so few that it has been deemed advisable to leave it without specific name until better material shall be obtained. The specimens are of rather unusually large size for a cyathophylloid coral of the Niagara group in this country, and as they are quite abundant, and apparently confined to this horizon, it was thought well that attention should be directed to them. There is some resemblance between the casts of this species and the cup of *O. verrucosa* Ed. & Haime, as identified and figured by Dr. C. Rominger, Geol. Surv. Mich., Vol. III, p. 118, Pl. XLIV, Fig. 2.

Formation and locality. In the Waukesha beds of the Niagara group, at Mr. Pelton's quarry, near Pewaukee, and in the Racine beds at Racine, Wauwatosa and Milwaukee, and in the town of Rhine, on the Sheboygan river, Wisconsin.

CRINOIDEA.

Genus CARYOCRINUS, Say.

Caryocrinus ornatus.

Plate XVI. Figs. 1 and 2.

Caryocrinus ornatus — Say; Jour. Acad. Nat. Sci. Phil., Vol. IV, p. 289.
" *loricatus — Say;* Ibid.
" *ornatus — (Say) Hall, Blainville, Castelnau, Von Buch* and others.
" *meconideus, C. hexagonus, C. granulatus, C. insculptus* and *C. globosus — Troost;* Cat. Foss. of Tennessee.

The specimens of this species, like most of the fossils of the Niagara rocks in southeastern Wisconsin, are only internal casts, and show but little of the true character of the object itself. Where the matrix has been preserved, there can, by taking an impression of it in wax, gutta-percha or some other substance, be obtained a representation of the external features; but as these portions of the remains are seldom preserved, owing to their bulk and the difficulty of obtaining more than a fragment of an individual, the internal cast only has been figured.

The internal casts are usually of an ovoid form, more or less truncated at the upper end, and occur from half an inch to fully two inches in length, the diameter varying greatly in different individuals. The surface markings on the casts differ very materially from those of the real object when perfectly preserved, and consist of a series, or several series of rhombic figures, with lines of minute tubercles bordering them. The lower series consists of six rhombs, arranged vertically, or with their points directed upward; the next series of six is arranged transversely; above this there is another series of more elongated rhombs, arranged, some vertical and others obliquely; the longitudinal axis of the rhombs depressed, and their surfaces striated in the same direction; above these last mentioned rhombic areas there is a series of irregular triangular areas bordering the filling of the arm openings; the dome is capped by smaller irregular plates, which are generally so arranged as to form a triangular pattern on the summit.

The markings above mentioned are the imprints of the interior surface of the plates forming the body, and do not represent, to any degree, the arrangement of the plates, except to one familiar with the structure of the perfect crinoid; they do, however, represent the exterior surface marking, which is entirely composed of rhombic and trapesoidal figures below the arm openings, six of which are arranged around the base of the body, with their longest diameters vertically placed; the next range is horizontal, and the third obliquely vertical, just as in the cast; the plates of the body are only four in the basal series, two quadrangular and two pentangular; the next or central range consists of six plates, two of which are pentagonal, two hexagonal, and two heptagonal; the third range consists of eight plates, six of which, if we consider the upper side, which is often truncated by several plates, as one face only, would be pentagonal, and the other two smaller ones would be quadrangular; upon the upper surfaces of these last plates rest those giving origin to the arms and to the oral aperture; they are small, irregular, and apparently increase in number with the increased size of the individual. The dome has usually a central, seven sided plate, with seven unequal plates surrounding it, completing the dome. The oral pyramid is a small elevation, situated laterally at the edge of the dome, and is composed of five small, pointed plates.

The species is a very beautiful one, but is subject to considerable variation in form, and the strength of the surface marking, which fact has given rise to the description and founding of several species. One of the specimens figured on Plate XVI, Fig. 2 represents a very marked variety; having a broad flattened dome, entirely different from the normal form, and may possibly have had a greater number of principal plates in its composition; but this portion of nearly all crinoideans is subject to much change at different stages of growth, and should not be considered as bearing upon the specific relations of individuals, unless where there is a decided and marked difference in structure.

Formation and locality. In the Niagara group generally, but in Wisconsin it has been detected only in the Waukesha and Racine beds. In the Waukesha beds, it has been noticed at Pewaukee and at Mr. Johnson's quarry, in the town of Genesee, and in the Racine beds, at Racine, Greenfield, Waukesha, and Sturgeon Bay, Wisconsin.

Genus GLYPTASTER, Hall.

Glyptaster occidentalis.

Plate XVI. Figs. 3 and 4.

Glyptaster occidentalis—Hall; Trans. Albany Inst. Vol. V, 1863.
" " " 20th Rept. State Cab. p. 326, Pl. X, fig. 3.

The original specimens of this species were from the soft clayey rocks of the Niagara group, at Waldron, Indiana, and preserved the substance of the organism, and also retained all the markings of the exterior surface of the plates of the body. The species as recognized in Wisconsin is in the condition of internal casts of the cup, and retains only slight indications of the ornamentations of the surface, consequently the identification is not positive; as we have not yet been favored with an impression of the exterior of the body; a part which it would be well for collectors to remember is of the utmost importance in making correct identifications of species, and to the perfect understanding of the true character of most of the fossils of these dolomitic limestones throughout the state.

The form of the body of the crinoid, as shown by these internal casts, is broadly obconical, more rapidly spreading below than above, and having an obscurely pentangular form, when viewed from below, owing to the flattening of the interradial and anal areas, between the more prominent angular radial series of plates. The lower part of the cup is also marked, when viewed in this manner, by a more or less distinct, five-pointed star; the apices of the rays of which are continued in a slender rounded ridge, often obsolete, traversing the crest of the angles of the cup, which forms the center of the radial series. The ridges forming the star-shaped pattern of the base rise from the center of the subradial plates, at the reentering angles of the star, and their points terminate at the center of the first radials. Above this there is a second and third radial, often plainly traceable on the cast, upon the last of which the ray divides and is continued upward to the margin of the cup in a double series of supraradials, so far as can be determined, making ten arms to the body at the top of the calyx, The true basal plates appear to have been small and concealed by the column. The interradial series have had one first interradial supporting two in the second and third ranges, at least in some of the areas, if not in all, above which they are not traceable on the specimen used. The first anal plate had been larger than the first interradial, and seems to have supported three others in the second range, above which they are too indistinct for determination. There have been intersupraradial plates, but above the first single one their characters cannot be ascertained.

The surface of the plates has been marked by radiating ridges, diverging from the centers and uniting with those of the adjacent plates in the ordinary manner, those of the principal rays forming ridges traversing the ray and its division from the first radial to the margin of the cup; while those from the centers of the subradials to the first radials form the star-shaped pattern of the base, as seen on the cast.

The species is a well marked form among the crinoidians of the Wisconsin Niagara rocks, and is readily distinguished by its broad, pentangular body, and the stellate base. It is very closely allied to, if not identical with *G. brachiatus* Hall, from the Niagara shales of New York.

Formation and locality. In the Niagara group (Racine limestone), at Racine, Wisconsin.

Genus GLYPTOCRINUS, Hall.

Glyptocrinus nobilis.

Plate XVI. Figs. 9 and 10.

Glyptocrinus nobilis—Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 21; and, 20th Rept. State Cab. N. Y., p. 328, Pl. X, Figs. 9 and 10; Geol. Rept. Wis., 1862, p. 431.

Body large and robust, somewhat rapidly expanding from the base to the origin of the free arms, above which it is highly dome-shaped and surmounted by a strong proboscis, rising from an inflation which characterizes one side of the body. Arm bases deeply lobed, the strongest constrictions being above the interradial series of plates, and the secondary lobation marking the divisions between the arms of the same ray.

As the specimens preserved in collections consist mostly of internal casts of the body, the external features of the plates are seldom seen, and the division of the calyx into series of plates, not observed. When these features are sufficiently preserved to be traced, the cup is seen to be composed of five series of radial plates, each consisting of three ranges, the upper one of which is surmounted by two other series of two ranges, and these again by two other series, at least in most of the rays, thus giving four arms to each ray, while yet forming the body of the cup. Above this the structure of the arms has not been determined. The interradial series consists of a first large plate, which rests upon the upper lateral faces of the first radials, and in turn supports two smaller plates in the second, with two or three in the next range, and smaller ones, the number not determined, situated higher up between the arm bases.

The surface of the plates, the markings of which are not unfrequently shown to a greater or less degree on the casts, is characterized by raised radiating lines passing from the center of one plate and uniting with those of the adjoining plates, so as to form a series of stellate markings, while along the course of the ray these lines are stronger, and form a set of elevated ridges, which traverse the ray and all its ramifications. The dome is composed of a series of large plates, with smaller intermediate ones, all having this same system of radiating lines, giving the stellate character to the surface so distinct on the calyx.

On many of the internal casts there are apparent the remains of a system of alimentary or vascular channels, which originate, one from each division of the ray at the arm opening, and as they pass upward over the surface of the dome, in the cast, unite with each other in pairs, and finally all join together at the base of the proboscis, usually in a tubercle or node, which has possibly marked the position of an anal opening.

The species is quite common in some of the upper layers of the Niagara group, and often attains a very large size. It may be readily distinguished from *G. armosus* McChesney, with which it is almost invariably associated, by the greater inflation at the base of the proboscis, and by noticing that the termination of this organ is directed upward from the highest point of the dome; while that of that species is directed across the top and down the opposite side. It is even more readily distinguished from *Lampterocrinus inflatus*, also associated in the same rocks, and which resembles it closely in the inflation of one side of the dome, by observing the double sets of arm bases in this one; whereas, they are single in that, and also by the proportional shortness of the calyx.

Formation and locality. In the upper part of the Niagara group (Racine limestone), at Racine, Greenfield and Waukesha, Wisconsin.

Glyptocrinus armosus.

Plate XVI. Fig. 11.

Eucalyptocrinus armosus — McChesney; Desc. New Pal. Foss., Chicago, 1859, p. 95. = *Glyptocrinus armosus* (*McC.*), Meek in reprint, Trans. Acad. Sciences, Chicago, Vol. I, Pl. VII, Fig. 6 a and b.

Glyptocrinus siphonatus — Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 22; 20th Rept. State Cab. N. Y., p. 328.

Glyptocrinus armosus (McC.) — Hall; 20th Rept. State Cab. Explan. of Pl. X, Fig. 11.

This species somewhat closely resembles *G. nobilis* in its general form, and in the structure of the body, it also attains an equal size; but the proportional depth or height of the calyx is much greater in comparison with the part above the arm openings; and the location of the arm bases is usually more decided at the interradial areas, and often less distinct between the different members of the same ray. This feature gives a more distinctly pentalobate character to the casts, when viewed from below. The principal point of distinction, however, between the two species, consists in the direction of the proboscis; that one rising upward from the summit of the dome, while in this it is folded over or across the summit, and terminates in a small point between two of the lobes of the body; forming as it were a siphon across the dome of the body. This feature results in an entirely different structure of summit in the perfect form, as in the former case it produces an upright proboscis of considerable length; while in this one the result is a rounded summit, and an anal opening low down on the side, between the postero-lateral rays; thus showing very conclusively that the inflation of the dome in both species characterizes the anterior side of the crinoid.

Formation and locality. In the upper part of the Niagara group (Racine limestone), at Racine, Greenfield and Waukesha, Wisconsin.

GENUS EUCALYPTOCRINUS, Goldfuss.

EUCALYPTOCRINUS CORNUTUS.

Plate XVI. Figs. 5-8.

Eucalyptocrinus cornutus — Hall; 20th Rept. State Cab., p. 322. Pl. XI, figs. 6-10.

The specimens of this species in the collections under examination are not as well preserved as those from which the original description was made, consequently I have reproduced Prof. Hall's published description of the species, and add some features, not previously known, from one of those under examination.

"Body (without the arms) somewhat turbinate, distinctly angular, with the base broadly truncate and more or less concave. Basal plates comparatively large, extending from the center nearly one-half the distance to the edge of the truncation. First radial plates large, forming the circumference of the base, and abruptly bending upwards, they extend nearly one-third the height of the calyx; second radial plates small; third radials much larger than the second, supporting the first supraradials, which are of moderate size. The first interradial plate is comparatively large, commencing just above the basal truncation, and supporting two smaller plates above.

"Each of the first radial plates on the part just above the basal truncation, bears a strong central spine, with a prominent rounded ridge on each side, extending to the upper lateral margin and joining a similar ridge on the interradial plate, and another ridge extends from the upper side of the central spine, and joins a similar ridge on the succeeding plate; this is continued to the third radial, where it divides and extends on the supraradials.

"The interradial plates of the first series are marked by similar strong ridges, which culminate in a strong node or short spine in the center.

"The finer surface markings are not known. Arms unknown."

A single individual in the collection preserves a part of the matrix with impressions of some of the interbrachial plates, a feature not before noticed in this species. The form of these appendages differs very materially from the corresponding parts of any hitherto known American form, and resembles somewhat those of *E. rosaceus* Goldf. from the European strata of similar age. Those between the divisions of the rays are small and rather short, extending only to about half, or a little more than half the height of the dome; their upper ends are thin, and projecting somewhat beyond the line of the outer surface. Those resting upon the upper interradial plates and dividing the two adjacent rays are larger, and extend to a much greater height, their upper ends extending outward and upward to a considerable distance, in the form of thin, flattened or laterally compressed spines, the top of which have apparently reached as high as the summit of the dome. This latter part, as shown in a gutta-percha cast made in the matrix, was of only moderate height, and nearly hemispherical to near the middle. The central range of plates forming the summit of the dome appears to have been removed previous to imbedding, so that the form of the center cannot be positively determined.

The internal cast of the specimen is of the deeply excavated form to which Prof. Hall gave the varietal name *excavata*, and it may be that the two forms possessed differently formed domes and interbrachial plates, as well as being more deeply excavated at the base; but this latter feature alone would scarcely be sufficient to warrant a specific separation, as is shown by specimens of *E. crassus* Hall, and some others. The surface markings of the calyx, as shown on a small portion preserved in the aforementioned matrix, is essentially the same as that of the *E. cornutus* figured by Hall.

Formation and locality. In the Racine beds of the Niagara group, at Racine, Greenfield, Waukesha and Wauwatosa, Wisconsin.

BRACHIOPODA.

Genus SPIRIFERA, Sowerby.

Spirifera radiata.

Plate XVII. Figs. 1 and 2.

Spirifera plicatellus, var. radiatus — Sow.; Minn. Conch., Vol. V, p. 493, Figs. 1 and 2.
" *radiatus J. D'C. Sowerby.;* Murch. Sil. Syst., Pl. XII, Fig. 6.
" *radiatus (Sow.) — Hall;* Pal. N. Y., Vol. II, p. 66, Pl. XXII, Fig. 2; pars. 8, p. 265, Pl. LIV, Fig. 6.
Spirifera plicatella, var. radiata (Sow.) —Hall; 20th Rept. State Cab., p. 371, Pl. XIII, Figs. 9-11.

Shell subglobose or transversely oval and extremely gibbous, with a strong ventral beak, rounded cardinal angles, and short, not well defined cardinal area. Ventral valve much larger than the dorsal, most ventricose just above the middle, and marked by a very distinct subangular mesial depression. Dorsal valve almost regularly arcuate, both longitudinally and transversely, with a very distinct rounded fold along the middle. Surface of the shell, as shown in the matrix, covered with moderately strong radiating striæ, and sometimes showing concentric varices of growth.

The specimens of the species observed from Wisconsin are all internal casts, and in this condition show peculiar features of the internal structure, as has been noticed by Prof. Hall in the 20th Rept. State Cab., *loc. cit.* These features consist principally of slits extending from the beak along the valve to near the middle and sometimes beyond the middle of its length, the slits being caused by the removal of prolongations of the dental lamella of the ventral valve, and of septa in the dorsal, these latter originating at the base of the crural supports. The specimen here figured possesses these septa to but a very slight degree, and in this respect, corresponds almost exactly with forms in the Niagara group at Waldron, Indiana, as well as in the more rounded outline of the body of the shell. It is a very widely distributed species, and an excellent guide in determining the age of strata, having been found in many parts of Europe, as well as being generally distributed in the rocks of this age throughout this country.

Formation and locality. In the upper part of the Niagara group (Racine limestone), at Racine, Burlington, Greenfield, Waukesha, Wauwatosa, Milwaukee, and at Sturgeon Bay, and in the Guelph limestone at Saukville, Wisconsin.

GENUS PENTAMERUS, Sowerby.

PENTAMERUS OBLONGUS.

Plate XVII. Figs. 4–9.

Pentamerus oblongus — *Sow;* in Murch. Sil. System, p. 641, Pl. XIX, fig. 10.
" " *(Murch)* — *Hall;* Pal. N. Y., Vol. II, p. 79, Pls. XXV and XXVI.
" " *(Sow.) H. & W.;* Pal. Ohio, Vol. II, p. 137, Pl. VII, fig. 9.
" " *Of Authors.*
Not Pentamerus bisinuatus — *McChesney;* New Pal. Foss, 1859, p. 85, nor Trans. Acad. Nat. Sci., Chicago, Vol. I, p. — Pl. IX, fig. 1.

Shell usually ovate, more or less elongate, widest below the middle, and narrowing toward the beak; valves depressed convex to extremely gibbous, the ventral valve the largest, and usually much the most ventricose. Surface of the valves marked on the dorsal side by a broad, undefined mesial elevation, and on the ventral, by a corresponding depression, or oftentimes by an elevation of similar character to that of the dorsal, in which case the front of the shell is extended in length to compensate for the additional depth of the valves.

This species is a very common one, not only within the limits of Wisconsin, but occurs in equal abundance in many other parts of the country where the Niagara formation exists, and also in Europe, at the same horizon. In character, it is extremely variable, often presenting, at a certain locality, local variations of form that prove very persistent over limited geographical areas, but within a few miles distance, perhaps, another form of quite a different character will prevail. These changes of form are also noticed as characterizing different geological horizons within limited geographical areas, and still prove so persistent throughout all the individual specimens occurring at that horizon, that they have often, and with much reason, been considered as distinct species. Within the limits of the Niagara group in Wisconsin, there are several of these local varieties, which differ from each other, either in size, in general form, or in surface markings. As the specimens are all in the condition of internal casts, the peculiarities of the internal divisions of the shell also add considerable to the peculiarities of form; so that there are almost as many varieties as there are localities and geological horizons represented in the collection.

From Elmore, Wisconsin, we have a form which is elongate-ovate in outline (figs. 4–6), widest near the lower end, and narowing towards the shoulders or extremities of the cardinal line; the lateral margins gradually diverge from this point to that of greatest width. In profile, the valves are only moderately convex, the dorsal being quite depressed convex, and the valve very shallow; the ventral valve is about twice as deep as the dorsal, and correspondingly convex, with the beak extending considerably above that of the dorsal valve and strongly incurved. The valves in most specimens are each characterized by a broad, indistinct elevation or fold accompanied by an extension of the front margin within the limits of the elevated part, and the surface of the shell is marked by a number of irregular, radiating plications, which are but faintly marked; and also by numerous distinct, concentric lines or varices of growth. The interior markings or cavities left by the removal of the internal septa, which form deep incisions in the upper part of each valve, are only moderately strong, and show the form of these parts in a very clear and distinct manner, as may be seen by inspection of the figure of the specimen from this locality. This variety appears to have approached more nearly to the normal form of the species, as it is represented in the Clinton group at Rochester, New York, and at nearly the same horizon in England, than those from any other locality in the state. They also occur of very large dimensions.

From the white cherty layers of the coral beds in the Niagara group, at Port de Morts, there occurs a short broad form of the species, which is generally subcircular or subpentangular in outline (fig. 7), having the valves moderately convex, being lenticular in profile, and the beak of the ventral valve quite prominent and incurved; the mesial fold is inconspicuous, and the surface covered by a large number of faintly marked, radiating plications. These beautiful white cherty casts show the internal septa to have been unusually slender, and extended to a much less distance into the valve than those of the last mentioned variety.

Another form presenting marked peculiarities occurs at Ashford, Fond du Lac county, in the upper coral beds of the formation (figs. 8 and 9). The form is short-ovate, widest across the extremities of the cardinal slopes, below which point the form is rounded or narrowed to the front, in this respect often just the reverse in shape from those first described. The valves are quite ventricose, being often gibbous and most prominent a little above the middle of the length, the dorsal valve but slightly less gibbous than the ventral, but considerably shorter; the beaks of each valve are strongly incurved. The surface of these specimens is marked by radiating plications, but quite indistinctly, the folds being broad and shallow. The cavities left by the removal of the internal septa are very large and rude in character, indicating strong processes much thickened by excess of shell material. The squareness of the shoulders or cardinal slopes, also indicates a great thickness of shelly matter beneath the hinge, in the rostral portions of the ventral valve. The peculiarity produced by this thickening of the upper portions of the interior of the shell in these specimens is such as to present the appearance of great deformity, and is not confined to a few individuals only, but is common to most of the shells from the same horizon at this locality.

Beyond the forms mentioned, there are many others equally marked and of local occurrence, presenting features that in most other genera would be considered of specific importance, and we are strongly impressed with the belief, that in most of these cases, these peculiarities were accompanied by external and other differences when in a living state, that would, could the shells be seen as they then were, be considered of specific importance; but which now appear, or are considered as only individual features, or the slight effects of local conditions acting upon specimens of one and the same species.

Formation and locality. The species occurs, in some of its forms, at most of the localities of the Niagara formation throughout the state. It also occurs abundantly at many places in Iowa, and in Ohio and New York, often forming beds of several feet in thickness, so densely packed together that the rock seems to be almost composed of its remains.

PENTAMERUS BISINUATUS.

Plate XVII. Fig. 3.

Pentamerus bisinuatus —*McChesney;* Trans. Acad. Sci., Chicago, Vol. I, p. 30. Pl. IX, Fig. 1.
" " *McC.;* Extract of the above. Descript. new sp. Fossils, 1859, p. 85.

Shell closely resembling *P. oblongus* (Sow. in Murch. Sil. Syst.) in all external features and form, being ovate in outline and lenticular in profile. The shells are also frequently characterized by a well marked sinus on each side of the center, extending from the middle, or from above the middle of the valve to the front margin, giving a well defined trilobed feature to the specimen. This feature is not always present however, and on small or medium sized individuals never shows to any great extent. There are also numerous raidiating plications, obscurely marking the casts in many cases, but not always present.

The principal and only important distinction between this and *P. oblongus* consists in the form of the internal appendages of the dorsal valve, which, instead of two long, projecting crura, gradually and gently diverging as they recede from the apex of the valve, consists of a single septum, which supports a broad and distinct spoon-shaped cup or process near the apex, and is continued on the inner surface of the shell, along the middle of the valve, as a single septum only, sometimes becoming free from the valve at the upper third of its length, but in other individuals remaining attached to, and extending along the shell to near the lower third of the length of the valve, producing on the internal casts the feature of a single slit, occupying the median line of the valve. In the features of the ventral valve it is in all essentials like those of *P. oblongus*. It will at once be seen that the internal arrangements of the dorsal valve of this species have been quite unlike those of *P. oblongus;* consisting, in short, of a single central septum, with a spoon-shaped cavity near its upper end, instead of two separate processes situated at some distance from each other. This difference appears to me to be of considerable importance, at least sufficient for retaining it as a distinct species.

Formation and locality. In the limestone of the Niagara group at Rhine, Sheboygan county. In the Lower Coral beds it occurs at Cato. In the Upper Coral beds it has been noticed from Cato, Gibson, Kewaunee and Forestville, and from the Racine beds, at Wauwatosa and Milwaukee, Wisconsin.

Pentamerus ventricosus.

Plate XVII. Figs. 11–13.

Pentamerus ventricosus—*Hall;* Geol. Surv. Wis., 1860, p. 2, Rept. Prog., and Geol. Rept. Wis., Vol. I, p. 436.
" " *Hall;* 20th Rept. State Cab., p. 374, Pl. XIII, figs. 18–21.
Comp. Athyris (Pent.) trisinuatus—*McChesney;* Pal. Foss., p. 86; accompanying plates, Pl. VIII, p. 2.

Shell small, rotund, approaching subglobose, usually wider than long; cardinal margin arcuate, becoming more strongly rounded towards the sides of the shell. Dorsal valve strongly ventricose, most highly elevated in the upper part, the middle portion forming a moderately broad, more or less elevated and rounded mesial fold; beak distinct and incurved. Ventral valve much larger than the dorsal, with a large rounded incurved beak; mesial sinus not always distinct over the valve, but extended at the margin, forming a lingulate extension of variable size in different individuals, and frequently marked on the sides by impressed lines. Not unfrequently the middle portion of both valves is marked by several incipient plications.

The surface of the shell, as indicated on casts, has been more or less marked by concentric lines of growth, and sometimes also by finer radiating lines.

The species does not appear to be a true *Pentamerus*, departing from the true character of that genus in the internal arrangement of parts. It is possible it may be, as Prof. Hall suggests in the 20th Rept. State Cab., a species of *Pentamerella*, still it is so unlike, in many particulars, true forms of that genus as to be equally doubtful. In some of the more strongly plicated forms it resembles, quite strongly, specimens of *P. fornicatus* Hall, from the Clinton limestone of New York.

Formation and locality. In the Niagara limestone at Kewaunee. In the lower coral beds it has been recognized at Cooperstown and Cato, and in the upper coral beds, at Cato Falls. In the Waukesha beds, at Pewaukee. In the Racine beds, at Racine, Greenfield, Waukesha, Wauwatosa, Milwaukee, Kewaunee and Sturgeon Bay, and in the guelph beds, at Saukville and Sheboygan.

LAMELLIBRANCHIATA.

GENUS LEPTODOMUS, McCoy.

LEPTODOMUS NEGLECTUS.

Plate XVIII. Figs. 3 and 4.

Ambonychia neglecta — McChesney; New Species, Pal. Foss., p. 88, 1861.
Petrinea neglecta — McC.; Explan. Pl. IX, Fig 2, Illust. New Pal. Foss., 1865.
" *neglecta — (McC.);* W. & Marcy; Mem. Bost. Soc. N. Hist., Vol. I, p. 96, 1865.
Amphicœlia neglecta — McChesney; Trans. Acad. Sci., Chicago, Vol. I, p. 41, Pl. IX, Fig. 2, 1868.
Amphicœlia Leidyi — Hall; Sup. to 18th Rept. State Cab., p. 35, 1865.
" " *Hall;* 20th Rept. St. Cab., pp. 339 and 387, Pl. XIV, Figs. 13-15.
" *neglecta — (McChesney);* M. & W. Geol. Ill., Vol. III, p. 358, Pl. V, Fig. 9.

Shell ovate or subquadrate in outline, with ventricose valves; provided with large, strong, enrolled beaks, which are situated very near the anterior extremity of the shell, and project somewhat above the line of the hinge. Valves most ventricose just below the beak and gradually declining backward to the posterior margin, with a very abrupt anterior slope. Anterior margin rounded and full, longest below the middle of the valve; base broadly rounded, and the posterior extremity more sharply rounded; hinge line straight, usually about two-thirds the length of the shell below, or less. Surface of the shell marked by fine radiating lines or ribs, which are simple and rounded, showing no evidence of bifurcations. On the anterior end, the rays are extremely fine, but are stronger on the middle and posterior slope of the valves. A few obscure concentric undulations of growth also mark the shell at certain stages of growth.

The shells of this species appear to undergo great variation in form in different individuals, some of them being much more prolonged posteriorly than others; some of them are almost quadrangular in outline, while others again present an almost orbicular form. They also vary much in the length of the anterior end, and the abruptness of the anterior slope, as well as in the degree of ventricosity of the valves. They are usually found only as internal casts, but occasionally an individual is obtained preserving a portion of the surface, as in the one figured, and in this condition the surface radii are plainly seen, though on the complete casts this feature can seldom be detected. The casts sometimes show evidence of an external and longitudinally striated hinge plate, and the remains of a large tooth and socket, or a ligament pit beneath the beak. The presence or absence of one or more of these features on specimens has caused it to be referred to several different genera, at different times, by those who have had occasion to speak of it. There seems to be little or no doubt, however, but that it should be referred to McCoy's genus *Leptodomus.*

Formation and locality. It seems to be rather generally distributed through the upper part of the Western Niagara group, but nowhere very common. It occurs in the Racine limestone, at Racine, Waukesha and Wauwatosa, in Wisconsin; also at several places in Illinois and Iowa.

LEPTODOMUS UNDULATUS.

Plate XVIII. Figs. 1 and 2.

Leptodomus undulatus — *Whitf.;* Ann. Rept. Geol. Sur. Wis. for 1877, p. 81.

Shell of rather more than medium size, obliquely broad-ovate in outline and highly convex; hinge-line short, not more than half as long as the shell below; beak broad and strong, but not at all prominent or projecting, situated near the anterior extremity, slightly enrolled and directed forward; umbo prominent below the beak; anterior margin of the shell rapidly sloping backward with a convex curvature, and with the basal and posterior margin forming two-thirds of an elliptical curve; posterior margin sloping rapidly backward from the extremity of the hinge-line, and rounded below; umbonal ridge prominent and rounded; cardinal slope abrupt and slightly concave just behind the beak. Surface marked by a few strong, regularly rounded, concentric undulations parallel to the margin of the shell, and regularly increasing in strength with the increased size of the shell.

The species is a well marked form, and readily distinguished by the strong concentric undulations.

Formation and locality. In the Niagara limestone (Racine), Wauwatosa, Wisconsin.

GASTEROPODA.

Genus EUOMPHALUS, Sowerby.

Euomphalus macrolineatus.

Plate XVIII. Figs. 5 and 6.

Euomphalus macrolineatus — Whitf: Ann. Rept. Geol. Surv. Wis. for 1877, p. 82.

Shell large and robust, subdiscoidal with a depressed convex spire, composed of about three strong, rounded or elliptical volutions, the inner one rising but little above the next succeeding, and the last more rapidly increasing in size; transverse section of the volution apparently broad-ovate, being more sharply rounded on the outer side than above; suture lines strongly marked. Under side of the shell unknown. Surface of the volutions marked with strong, distinct, angularly elevated, revolving lines or ridges, with concave interspaces on the top and sides; those on the upper side of the impression of a fragment, where the volution has been a little more than one inch in diameter, are about one-sixth of an inch from crest to crest. Transverse lamellose striæ are observed crossing the revolving lines, and apparently rising into points on the ridges.

One fragment in the collection indicates a shell of more than four inches in diameter. The large size and strong revolving lines will readily distingush this from any other American species. The species is of the type of *E. discors; E. angulatus* and *E. rugosus* of the European Upper Silurian, but differs from them all in the greater number of revolving ridges, and in being much less rugosely lamellose; its nearest relations are with *E. discors*, but would never be mistaken for that one.

Formation and locality. In the Niagara group (Racine), at Kunz's quarry, Manitowoc Rapids, Wisconsin.

GENUS RAPHISTOMA, Hall.

RAPHISTOMA NIAGARENSE.

Plate XVIII. Figs. 10–12.

Raphistoma Niagarense — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 82.

Shell of rather large size, trochiform or subdiscoidal, depressed convex above and below, and acute on the periphery; transverse diameter almost twice as great as the height of the shell, measured from the base of the aperture to the top of the spire. Volutions about three, subtriangular in section and slightly wider than high, the upper surface very slightly convex between the suture line and the edge of the shell; lower side of the volution a little more rounded than the upper, to near the margin of the umbilicus, where it is more sharply rounded into the cavity, and vertical above. Umbilicus small and deep, exposing all of the inner volutions. Aperture subtriangular, most acute at the outer edge, rounded on the lower inner border, and slightly modified on the upper side by the preceding volution, which is apparently overspread by the inner lip. Columellar portion thin and nearly vertical. Margin of the lip thin and sharp, strongly receding from the suture to the exterior angle of the volution, with a distinctly sigmoidal curvature both above and below. Substance of the shell thin. Surface marked by fine striæ of growth parallel to the margin of the aperture, and also by revolving lines, which on the upper surface of the outer volution are about half a line apart, and on the under surface are finer and more numerous.

This shell has all the features of the genus *Raphistoma* Hall, so far as can be determined from a very well preserved example retaining portions of the original shell; and we can see no reason why it should not be so placed. Similar forms have been referred with doubt to the genus *Xenophora* Fischer, by Mr. Meek, who proposes the name *Pseudophorus* for an Upper Helderberg form from Ohio, which probably has the umbilicus closed (Pal. Ohio, Vol. I, p. 222); but this species having the umbilicus open, and constructed exactly as in *Raphistoma lenticularis*, would hardly answer to that requirement.

Formation and locality. In the Niagara group, at Schoonmacker's quarry (Racine limestone), near Wauwatosa, Wisconsin.

GENUS PLEUROTOMARIA, De France.

PLEUROTOMARIA LAPHAMI.

Plate XVIII. Fig. 9.

Pleurotomaria Laphami—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 84.

Shell of medium size, spire conical and moderately elevated, the apical angle being ninety degrees or a little less. Volutions three and a half to four, subtriangular, flattened exteriorly in the direction of the apical angle, subangular on the periphery and rounded below; suture indistinctly marked on the exterior of the shell, as shown by the impression left in the stone, but very distinct on the cast of the interior; aperture round—triangular; umbilicus proportionally large. Surface of the shell smooth, or marked only by fine striæ of growth.

This species very closely resembles *P. subconica* Hall, from the Trenton limestones, but is somewhat more slender, is less rounded on the lower side of the volutions, and they also increase less rapidly in size.

Formation and locality. In the limestone of the Niagara group, at Ashford railroad cut, Ashford, Wisconsin.

PLEUROTOMARIA RACINENSIS.

Plate XVIII. Figs. 7 and 8.

Pleurotomaria Racinensis—Whitf.; Ann. Rept. Geol. Surv. Wis. 1877, p. 84.

Shell of medium size, composed of from three to three and a half volutions, which increase very gradually in size with the increased age of the shell, and are subquadrangular in a transverse section. Spire very low, the entire height of the shell equaling only about one-half of the transverse diameter. Volutions flattened on the upper surface and very rapidly sloping on the outer surface, the edge being nearly vertical; under surface very depressed convex, more rapidly rounding within the broad umbilical cavity. Along the lower peripheral angle of the volution, as seen on the internal cast, there occurs a thin, sharp carina, indicating the presence of a revolving groove in the shell, and probably a slit in the margin of the lip. Surface of the cast marked on the nearly vertical exterior margin by distant, vertical ridges, at regular intervals of about one line on the outer volution of the specimen figured.

The species has the general form and appearance of *Euomphalus*

(Straparollus) mopsus Hall, from this same formation, but differs in the presence of the carina and in the subquadrangular form of the volution.

Formation and locality. In the Niagara group (Racine limestone), at Racine, Wisconsin. There is also a form undistinguishable from it in beds referred to the lower part of the formation, two miles south of Little Sturgeon Bay.

CEPHALOPODA.

GENUS ORTHOCERAS, Breyn.

ORTHOCERAS WAUWATOSENSE, n. sp.

Plate XIX. Fig. 2.

Shell cylindrical, very gradually enlarging from the apex; the increase in diameter being only one-fourth of an inch in a length of three and a half inches. Section circular and the shell quite thick. Septa very deeply concave, in fact but little less than hemispherical. Siphuncle apparently central. Surface of the shell marked by strong, elevated, flattened, encircling lines, which will average about six in the space of one-fourth of an inch; but which are not quite regular, sometimes interrupted, and have from one to three finer striæ in the spaces between. On one side of the shell the lines make a broad, sweeping curve upward. There are also fine longitudinal lines at irregular distances and of irregular strength, on some parts being obsolete.

The shell has been a very elegant one when perfect, and in its peculiar encircling striæ differs from any species known. The specimen, unfortunately, consists of the outer chamber and a single septum only, so that the relative distance of the septa cannot be determined. The striæ under a magnifier show considerable variation of form; in some parts being flattened on the surface, in others slightly rounded, and again grooved by deep lines, while the interspaces undergo similar changes; but these variations are too obscure to be apparent to the unaided eye.

Formation and locality. In the Niagara group (Racine limestone), at Schoonmacher's quarry, near Wauwatosa, Wisconsin.

ORTHOCERAS ANNULATUM.

Plate XIX. Fig. 1.

Orthoceras annulatum — *Sow.;* M. C. Tab. 133, — 1818.
Orthoceratites undulatus — *Hisinger;* Auteckn. V., Tab. IV, Fig. 6. Vet. Akad. Handlingar, Tab. VII, Fig. 8.
O. " " *Hisinger;* Lithea Suecica, p. 28, Tab. X, Fig. 2, 1827.
Orthoceras annulatum — Murchison's Sil. Syst. and Siluria.
O. " *undulatum (Sow.)* — *Hall;* Pal. N. Y., Vol. II, p. 293, Pl. 64 and 65. 20th Rept. State Cab., p. 351, Pl. XX, Figs. 4–5.
O. " " *(Sow.)* — *H. & W.;* Pal. Ohio, Vol. II, p. 147, Pl. IX, Fig. 1.
O. " *nodocostatum* — *McChesney;* New. Pal. Foss., 1861, p. 94; Trans. Chicago Acad. Nat. Sci., p. 53, Pl. IX, Fig. 5.
O. " *Laphami* — *McChesney;* N. Pal. Foss., p. 91.

Shell attaining a considerable length, but is generally of rather slender proportions; owing to its very gradual increase in diameter, the expansion being scarcely more than three-eighths of an inch in a length of seven inches in the specimen figured, and is sometimes even less. Transverse section, when uncompressed, circular or nearly so; with a central siphuncle of moderate size. Surface of the shell strongly annulated by rounded or subangular, encircling rings, with somewhat wider concave interspaces. The distance of the annulations vary somewhat with the increased size of the shell, but are usually from one-fourth of an inch to half an inch apart. The exterior of the shell is further ornamented by wavy or undulating, concentric, lamellose striæ, parallel to the annulations, which usually present great uniformity in their distance from each other, and number about twenty-four or twenty-eight in the space of an inch, but are sometimes quite crowded and interrupted. There are also longitudinal ridges marking the surface, which cross the encircling rings, and often form nodes on their crests, varying in strength and distance, but are never very closely arranged. This feature is most distinct on the larger specimens, seldom showing on those of less than one and a quarter inches in diameter, but is frequently retained on the internal casts. Septa deeply concave, arranged at distances from each other corresponding to the annulations, the septa uniting with the outer shell at the bottom of the depression between the rings.

The species is subject to extreme variation in the character of the surface markings, especially in the presence or absence, as well as in the strength of the longitudinal ridges, owing to which fact, it has been described under several different names; but an examination and study of a large number of specimens from different localities and in different conditions of preservation soon convinces the careful observer of the identity of the different varieties. Although there are closely allied species in the Trenton and other Lower Silurian formations, and similar forms at still higher horizons, it is readily distinguished from them by the nature of the annulations and the peculiar wavy or undulating lamellose surface striæ, and has always proved an excellent guide in determining the age of strata.

Formation and locality. The species occurs in the Niagara group at most of its localities, both in this country and in Europe; but in Wisconsin, has been observed mostly in the upper half of the formation, occurring in the Waukesha, Racine and Guelph beds, but not in the Mayville, Byron or Coral beds, so far as yet observed. The localities where it occurs may be seen by reference to the lists of fossils under the different divisions of the group.

DISCOSORUS CONOIDEUS, Hall.

Plate XX. Fig. 6.

Discosorus conoideus — Hall; Foster & Whitney's Rept. Lake Superior, p. 222, Pl. XXXIV, Figs. 2-3.

The nature of the peculiar fossil bodies to which the above name was originally applied seem never to have been entirely understood, and consequently they have been variously referred. A specimen in the collection of the survey, from the Niagara group at Ashford, Fond du Lac Co., Wis., probably identical with the typical species, throws some additional light on their nature. In it the discs are seen occupying the position of the ordinary siphuncle within the body of an *Orthoceras*, with the true septa and outer shell surrounding it. The discs corresponding in number and position to the septa, and the obliquity of the discs to the axis of the series is seen to correspond to the eccentricity of their position within the *Orthoceras*, as is often the case with the ordinary siphuncle. The outer shell of the individual tapers very rapidly, resembling in form a species of *Gomphoceras*, but is too imperfect to permit a description. It is, however, interesting to know just what relation the organism holds in nature, instead of relying on conjecture alone.

GENUS CYRTOCERAS, Goldfuss.

CYRTOCERAS INFUNDIBULUM, n. sp.

Plate XX. Figs. 4 and 5.

Shell small, very slightly curving, and very rapidly expanding from the apex to the aperture; the increase in diameter being half an inch in a length of one and one eighth inches. Transverse section very slightly transversely oval, the two diameters at the upper end being as eight to nine, and the inner side of the shell a little more flattened than the outer curve. The longitudinal curvature not perceptible on the inner face, but on the outer side it is quite apparent, although the swell of the arc is not more than one-twentieth of an inch in a length of one inch. Septa not positively determined, but so far as can be seen have been nearly flat, and comparatively distant. Siphuncle not seen. Surface of the shell marked by elevated, rounded, encircling bands or ridges, which are distant about one-twelfth of an inch on the lower end of the fragment figured, but increase in distance from below upward. The spaces between the bands are flattened, and have a faint line midway between the stronger bands, barely perceptible to the naked eye.

The species is peculiar for its rapidly expanding form, slight curvature and banded surface. It is most nearly allied to *Cyrtoceras brevicorne* Hall (20th Rept. State Cab. p. 356, Pl. XVII, figs. 8 and 9), but differs in being less arcuate; more rapidly expanding, and in being widest from right to left instead of in a dorso ventral direction. The surface characters also differ; although in the description of that one these are not stated, the impression left in the rock to which the individual is attached shows no surface markings, which would have been the case had such lines as exist on this one ever occupied the surface of that shell.

Formation and locality. In the Niagara group at Racine, Wisconsin.

GENUS PHRAGMOCERAS, Broderip.

PHRAGMOCERAS HOYI.

Plate XIX. Figs. 4 and 5, and Plate XX, Fig. 3, Var.

Phragmoceras Hoyi — Whitf: Ann. Rept. Geol. Surv. Wis. for 1877, p. 86.

Shell of medium size or smaller, very rapidly expanding, strongly curved and broadly ovate in a transverse section, rounded on the back and sharply subangular on the inner side of the curve. Outer chamber most rapidly expanding on the inner side from the base to the extremity of the lip, so that the dorso-ventral diameter at the summit is nearly once and a half greater than at the base of the outer chamber; expansion of the aperture on the inner end small and transverse, that of the opposite end large and ovate; connecting slit short and narrow, the contraction of the chamber approaching the slit being abrupt. Septa concave, the chambers being about three times as deep on the outer curve as on the inner side. Siphuncle small, marginal on the inner curved surface, and situated in the angularity of the transverse section. Surface marked by transverse striæ which are strongly arched upward on the sides of the shell a little within a central line, and very broadly curved downward on the back.

This shell resembles *P. Nestor* Hall, 20th Rept. State Cab., p. 348, Figs. 7 and 8, but differs in the greater curvature, more rapid expansion, greater lateral diameter, and in the form of the openings at the summit.

Formation and locality. In the upper part of the Niagara group (Racine limestone), at Schoonmacher's quarry, near Wauwautosa, Wisconsin. A similar form, but with a more compressed section and more protruding and laterally compressed lip on the inner side, occurs at Busock's quarry, which we propose to designate under the varietal name *compressum* (Pl. XX, Fig. 3) =*P. Hoyi*, var. *compressum.*

Phragmoceras Hoyi, var. Compressum, new var.

Plate XX. Fig. 23.

Formation and locality. In the Racine Limestone; Busack's quarry, Racine, Wisconsin.

Phragmoceras Nestor.

Plate XIX. Fig. 3.

Phragmoceras Nestor — Hall; 20th Rept. State Cab., p. 347, Figs. 7 and 8.

Shell of moderate size, strongly curved, and rapidly expanding in the lower part, and less rapidly expanding along the outer chamber, which is wider than high when uncompressed, much the shortest on the ventral side, and somewhat projecting toward the upper part, to form the lip of the inner opening, which is rather small and rounded on the margin. Dorsal surface contracted below the larger opening, and the sides of the shell along the median line, between the dorsal and ventral openings, abruptly infolded, leaving only a long narrow slit connecting them. Septa distant and rather deeply concave. Siphuncle and surface of the shell not observed.

The example used in description and illustration is much compressed laterally, so that the true proportions of the shell cannot be given by measurement. The type specimen, however, is broadly elliptical or slightly ovate in a dorso-ventral direction, the greatest transverse diameter being outside the median line. The proportional height and width of the outer chamber differs somewhat in the two individuals, being somewhat shorter in this than in the type, and also more contracted below the dorsal opening, giving a slightly hunched form to the back of the shell. Both individuals are marked near the base of the outer chamber by a series of vertical ridges, or lines, which were probably scars for muscular attachment.

Formation and locality. In the lower part of the Niagara group (Waukesha limestone), at Waukesha and Wauwatosa, Wisconsin.

Phragmoceras labiatum.

Plate XX. Figs. 1 and 2.

Phragmoceras labiatum — Whitf.; Ann. Rept. Geol. Surv. Wis., for 1877, p. 86.

Shell rather below the medium size, rapidly expanding from below upward, and but slightly curved in its form; very regularly oval in a transverse section, lateral diameter about three-fourths as great as the dorso-ventral diameter. Outer chamber of the shell a little wider than high, closely compressed at the top, so as to entirely close the opening of the aperture along the center of the summit in some cases. Ventral opening forming a slightly expanded lip-like tube. Dorsal opening large and tubular, the tube being short and broad, and appearing as if it had been forcibly inserted into the body chamber so as to leave a sharp, distinctly impressed suture-line at the junction. The lower side of the tube forms a section of an oval figure, while the upper half is deeply impressed on each side of the central slit or opening, giving a deeply trilobed form to this part of the tube. Septa moderately concave, arranged so that about six chambers occupy a space equal to the lateral diameter of the outer one counted. Siphuncle rather small and submarginal. Surface of the shell unknown.

The form of the apertural tubes is a distinguishing feature.

Formation and locality. In limestones of the Niagara group at Ashford, Fond du Lac county, Wisconsin.

Genus LITUITES, Conrad.

Lituites multicostatus, n. sp.

Plate XX. Fig. 7.

Shell rather below a medium size, consisting of three and a half or four volutions, the outer of which slightly embrace the dorsal edge of the inner, are very gradually increasing in size throughout and probably circular in a transverse section when not compressed, but in the specimen used and figured are of very much greater diameter in a dorso-ventral direction than laterally, giving a rather acute dorsal keel; most likely due to compression, the specimen being imbedded in the rock parallel to the stratification. Surface of the volutions marked by numerous, closely arranged and very regular, transverse costa, which are separated by concave spaces and are directed rather gently backward in crossing from the inner to the outer margin of the volution; but more strongly retral on the dorsum, where they make an acute angle on the compressed keel. On the concave space between the costa there appear to have been very fine striæ of growth, parallel to the ridges, but too fine to be distinguished without the aid of a lens. Septa gently concave, as shown on the sides of the specimen, and arranged at a trifle greater distance from each other than the transverse costa, which they cross in their course from the inner to the outer edge of the volution. Position of the siphuncle not determined.

The very gradual increase in size of the volutions gives to the sides of the shell a very wide, open umbilical surface. The species differs from any other described, so far as we are aware, in its gradual increase in size coupled with the fine and closely arranged transverse costæ; which count about seven, on the side of the shell, in a space equal to the dorso-ventral diameter of the volution at the same point.

Formation and locality. The species is comparatively rare and occurs in the lower beds of the Niagara limestone, at the Railroad quarries above Waukesha, Wisconsin.

CRUSTACEA.

Genus ILLÆNUS, Dalman.

Illænus Ioxus.

Plate XXI. Figs. 11 and 12.

Illænus Ioxus — Hall; 20th Rept. State Cab., p. 378, Pl. XXII, Figs. 4–10.
I. " *Barriensis (Murch.) — Hall;* Pal. N. Y., Vol. II, p. 302, Pl. 66; and 20th Rept. State Cab., p. 332.
Illænus Barriensis of many authors, not of Murch. Silurian System.

This most common and very characteristic species of the Niagara group of Wisconsin is seldom seen in the rocks of the state except in dismembered fragments; but the heads and caudal plates are very common, and often occur of large size; one individual head among the survey collections having been, when entire, fully five inches in width.

The form is extremely robust and highly convex; the head, when the movable cheeks are in place, being nearly semicircular in specimens of medium size, the width measuring about twice the length, if viewed in a natural position, with the basal line horizontal. The occipital line, in a profile view, is almost at right angles with the basal line, or in some cases a little within a right angle. The upper outline of the profile, from the occipital line to the antero-basal line, when not distorted, forms nearly a true arc. Eyes large, but not very prominent, and surrounded by a slight depression limiting the palpebral lobe, and also the base of the eye; visual surface narrow in a vertical direction, but elongated in an anterior and posterior direction. Dorsal furrows slight. Movable cheeks of moderate size, subquadrangular in outline, nearly two-thirds the length of the head, and rounded at the posterior angles. Facial sutures rounding outward for nearly half the depth below the eye, as seen in front, and then directed inward, reaching the margin on a line with the inner end of the eye; but in a profile view, are almost vertical to near the base, and are then directed forward to the lower margin of the head.

Pygidium transversely subelliptical, the outer margin approaching a semicircle in outline, and the anterior border irregularly arched, but having the curvature of a much larger circle. Surface strongly convex, but less elevated than that of the head of a corresponding size; outer margin thickened on the under side, the selvage being proportionally wide.

The species differs from those associated with it in the same beds, in the short broad form of the head and its large eyes. The head differs from that of *I. armatus* Hall, 20th Rept. State Cab., p. 330, Pl. XXII, figs. 1 and 2, in wanting the spines at the extremities of the movable cheeks. The pygidium resembles that referred to *I. armatus* Hall., loc. cit., fig. 3, but is more arched on the anterior border and less regularly semicircular.

It is noticeable in examining a large collection of specimens, that they differ greatly in the proportional length and relative convexity; especially is this the case among the cephalic shields; those of large size being usually much shorter in comparison with their width than the smaller individuals. Still many of the smaller specimens are quite short, which would appear to indicate that there is no law governing these relations, so far as can be ascertained from the examination of a moderate number. But probably, should the study be conducted through ample collections, the result might be quite different.

Formation and locality. In the Niagara group, in most parts of the country where fossils are abundant. It occurs within the state in the Mayville beds, doubtfully identified, at Blodgett's quarry in the town of Hartford; in the Waukesha beds at Pewaukee and Genesee; in the Racine beds at Racine, Greenfield, Waukesha, Grafton, and at Sturgeon Bay; and in the Guelph beds at Cedarville, Wisconsin.

ILLÆNUS INSIGNIS.

Plate XXI. Figs. 6--10.

Illœnus insignis — Hall; 20th Rept. State Cal., p. 331, Figs. 5 and 6, Pl. XXII, Figs. 13 and 14.

The following is Mr. Hall's description of this species:

"Head large; glabella prominent and somewhat regularly arcuate from front to base; anterior border with the margin a little recurved. Dorsal furrows distinctly marked from the base of the head for three-fourths the distance to the anterior margin, where they terminate in a distinct rounded pit; palpebral lobe large, elongate, the eye being situated at some little distance from the posterior margin of the head. Facial suture running out on the anterior border within the line of the eye."

"The full extent of the cheek is not known."

"The form of the glabella and the convexity of a single articulation of the thorax indicate the general form to have been very convex."

"The pygidium is parabolic, very convex; about as long as or a little longer than wide. Anterior margin nearly straight along the middle for about half the width, for the attachment of the axis of the thorax, and abruptly receding towards the sides."

The specimen figured, and another in the collection which preserves the crust, correspond very closely with the above description; differing principally in not having the dorsal furrows extended quite so far forward as the one on which the above description was based, nor do they terminate in the rounded pit as there stated, but in a broader depression situated nearly on a line with the front of the eye. The eyes are placed quite far back on the head as compared with some of the other species of this group, and are also situated far out on the sides of the head. The species, in the form of the head, differs from *I. Madisonianus* herein described, in being more regularly and gradually sloping from the anterior margin to within a very short distance of the occipital line. The thorax appears to differ from that one in being much less convex, as is shown on a small specimen preserving parts of five consecutive segments.

Formation and locality. In the Racine limestones of the Niagara group, at Burlington; Racine; Waukesha; at Moody's quarry near Milwaukee, and at Schoomacher's quarry near Wawatosa, Wisconsin.

ILLÆNUS IMPERATOR.

Plate XXI. Figs. 4 and 5.

Illænus imperator—Hall; Rept. Prog. Geol. Surv. Wis., 1861, p. 49.
I. " " Geol. Rept. Wis., Vol. I, p. —.
I. " " 20th Rept. State Cab. N. Y., p. 332, Pl. XXII, Figs. 15–17, and Pl. XXIII, Fig. 2.

Entire body attaining a large size, but is seldom found with the several parts united, being generally represented only by the detached glabellas and caudal shields.

Glabella and fixed cheeks united, transversely elliptical in form, nearly twice as wide as long, broadly rounded on the front margin and less rounded and lobed along the occipital line, with the general surface strongly convex; dorsal furrows proportionally wide and distinct, extending less than one-half the length of the head, and directed inward in their course from the occipital border forward, and slightly curved; axial lobe about as wide, or a little wider than the fixed cheeks, and depressed-convex on the surface. Eye-lobes prominent and very narrow from front to rear, but considerably longer in a lateral direction; indicating a semi-pedunculated eye, situated almost on the occipital line. Facial sutures cutting the anterior border in such a manner as to leave no perceptible angle at the junction, and passing backward, from a point on a line with the outer limit of the eye, to the junction with the lobe at its inner angle, forming an irregular sinus, the depth of which is equal to the length of the eye lobe; the fixed cheek being prominent and convex near the eye and along the occipital line. Glabella and occipital furrows obsolete.

Thoracic segments as shown by Prof. Hall, broad and flattened, slightly curving backward beyond the origin of their free extremities.

Pygidium narrowly elliptical in the smaller specimens, and somewhat longer in proportion in older examples, with the surface strongly convex. In the smaller examples the width is nearly twice the length, but in larger individuals is not more than once and a half as wide as long. Axial lobe less than one-third the entire width, and extending less than half the length of the plate; rather prominently rounded on the front margin, but becoming gradually lost in the general convexity posteriorly. Lateral lobes less prominent, straight on the anterior margin for two-thirds their width, and then obliquely truncate to the lateral angles.

The species varies considerably in the form of the several parts in specimens of different sizes, as has been described; so much so, in fact, that a single description will not give the characters of but a few individuals. It often attains to very considerable dimensions; one caudal plate in the collection measuring five and a half inches in width by a length of three and a half, while the convexity of the specimen is not more than one-third as great, proportionally, as in the small specimen figured. This same remark holds good, as a general thing, with the cephalic plates as well. Although many individual specimens of glabellas are present in the collection, no movable cheeks have been observed. They are probably quite insignificant in size, but collectors would do well to search for them, as they may present important specific features.

Formation and locality. In the Racine beds of the Niagara group. Prof. Hall mentions it from Racine, but all the specimens in the state collections at present are from Burlington, Wisconsin.

ILLÆNUS MADISONIANUS, n. sp.

Plate XX. Figs. 8 and 9.

Body of moderate size, elongate-oval in general form, and very highly convex, with the trilobation very indistinct; length a little less than twice the greatest width, and the height nearly or quite half equaling the width. Anterior and posterior extremities nearly equally rounded, and the lateral margins but slightly rounded, or almost straight along the thorax. Thorax shorter than the cephalic shield, and the pygidium equaling the length of the head and half of the thorax combined.

Cephalic shield short, paraboloid in form, and highly convex, the anterior portion full, and projecting beyond the anterior margin; also very full and prominent along the central line and between the eyes. Occipital line strongly arching forward from the rounded genal angles. Eyes full, prominent and protruding, widely separated, and situated so as to bring their anterior margins nearly on a line with the middle of the length of the head. Dorsal furrows distinctly marked from the occipital line to the front of the eyes, directed inward anteriorly to the eyes, and bending downward in front, limiting the eye lobes. The facial sutures are quite indistinct, but appear to reach the anterior margin far out on the sides of the head, or nearly on the outer line of the eyes; and behind, to follow nearly in a line with the dorsal furrows.

Thorax very short, composed of ten very short equal segments, which are flat or but very slightly convex on their surfaces, and have a very decided forward curvature from their extremities to the center, but more strongly so just within the dorsal furrows; lobation of the thorax not very marked, the axial lobe occupying about two-thirds of the width, as measured with the curvature of the body. Free pleura short, rounding forward at their extremities.

Pygidium paraboloid in outline, and the anterior margin strongly arching forward in the middle; the surface highly convex, and much more abrupt on the sides than across the middle; the margin is again more spreading, forming a broad, shallow furrow around the sides and behind, just within the edge. Bordering the articulating slope or facett of the pygidium, there is an elevated ridge extending from the margin to the dorsal furrow of the thoracic segments.

The species differs from any of those heretofore described, in its long-oval form and highly convex surface, as also in the paraboloid outline of the extremities. It is most nearly allied, in the features of the head, to *I. cuniculus* Hall, 20th Rept. State Cab. Pl. XXII, Fig. 12; but differs in the greater proportional length; greater convexity; fuller and more prominent front; in having the occipital margin concave instead of convex, and in the position of the eyes, which are more distant, and placed further from the posterior margin. The pygidium resembles most closely that referred to *I. insignis* Hall, 20th Rept. State Cab., Pl. XXII, Fig. 14. It differs, however, in the greater convexity; in the spreading or recurved margin; in being less diverging along the lateral borders toward the antero-lateral extremities, and in its greater proportional length. The species greatly resembles *I. orbicaudatus* Bill. (Cat. Anticosti foss., Pl. XXVII, Fig. 10), from the Hudson river group, at English Head, Anticosti.

Formation and locality. In the Niagara group of Wisconsin; the particular locality not given. The specimen figured is the property of the State Historical Society at Madison, Wisconsin.

Illænus pterocephalus

Plate XX. Figs. 10–12.

Illænus pterocephalus — *Whitf.;* Ann. Rept. Geol. Surv. Wis. for 1877, p. 87.

Cephalic shield short, broad and of unusual depth, when viewed in its natural position, with the occipital border forming a vertical line; the distance from the under surface of the head to the highest part of the glabella being nearly or quite twice that from the occipital line to the anterior margin. The extreme width of the head, including the movable cheeks is equal to three and a half times the length. Movable cheeks small, forming thin, wing-like expansions at the sides of the head, and on a line with the occipital border, but so contracted anteriorly as to be scarcely more than half as long as the glabella; anterior margin and surface of the head round and highly convex in the middle, rapidly contracting in front of the eyes, and expanding laterally along the occipital border. Glabella and fixed cheeks united, but without the movable cheeks, elliptical or oval in form, very convex on the surface, and nearly half as wide again as long, broadly rounded in front and strongly lobed in the posterior part of the dorsal furrows, which are short and directed inward, but are not visible on the cast beyond the posterior third of the head, as measured along the curve of the glabella. Eyes prominent and obtusely pointed, as shown in the cast, and situated very near the posterior margin of the head. Facial suture cutting the anterior margin considerably within the line of the eyes and passing to the eye with a regular outward curvature; behind the eye, it passes almost directly to the posterior margin. Throax and pygidium unknown.

The species is peculiar for the short but laterally expanded movable cheeks, which appear only as thin, short appendages to the posterior half of the fixed cheeks, giving a peculiar winged expression to the head, which will readily distinguish it from any previously known species when these parts are present; but when absent, the central portions of the head have much the appearance of a small specimen of *I. imperator* Hall; but differs in having the dorsal furrows strongly directed inwards instead of the reverse as in that form, and also in being very much more rotund.

Formation and locality. In the Niagara limestone, at Pewaukee, Wisconsin.

Genus BRONTEUS, Goldfuss.

Bronteus Laphami.

Plate XXII. Figs. 1–4.

Bronteus Laphami — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 88.

Entire form unknown, the specimens from which the following description is taken consisting of fragments of the glabella and several imperfect pygidiæ.

Glabella short and broad, very depressed convex, the division of parts somewhat obscure. Anterior lobe very broad in front, and rapidly decreasing in width from its junction with the marginal rim to behind the middle of its length, where it is not more than two-thirds as wide as in front; dorsal furrow obscure; posterior glabellar furrow well marked; occipital furrow distinct and the occipital ring rather large. Fixed cheeks narrow, rather strongly lobed; anterior marginal rim of the head narrow and rounded, indistinctly separated from the anterior lobe of the glabella in the middle, but not definitely so at the sides, its surface rather strongly striated.

Pygidium paraboloid in form, and depressed convex with an entire external margin; anterior border of the shield gently rounded and moderately convex on the surface; lobation distinct. Axial lobe short, round-obconical in form, more strongly convex than the lateral lobes and marked by a single narrow articulating ring on the anterior end; lateral lobes gently convex on the inner part, more abruptly declining at about the outer third of their width, and slightly recurving again near the border; articulations very distinct and directed strongly backward in their course to the margin, rounded on the surface and separated by short, deep depressions to near the border of the shield, just within which they become obsolete. The central rib, or that extending from the termination of the axial lobe, rapidly narrows for one-third of the length from the anterior margin of the shield, then widens more abruptly to the posterior margin, where there are very slight indentations in the external border corresponding to the depression at its sides. Near the middle of the length of this central articulation, or rib, there rises a central depression, or furrow, dividing it from this point posteriorly into two divisions, presenting the appearance of a bifurcation.

Surface of the crust of the pygidium marked on the lower part of the lateral expansion, by strong squamose concentric lines. Other portions of the plate smooth.

This is a beautiful species, and remarkable for its large size; one of the pygidiæ measuring about four inches in length by more than three and a half inches in width. It is readily distinguished from *B. acamas* Hall (*B. occasus* Winchell & Marcy), by the backward curving articulations of the lateral lobes of the pygidium, and by the bifurcation of the axial member of the same.

Formation and locality. In the Niagara group (Racine limestone), at Kewaunee, Wisconsin. Named in honor of the late Dr. I. A. Lapham.

Genus SPHÆREXOCHUS, Beyrich.

Sphærexochus Romingeri.

Plate XXI. Figs. 1–3.

Sphærexochus Romingeri — Hall; Geol. Rept. Wis. 1862, p. 434. 20th Rept. State Cab., p. 374, Pl. 22, figs. 4–7.

S. " *mirus — Hall;* (Not of Beyrich). 20th Rept. State Cab., p. 334, and Geol. Rept. Wis., p. 434.

S. " " Of many authors, but not of Beyrich.

Glabella smooth-spheroidal in general form, composing almost the entire bulk of the head and extending far in advance of the anterior border. Its posterior part is marked by a single pair of furrows, which are narrow and deep, and entirely surround and isolate the posterior glabella lobes, as large, round tubercles which are placed low down on the sides of the head, and extend from the occipital furrow to the middle of the length of the glabella; the distance between them, across the posterior part of the glabella, being equal to nearly twice their diameter. Occipital ring short, but highly elevated; the furrow is deep and well marked. Dorsal furrows deeply marked, distinctly limiting the glabella. Fixed cheeks minute, scarcely extending beyond the limits of the dorsal furrows, and the posterior lateral limbs short and subtriangular in form; the continuation of the occipital furrow occupying most of their area. Frontal limb short, entirely embraced within the dorsal furrow in its anterior extension, one half of the bulk of the glabella projecting beyond its front margin when the head is held with the occipital line in a vertical position, and the anterior portion of the fixed cheeks is curved abruptly downward in front of the ocular sinus, bringing the lower front margin of the glabella on a horizontal line with the outer ends of the postero-lateral limbs. When the head is viewed from above, the axial lobe of the occipital region is a trifle more than half as wide as the anterior portion of the glabella, and is very highly arched; while the lateral limbs of the fixed cheeks are very narrow, and bend abruptly downward a little outside of the dorsal furrows. The ocular sinus is small but deep, and situated behind the center of the glabellar lobe. Judging from the size and form of the sinus, the eye has been small and inconspicuous.

Movable cheeks and thorax unknown. The pygidium, as figured by Prof. Hall (20th Rept. State Cab., Pl. XXI, Fig. 7), is transversely elliptical in form, the axial lobe is large and strongly convex, extending the entire length of the plate, and marked by three strong rings, exclusive of the terminal one. The lateral lobes are a little more than half as wide as the axis, and each deeply divided into three unequal points, the anterior one of which is the largest, and the others decreasing in size posteriorly.

This species has generally been referred to and considered as identical with *S. mirus* Beyrich, of Europe, and some of the specimens which I have seen among European collections are certainly very like it, while from others it differs very materially. When compared with such forms as those figured by Prof. J. Barrande, in his Syst. Sil. Boheme, Vol. I, Pl. XLII, Figs. 16 and 17, and Sup. to Vol. I, Pl. VII, Figs. 3 and 4, it differs in the much greater sphericity of the glabella, and in its greater anterior extension. In all the figures referred to, the line of the dorsal furrow in front of the occipital ring, is represented as running nearly or quite horizontal, and on a line with the dorsal furrow of the thorax, to the anterior border; while in these western forms it begins to curve downward immediately in front of the occipital ring, and is more abruptly bent in front of the posterior glabellar lobe, and to the anterior margin of the head; thus leaving nearly one-half the length of the glabella in front of the anterior rim of the head, and more than one-third of the depth of the spherical portion below the line of the dorsal furrow at the neck, when the specimen is placed with the occipital line in a vertical position; instead of having all the bulk of the glabella above that line, as in the figures referred to. The pygidium also differs from the European specimens in having a very much wider axial lobe, and in being more deeply divided on the lateral margins.

Formation and locality. In the upper part of the Niagara group (Racine limestone), at Racine, Waukesha and elsewhere in Wisconsin.

SPECIES FROM THE GUELPH LIMESTONE.

RADIATA.

GENUS FAVOSITES, Lamark.

FAVOSITES OCCIDENS.

Plate XXIII. Figs. 6 and 7.

Favosites occidens —Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 78.

Corallum growing in hemispherical or irregular formed masses of medium size, which are composed of two kinds of radiating cell tubes, the one larger than the other; the larger cells being scattered through the corallum at somewhat irregular intervals, with from one to three of the smaller cells between. Large cells more or less circular in form and usually measuring from a sixteenth to a tenth of an inch in diameter. Smaller cells, variable in form and size, generally adjoining the larger circular cells, and ranging from minute to more than two-thirds the size of the larger ones. Transverse diaphragms complete, closely arranged, or distant more than the diameter of the tube, in the same individual. Mural pores apparently arranged in single rows. These have not been very distinctly observed, owing to a deposit of minute crystals of dolomite on the walls of the cells.

This feature, the presence of two distinct kinds of cells, is one pertaining more particularly to corals of the Devonian period than to those of the rocks of the lower formations, at least in this country; but it is occasionally seen in species from the Niagara group. The larger kind of cell appears to be that which gives origin to new individual polyps, as is readily determined by the examination of sections of the coral; they also extend further toward the initial point of the corallum than do the intermediate ones, and would be properly considered as parent or prolific cells. As the corallum increases in size, others take upon themselves this form of parent-cell whenever the intermediate ones become too numerous, thus keeping the number of intermediate cells relatively the same in masses of any size.

Formation and locality. In the upper part of the Niagara group (Guelph horizon), near Ozaukee and elsewhere in Wisconsin. It is not exclusively confined, however, to this horizon, but occurs sparingly as small individual masses in the upper part of the true Niagara formation, at several localities in the state.

GENUS AMPLEXUS, Sowerby.

AMPLEXUS ANNULATUS.

Plate XXIII. Figs. 8–11.

Amplexus annulatus — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 80.

Corallum simple, elongate turbinate in form, more or less curving throughout, from one and a half to three inches in length, by about five-eighths of an inch in diameter, seldom attaining to more than three-fourths of an inch; somewhat rapidly expanding for the first inch from the base, above which it is subcylindrical in form, with the exterior surface distinctly and strongly annulated by varices of growth, giving to the body much the appearance of a species of *Cornulites.* Longitudinal rays numerous and moderately well developed near the margin, but only extending a short distance from the outer walls; transverse partitions or tabulæ distinct and strong, more or less curved and tortuous, extending to within a short distance of the walls of the body, and arranged at varying distances, often to the extent of half the diameter of the coral. External calyx comparatively deep.

The strongly annulated exterior surface of the coral is quite a distinguishing feature.

Formation and locality. In the Guelph limestone, at Sheboygan and Carlton, Wisconsin.

BRACHIOPODA.

GENUS PENTAMERUS, Sowerby.

PENTAMERUS OCCIDENTALIS.

Plate XVII, Fig. 10, and Plate XXIII, Figs. 1 and 2.

Pentamerus occidentalis—Hall; Pal. N. Y., Vol. II, p. 341; Pl. LXXIX, Figs. 1 and 2.

Shell rather above the medium size, ovate in outline and extremely ventricose, generally much longer than wide, but very variable in form. Ventral valve strongly arcuate, more abruptly curving in the upper half; beak strong, elongated, obtusely rounded and incurved. Dorsal valve less ventricose than the opposite, almost regularly arcuate, and with the umbo not very prominent, the middle of the valve marked by a slight mesial depression on some of the specimens; cardinal slopes of both valves generally rounded, but often flattened or slightly concave. Surface of the shell marked by coarse, irregular, bifurcating or fasciculate radii, generally somewhat stronger along the middle of the valves than on the sides.

The specimens obtained within the limits of the state are in the condition of internal casts; and in this condition show the internal processes to have been extremely variable in strength and extent. The triangular foramen in the ventral valve has been broadly triangular and of large size.

Many of the individuals obtained have so exactly the form and expression of those from Galt, Canada, and show the same peculiar variation in form and degree of gibbosity, that there cannot be the least question as to their positive identity.

Formation and locality. In the upper part of the Niagara group (Guelph horizon), at Williamstown, Wisconsin.

Genus STRICKLANDINIA, Billings.

Stricklandinia multilirata.

Plate XXIII. Figs. 3-5.

Stricklandinia multilirata —Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 81.

Shell of medium size but very diverse in form, varying from longer than wide to nearly one-third wider than long, and from depressed biconvex with nearly equal valves to extremely gibbous with the ventral valve very much the deepest, as seen in profile. Hinge-line straight, usually longer than the width of the shell, and often with mucronate extremities, but frequently much shorter than the width of the shell below; front of the valves slightly protruding beyond the general contour, or subtruncate. Area of the ventral valve distinct but not wide. Dorsal valve with an inconspicuous or depressed umbo; and a moderately wide, poorly defined, and slightly elevated mesial fold. Ventral valve more convex, with a deeper, more conspicuous, and often subangular mesial depression, but a not at all prominent beak. Surface of the shell marked by numerous distinct, but not strongly marked, bifurcating, radiating plications, both on the sides of the shell and on the mesial fold and sinus; the number not constant, but usually from four to six in the space of one-fourth of an inch on the margin of the shell. Spoon-shaped process in the interior of the ventral valve, as shown by the cavity left in the casts by the removal of the substance of the shell, distinct but not large.

The species is a well marked form of *Stricklandinia*, showing the generic characters strongly developed. It differs from any others described, in the great extent of the hinge-line, and from most in the finer bifurcating striæ of the surface. It is remarkably variable in form in different individuals, some of them presenting much the form of a *Productus* in the great convexity and sometimes geniculation of the ventral valve.

Formation and locality. In the Guelph limestone, at Sheboygan, Wisconsin.

GASTEROPODA.

Genus HOLOPEA, Hall.

Holopea magniventra.

Plate XXIV. Figs. 2 and 3.

Holopea magniventra—Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 83.

Shell of large size, ventricose and robust in habit; spire low or depressed-convex; volutions about three, very rapidly increasing in size, and strongly rounded on the periphery; suture distinct, but not deep; aperture subcircular or very broadly ovate, and pointed above, where it is slightly modified on the inner side by the preceding volution; umbilicus probably closed and apparently covered by a callus on the overspreading collumellar lip, as indicated by the form of the cast Surface of the shell, as far as can be determined by the specimens, marked only by transverse lines of growth.

The generic relations of this shell, like most of those of this form, especially when known only by the internal casts, are not very readily determined; the species, therefore, can only be referred to a genus provisionally, until some more fortunate individual shall chance to discover specimens which will more fully illustrate them. The above species resembles in form and general features that described and figured by Prof. J. Hall, as *Euomphalus rotundatus*, from the limestones of the upper Helderberg group of New York, but which is certainly not an *Euomphalus*, and is equally removed from the genus *Pleurotomaria*, as it does not possess the spiral band or slit on the middle of the volution which characterizes that genus.

Formation and locality. In the Guelph limestone, at Carlton, Wisconsin.

Genur LOXONEMA, Phillips.

Loxonema magna.

Plate XXIV. Fig. 1.

Loxonema magna — *Whitf.*; Ann. Rept. Geol. Surv. Wis. for 1877, p. 83 (By typographical error *Toxonema*).

Shell very large and robust, spire highly elevated and rapidly ascending, the rate of increase being very gradual. Volutions in the lower part proportionally long, entire number unknown, very depressed convex on the external surface; columella prolonged below, giving an elongate-pyriform aperture; suture between the volutions, as seen on the internal casts, moderately wide, indicating a shell of considerable thickness. Surface features unknown.

The specimens from which the description is taken are internal casts, the larger one being about one inch and three-fourths in diameter across the body volution, and the rate of increase as shown would indicate an entire length of fully eight inches when perfect. The species is more nearly related to *L. robusta* Hall, from the Schoharie girt of New York, than to any of those described from the Guelph limestone, but has been of much greater size.

Formation and locality. In the Guelph limestone in section 28, Carlton township, Wisconsin.

Genus MURCHISONIA, D'Arch. et Verneuil.

Murchisonia Chamberlini.

Plate XXIV. Fig. 4.

Murchisonia Chamberlini — *Whitf.*; Ann. Rept. Geol. Surv. Wis. for 1877, p. 84.

Shell very large and robust, and of a general oval form; the example from which the description is taken being a cast made in the natural mould left in the rock by the removal of the shell by natural solution, measures about four inches in length by about two inches in its greatest diameter. Spire moderately elevated, the apical angle being about forty or forty-five degrees. Volutions about six, strong and highly convex, marked on the periphery by a strong, distinct, and moderately elevated, revolving band, which produces a slight angularity on the middle of the upper volutions. Aperture large, broadly ovate, prolonged below, and the lip distinctly rimate in the lower part. Columella strong, slightly curved below, and spreading upon the body volution in the upper part; but becoming free in the lower portion, leaving a distinct umbilical opening behind it, which continued to nearly the entire length of the spire. In the cavity left in the rock by the decomposition and removal of the shell, this was represented by a strong spiral core of stone, three-eighths of an inch thick in the lower part, which remained supported in the center of the cavity by its attachment at the base through the umbilical opening. Minute surface markings of the shell not preserved, but remains of lines of growth can be faintly traced.

This is one of the largest and most magnificent species of the genus yet discovered. It is of a type more characteristic of the Devonian rocks of Germany, than of those of Silurian age, and its occurrence in rocks of this period is somewhat remarkable.

Formation and locality. In the Guelph limestone, near Carlton, Wisconsin.

CEPHALOPODA.

Genus ORTHOCERAS, Breynius.

Orthoceras Carltonense.

Plate XXIV. Fig. 5.

Orthoceras Carltonense — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 85.

Shell of moderate or large size, and very gradually tapering, the rate of increase being about one-fourth of an inch in a length of two inches. Section circular; septa of moderate depth and closely arranged, about eight chambers occupying a space equal to the diameter of the shell at the top of the upper one of those counted. Siphuncle unknown. Surface marked by longitudinal flutings, numbering about twenty-four in the circumference of the shell.

The species is of the type of *O. Columnare* Hall, from the Niagara group; but differs from that, or any of those described of that form, in the more closely arranged septa, there being nearly twice as many in a given length, as in that species. It also differs from most of the fluted species in having a circular section instead of an oval form.

Formation and locality. In the Guelph limestone, at Carlton, Kewaunee county, and at Ozaukee, Wisconsin.

Genus CYRTOCERAS, Goldfuss.

Cyrtoceras rectum.

Plate XXIV. Figs. 6 and 8.

Cyrtoceras rectum — Whitf.; Ann. Rept. Geol. Surv. Wis. for 1877, p. 85.

Shell of moderate size, nearly straight in form and ovate in transverse section, the lateral diameter being about three-fourths as great as the dorso-ventral, and the greatest width being on the inner side of a central line; curvature of the tube on the inner face scarcely perceptible, and the rate of increase in diameter, in the dorso-ventral direction, about an eighth of an inch in a length of two inches. Septa flat in a lateral direction, but strongly arching along their dorso-ventral axis, so arranged that about nine chambers occupy a space equal to the dorso-ventral diameter of the outer one counted. Outer chamber not constricted at the aperture, so far as observed. Siphuncle proportionally large and expanded within the chambers, situated at about its own diameter from the inner or shorter curved surface of the shell. Surface features not observed.

The straight form, and septa flattened in the direction of their lateral axis, are features which will readily distinguish this one from any other known species.

Formation and locality. In the Guelph limestone, at Carlton, Kewaunee county, Wisconsin.

SPECIES FROM ROCKS REFERRED TO THE LOWER HELDERBERG GROUP.

BRACHIOPODA.

Genus ORTHIS, Dalman.

Orthis subcarinata.

Plate XXV. Figs. 3 and 4.

Orthis subcarinata—*Hall;* 10th Rept. State Cab., p. 18.
" " " Pal. N. Y., Vol. III, p. 196, Pl. XII, Figs. 7–21.

The specimens representing this species consist of a single impression of the exterior of the dorsal valve, and one cast of the interior of the same, together with other casts of the interior of the ventral; they have the form of this species, and also much the form of *O. elegantula* Dalman. From the last, however, they differ somewhat in the greater rotundity of the dorsal valve, and more decidedly rounded cardinal extremities. The ventral valve is much more ventricose than that of the one referred to *O. oblata* associated with it, and may be readily distinguished by this feature, as well as by the subcarinate prominence of the median line of the valve. The specimens are all small, and do not exceed the usual size of *O. elegantula*, none of them being more than three-eighths of an inch in their greatest diameter.

Formation and locality. In beds referred to the Lower Helderberg group, at the river bottom, at Waubakee, Wisconsin.

Orthis oblata, Hall?

Plate XXV. Figs. 1 and 2.

Orthis oblata—*Hall;* Pal. N. Y., Vol. III, p. 162, Pl. X, Figs. 1–22.

The specimens which I have referred with doubt to this species, consist of impressions left in the rock, by the removal of the substance of the fossil, and are therefore more or less unsatisfactory in character. The features as described and figured are obtained from impressions in gutta-percha, taken from these natural moulds, and serve to give a much better idea of the shell than the impression in the rock only. The shell is shown to be more or less discoid, the dorsal valve being more convex than the ventral, while the latter is marked by a broad, almost obsolete depression along the middle. The form is transverse, a little wider than long; hinge-line short and the beaks somewhat pointed and slightly incurved; cardinal slopes proportionally long and inclined, bringing the point of greatest width as low or lower than the middle of the valve; front margin straightened or imperceptibly emarginate.

Surface of the shell coarsely striate, and marked also by distinct concentric lines, marking stages of growth, toward the front margin.

The shell very closely resembles specimens of *Orthis hybrida* Dalman, and as far as the examples themselves afford means of determination, there is no evidence to show that they are different. They also equally resemble a form which occurs very abundantly in the Lower Helderberg group of New York, associated with *O. oblata* Hall, and which has generally been considered as the young of that species. They are, however, not young shells, but adult, as can readily be seen by their thickened and rotund form, and the possession of a full series of old-age characters. The Wisconsin specimens, as well as the similar ones from New York, are so exactly like *O. hybrida* that it seems like doing violence to nature to place them under any other name. Still, as they are usually more rotund and ventricose than many of the Scandinavian specimens, and more especially as those have received several varietal names, it may become necessary to do so, in order to distinguish them.

Formation and locality. In beds referred to the Lower Helderberg, at Waubakee, Wisconsin.

Genus MERISTELLA, Hall.

Meristella nucleolata.

Plate XXV. Fig. 5.

Atrypa nucleolata — Hall; Pal. N. Y., Vol. II, p. 328, Pl. LXXIV, Fig. 10.
Merista " " 12th Rept. State Cab., p. 78.

Shell small, subglobose or slightly elongated in general form, with a minute, scarcely pointed beak, and deeply impressed mesial sinus on the ventral valve. Dorsal valve not seen; surface of the shell marked by a few strong concentric lines of growth, but otherwise smooth.

The only individuals seen are represented by impressions in the thin shaly layers of rock, and present much the appearance of those from the Coralline limestone of New York. They also slightly resemble a form from the Hydraulic beds of Herkimer county, New York, given by Vanuxem in the 3d Dist. Rept. as *Atrypa brisulcata*, but are not quite so much elongated, and it is not certain that the mesial depression exists on each valve as on that species.

Formation and locality. In thin shaly beds on Mud Creek, Milwaukee, Wisconsin.

LAMELLIBRANCHIATA.

Genus PTERINEA, Goldfuss.

Pterinea aviculoidia.

Plate XXV. Figs. 6 and 7.

Megambonia aviculoidia — Hall; Pal. N. Y., Vol. III, p. 274, Pl. XLIX, Figs. 7 and 8.

Shell of small size, subquadrangular or quadrangularly ovate in outline, varying somewhat in different individuals; the anterior end being sometimes more contracted. Height and length of the shell about as three to four, or in some cases as four to five. Hinge-line straight, nearly as long as the posterior end of the shell, with a very broad, shallow sinus dividing it from the body of the shell below. Anterior end short, slightly winged and narrowly rounded, especially on the right valve. Basal line rounded, but more rapidly contracting anteriorly, the greatest height of the shell being at about the middle of the length. Surface of the shell marked on each valve by distinct, somewhat regular concentric lines of growth, which become grouped and slightly stronger anteriorly. Slight indications of faint radiating lines occur on one of the left valves.

The specimens are all very thin and flattened from compression, and present a macerated appearance, but retain the substance of the shell with the outline and surface characters well preserved on some of them; the conditions of preservation being better in fact than most of those from the Tentaculite limestone of New York. These Wisconsin specimens differ slightly from the figures of the species as given in Vol. III, Pal. N. Y., above cited, particularly in the greater proportional height of the shell; but in making the comparison directly with specimens from the Tentaculite limestone of New York, they are found to correspond much more nearly than with the figures cited, few of them presenting the great height represented in the figures referred to.

Formation and locality. In thin shaly layers referred to the base of the Lower Helderberg group, at the bottom of the Milwaukee river, near Waubakee, Wisconsin.

CRUSTACEA.

GENUS LEPERDITIA, Ronault.

LEPERDITIA ALTA.

Plate XXV. Fig. 8.

Cytherea alta (Conrad) Vanuxem; Geol. Rept. 3d Dist. N. Y., 1843, p. 112, Fig. 6.
Leperditia alta (Con.) Hall; Pal. N. Y., Vol. III, p. 373.
" " *Jones;* Ann. Mag. Nat. Hist., Vol. XVII, 2d series, p. 88.
" " *(Con.) Meek;* Pal. Ohio, Vol. I. p. 187, Pl. XVII, Fig. 2.

Body of medium size, somewhat ovate in form, being narrowed anteriorly. Dorsal line straight, from two-thirds to three-fourths of the entire length, and the height of the valves equaling about two-thirds of the length. Surface of the valves convex, more strongly elevated anteriorly, where they sometimes present a slight, almost imperceptible angularity; lower margin convex, and on the right valve rather abruptly inflected. Ocular (?) tubercle of small size, and often imperceptible, situated anterior to and below the point of greatest convexity and quite near the anterior end, when present, though varying somewhat in position on different individuals. Surface of the crust apparently smooth.

The specimens of this species from Wisconsin present all the features possessed by the New York individuals, both in size and form; and, although existing usually as casts and impressions only, are readily recognized as of the same species. Their mode of occurrence is also very similar, in some layers being so abundant as to entirely cover the surfaces, causing the rocks to readily separate into thin laminæ along the planes of their occurrence.

Formation and locality. In rocks of the age of the Onondaga salt group, or base of the Lower Helderberg group of New York; at Waubakee.

SPECIES FROM THE HAMILTON GROUP.*

BRACHIOPODA.

GENUS LINGULA, Brug.

LINGULA PALÆFORMIS.

Plate XXV. Fig. 10.

Lingula palæformis — Hall; Pal. N. Y., Vol. IV, p. 8, Pl. I, Fig. 7.

Shell rather larger than medium size; broadly triangular in general form, being widest near the front and pointed at the beak, with the cardinal slopes nearly straight or but slightly convex to below the middle of the length, and diverging at an angle of about eighty degrees. Front margin broadly rounded or flattened, and the lateral angles abruptly rounded from the extremity of the cardinal slopes to the basal border. Body of the shell, as indicated by the specimen, flattened in the central portions or very depressed convex. The surface of the shell has been distinctly and very regularly marked by even, closely arranged, elevated, concentric ridges parallel to the margin, marking stages of growth, and with regularly increasing distances from the apex outward.

Judging from the appearance of the only individual seen, the beak of the ventral valve has been considerably extended beyond that of the dorsal and more narrowly pointed.

The only distinction that can be noticed in a direct comparison between these specimens and the types of the species from New York, is the more distinct concentric lines of the surface; but the most perfect individual of those, the one figured in the N. Y. Vol., is considerably exfoliated and abraded over much of the surface, thereby obscuring the characters to some extent. There is also great resemblance between this species and small specimens of *L. spatiosa* Hall (Pal. N. Y., Vol. III, p. 158, Pl. IX, fig. 10), from the Lower Helderberg group; but when the comparative size of individuals is considered, the resemblance is stronger to the Hamilton group species.

Formation and locality. In rocks of the age of the Hamilton group of New York, at Washington street bridge, Milwaukee, Wisconsin.

* See note A on page 349.

GENUS DISCINA, Lamark.

DISCINA MARGINALIS, n. sp.

Plate XXV. Fig. 11.

Shell small, rather below the medium size, discoid, and very nearly circular. Upper valve very depressed convex, gradually rising from the front margin to the apex, which is situated quite near the margin, but not terminal. The outline of the border of the valve is very slightly narrowed as it approaches this part. Lower valve flat, a very little less in diameter than the upper one, and the apex situated more than one-third of the width of the valve from the anterior margin; between which and the apex there is a slit or foramen of medium size, apparently not extending entirely to the margin. Surface of the upper valve marked by irregular, concentric lines of growth, which have a slightly lamellose character. That of the lower valve has been marked by quite regular, elevated lines or ridges, parallel to the margin, and placed at regularly increasing distances from each other.

The species closely resembles *D. Lodensis* Hall, from the Hamilton group of New York, but differs in the position of the apex of the upper valve. One peculiarity of the shell is the difference in the position of the apex as shown on the opposite valves, the one being nearly central, while the other is almost marginal. There is no question, however, as to their belonging to the same individual, as they are almost in their natural position with regard to each other, in the specimen used; and as but few individuals of the species have been obtained, they cannot have been abundant in the seas of the period, giving but little chance for accidental mingling of individuals. The lower valve closely resembles that of *D. humilis* Hall, from the Hamilton shales of New York, but differs principally in the smaller size; but as the upper valve of that species is unknown, there is no further means of comparison.

Formation and locality. In rocks of the age of the Hamilton group of New York, near Milwaukee, Wisconsin.

Genus ORTHIS, Dalman.

Orthis impressa.

Plate XXV. Figs. 13-15.

Orthis impressa—*Hall;* Geol. Rept. 4th Dist. N. Y., 1843, p. 268, and Fig. **2, p. 267;** Pal. N. Y., Vol. IV, p. 60, Pl. VIII, Figs. 11-19.
Comp. *O. Tulliensis* —*Vanuxem; O. Iowensis;* and *O. Macfarlani* — *Meek.*

Shell of large size, transversely oval in outline, with highly convex dorsal and depressed-convex ventral valves; the latter marked along the middle by a very broad, ill-defined, mesial depression, which often modifies the front margin of the dorsal valve, to a slight extent, causing a broad emargination of the border. Surface of the shell marked by fine, closely arranged, radiating striæ.

The specimens of this species, like most of the fossils of these beds, are represented only by the internal casts and impressions of the exterior surface of the same, and usually only of separated valves; so that the entire form of the shell is seldom seen. The internal casts retain the imprints of the muscular impressions, often in a very perfect condition, and in this state the species is so exactly similar to specimens from the Chemung group of New York, as to almost persuade one they were from the same locality and bed. The muscular imprints of the opposite valves of the species are quite distinctive, and, aside from the difference in the degree of convexity, will readily serve to distinguish them. That of the ventral is elongate and deeply bilobed, the point projecting somewhat beyond the line of the cardinal area; while that of the dorsal is wider than long, bilateral and flabelliform; each side being divided into anterior and posterior lobes by a usually quite distinct, obliquely transverse depressed line.

Species of this type of Orthis range almost uninterruptedly through the different geological formations from the Lower Helderberg group to the Carboniferous; and differ so little in form and general character, that they are often quite difficult of distinction. The *O. impressa* differs from most others in the greater proportional difference in the convexity of the valves, but is also generally proportionally wider than most other forms, with a broader and sometimes deeper mesial depression of the ventral.

Formation and locality. In the Hamilton group beds, at Washington street bridge, Milwaukee, and at White Fish Bay, Wisconsin.

GENUS STROPHODONTA, Hall.

STROPHODONTA DEMISSA.

Plate XXV. Fig. 18.

Strophomena demissa — Conrad; 1842; Jour. Acad. Nat. Sci. Phil., Vol. VIII, p. 258, Pl. XIV, Fig. 14.

Strophodonta demissa (Con.) — Hall; 1847; 10th Rept. St. Cab., p. 137; — Rept. Geol. Surv. Iowa, Vol. I, Pl. II, p. 495, Pl. III, Fig. V; — Pal. N. Y., Vol. IV, p. 101, Pl. XVII, Fig. 2.

S. " demissa (Hall) — Owen; Rept. Geol. Surv. Iowa, Wis. and Minn., Tab. 3 A., Fig. 14.

Strophomena demissa (Hall)—Meek; Trans. Chi. A. Sc., Vol. 1, p. 87, Pl. XIII, Fig. 6.

" " (Con.)—Billings; Devonian Foss. Can., 1861, p. 77;—Can. Jour., 2d Series, Vol. VI, p. 341, Figs. 116–118; Nich. Pal. Ontaria, 1847, p. 65.

Shell semi-oval or semi-elliptical in outline, and plano-convex or concavo-convex in profile. Hinge-line straight, longer than the shell below; the extremities often submucronate; area moderate on each valve, but largest on the ventral. Dorsal valve flat or slightly convex, often with a slight depression extending along the middle. Ventral valve convex or depressed convex over the visceral region, becoming depressed at the sides near the cardinal line. Surface of both valves marked by coarse, angular, bifurcating or fasciculate radiating striæ, which are usually strongest in the center near the upper part of the valves. Numerous strong concentric lines of growth, especially toward the front margin, also characterizes the shell.

Formation and locality. In the Hamilton group beds, at Washington street bridge, Milwaukee, and at White Fish Bay, Wisconsin.

GENUS CHONETES, Fischer.

CHONETES CORONATA ?

Plate XXV. Fig. 16.

Strophomena coronata (by error carinata) — Conrad; Jour. A. N. S. Phil., Vol. VIII, p. 257, 1842.

Chonetes coronata (Con.) — Hall; Pal. N. Y., Vol. IV, p. 133, Pl. XXI, Figs. 10–12.

Two imperfect individuals, which have been referred with doubt to this species, are present in the collection, one, an internal cast of a ventral valve, the other an impression of the exterior of a ventral; neither of them perfect enough to afford means for positive determination. The specimens have been figured as they appear, the latter from a gutta-percha impression in the natural mould, that they may, in part at least, tell their own story. The internal cast of the ventral valve presents some slight variation from New York specimens, in the greater strength of the muscular impressions, but in the punctate character of the cast and the general form, it corresponds closely. The external impression closely resembles those from New York.

Formation and locality. From the Hamilton group beds, at Washington street bridge, Milwaukee, Wisconsin.

Genus SPIRIFERA, Sowerby.

Spirifera mucronata.

Plate XXV. Figs. 27 and 28.

Delthyris mucronata — Conrad; Ann. Rept. Geol. Surv. N.Y., 1841, p. 54, Pl. —, Fig. 18.
" " *(Con.)—Vanuxem;* Geol. Rept. 3d Dist. N. Y., p. 150.
" " *(Con.)—Hall;* Geol. Rept. 4th Dist. N. Y., p. 198.
Spirifera " *(Con.)—Bill.;* Can. Jour., May, 1861.
" " *(Con.)—Hall;* Pal. N. Y., Vol. IV, p. 216, Pl. 34, Figs. 1–32.
" " *(Con.)—Nich.;* Pal. Ontario 1874, p. 80.

A few specimens, undistinguishable so far as the characters are preserved, from this species, are present in the collection, representing both dorsal and ventral valve in the condition of casts. The ventral valve is four times as long, measured on the hinge, as the length from beak to base, with the extremities slenderly mucronate. The valve is divided in the middle by a deeply concave mesial sinus, strongly limited, and about half as wide on the front margin as the length of the shell along the sinus. Each side of the shell is marked by about twelve or fourteen distinct, rounded or subangular plications, exclusive of that bordering the sinus; four or five of which are small, and situated near the extremity. Area of the valve narrow. Dorsal valve, although less perfect than the others, is still characteristic; the fold is of similar proportions to the sinus, flattened on the top with a depressed line in the middle, and the plications slightly more angular than those of the other valve.

Surface of both valves, as indicated on the casts, marked by coarse, imbricating lines parallel to the anterior border of the valve, and crossing the plications, to which they give a semi-nodose or rugose character.

Formation and locality. Hamilton group beds, at Washington street bridge, Milwaukee, Wisconsin.

Spirifera audacula.

Plate XXV. Figs. 25 and 26.

Delthyris audacula — *Conrad;* Jour. Acad. N. Sci., Phil., Vol. VIII, p. 202.
Delthyris medialis — *Hall;* Geol. Rept. 4th Dist. N. Y., 1842, p. 208, Fig. 8.
Spirifer medialis — *Hall;* 10th Rept. State Cab., p. 164.
Spirifera medialis — *Hall;* Pal. N. Y., Vol. IV, p. 227, Pl. XXXVIII, Figs. 1–25.

The specimens in the collection representing this species are dorsal valves only; they are, however, so entirely characteristic and so readily distinguished from any of the associated species, that there can be no difficulty in distinguishing them, and certainly no question as to their specific identity.

The form is triangular, or in some cases trapezoidal, from the truncation of the front, hinge-line straight, one and three-fourths to twice and a half as wide as the length from beak to base, the extremities sometimes narrowed and slender, but in the shorter forms, obtuse; sides of the valves straightened; surface moderately convex and marked on each side of the narrow, convex or slightly flattened mesial fold, by from fifteen to twenty-two or more slender, rounded plications, most of which pass off on the cardinal line. The plications have evidently been crossed by a few imbricating lines of growth, not strongly shown on the internal casts.

Formation and locality. In beds of the Hamilton group, at Washington street bridge, Milwaukee, Wisconsin.

Spirifera angusta.

Plate XXVI. Fig. 3.

Spirifera Angusta — *Hall;* 10th Rept. State Cao., p. 164.
S. " " Pal. N. Y., Vol. IV., p. 230, Pl. XXXVIII A, Figs. 23–32.

A single imperfect ventral valve of this species has been recognized. The form is much elongated in the direction of the hinge-line and short from beak to base, with a proportionally elevated hinge-area, slightly arcuate or recurved at the apex as it occurs imbedded in the rock; sinus narrowly triangular, more rapidly widening in the front half, with the sides angular and the bottom slightly flattened. Plications twelve or thirteen on each side, angular in form, arching backwards as they approach the hinge-line, but becoming obsolete within the margin. The surface has been marked by a few imbricating lines of growth, parallel to the margin, which are preserved on the cast.

Aside from the general form of the shell, the form of the plications is characteristic; the strongly recurving direction of their extremities as they approach the cardinal border, not being a common feature of the Spirifera of the Hamilton group. It is, however, strongly shown on specimens of *S. arctisegmenta* from the Upper Helderberg limestone, which is a closely allied form.

Formation and locality. In the Hamilton group beds, at Washington street bridge, Milwaukee, Wisconsin.

Spirifera euruteines, var. fornacula.

Plate XXV. Fig. 22.

Spirifera fornacula — Hall; 10th Rept. State Cab., p. 154.
" *euruteines var. fornacula — Hall;* Pal. N. Y., Vol. IV, p. 211, Pl. XXXI, Figs. 11–13.

Shell small, ventricose in profile and transversely oval, or sub-elliptical in outline, with an elevated cardinal area. Ventral valve most convex on the umbo, with gently convex sloping sides, and rounded cardinal extremities; center of the valve marked by a narrow, concave, well marked mesial sinus, and each side by about ten low, rounded, radiating plications; area moderately high; fissure narrow. Dorsal valve less elevated, but more regularly convex than the ventral, the greatest elevation being about the middle of the valve; mesial fold and plications corresponding to those of the ventral, with the exception of a perceptible flattening on the middle of the fold.

The specimens correspond very closely with the originals of the variety *fornacula*, described and figured by Prof. Hall. They differ essentially from the form usually known as *S. euruteines* Owen, in the overarching of the ventral beak and the rounding of the cardinal extremities; and for these reasons I think they will prove to be a distinct species when more perfect material can be had.

Formation and locality. In the Hamilton group, at Washington street bridge, Milwaukee, Wisconsin.

Spirifera pennata.

Plate XXVI. Fig. 4.

Spirifer pennatus — Owen; Rept. Geol. Surv. Iowa, Wis. and Minn., Tab. 3. Fig. 3.
S " " *(Owen) — Hall;* Geol. Iowa, Vol. I, pt. 2, p. 510, Pl. V, Fig. 1.

Shell large or above a medium size, short from beak to base and very extended on the hinge-line, which is often prolonged intc mucronate points of varying degrees. Valves angularly ventricose, the ventral much the deepest and marked in the center by a broad, somewhat abruptly depressed, subangular mesial sinus, which extends to the apex of the valve. Sides of the valve between the sinus and the hinge-extension slightly concave, and occupied by from sixteen to twenty or more low, rounded or subangular, simple, radiating plications, which gradually decrease in size from the sinus outward, becoming minute and very oblique near the hinge-extension. Dorsal valve depressed-convex, and the fold less angular than the sinus of the ventral; the plications on the sides very similar to those of the ventral. Hinge-area high on the ventral valve, and divided in the middle by a broad foramen. Surface characters of the shell not preserved.

The individuals of this species are numerous, but usually not well preserved, so the features of the shell has not been observed on them. They are sufficiently distinct, however, to leave no possible doubt of their specific identity with the specimens from Independence, Iowa.

Formation and locality. In beds of the Hamilton group, at Washington street bridge, Milwaukee, Wisconsin.

Spirifera (Cyrtina) aspera.

Plate XXVI. Figs. 1 and 2.

Spirifer aspera—Hall; Geol. Iowa, Vol. I, Pl. II, p. 208; Pl. IV, Fig. 7.

Shell of moderate size, semicircular in a dorsal view, trapezoidal when viewed from the ventral side, and highly subpyramidal in profile. Dorsal side moderately convex, with the hinge-line about as long as the greatest width in the internal casts; beak rather large and projecting beyond the hinge-line; mesial fold simple, of moderate width, strongly convex and rather less than half as wide across the front as the length of the valve from beak to front; sides of the valve marked by fifteen or more simple, low, rounded plications. Ventral valve highly pyramidal, with a pointed apex and a highly elevated, nearly vertical cardinal area, which is about half as high as the entire length of the hinge-line, and is divided in the middle by a narrowly triangular fissure, not more than one-third as wide at the base as the height of the area; mesial sinus appearing wider in proportion than the dorsal fold, moderately to deeply concave, with angular margins; sides of the valve somewhat flattened between the fold and the cardinal border, and marked by plications corresponding to those of the dorsal side.

The Wisconsin specimens of the species are all casts, and consequently do not show the minute surface structure of the shell. The species was first described from rocks of Devonian age at Rock Island, Ill.; and on the type specimens the surface is shown to be strongly granulose, in fact densely covered with comparatively large, rounded granules, without apparent arrangement; still on close examination they are found to be concentrically arranged on the fine transverse lines of growth. The Rock Island specimens figured by Prof. Hall, shows about twenty plications on each side of the fold and sinus; the specimen retaining the shell of course will preserve more in number than internal casts even of a corresponding size.

The species presents to some extent the features of CYRTINA, having very broad dental lamellæ which extend across the apex of the ventral valve to considerable extent, and also a mesial septum dividing the muscular impression, and an internal depressed pseudo-deltidial plate, extending across the fissure for from one-half to two-thirds of the depth of the valve. The granulose structure of the surface is also similar, although no absolute punctate structure can be detected in the shell of the type specimens.

Formation and locality. In the rocks of the Hamilton group, at Washington street bridge, Milwaukee, Wisconsin.

GENUS SPIRIFERINA, De'Orb.

SPIRIFERINA? ZICZAC.

Plate XXV. Figs. 23 and 24.

Delthyris ziczac — Hall; Geol. Rept. 4th Dist. N. Y., pp. 200 and 201, 1842.
Spirifera ziczac — Hall; Pal. N. Y., Vol. IV, p. 222, Pl. 35, Figs. 15–23.
Spirifera clio — Hall; 13th Rept. St. Cab., p. 93, 1860.

Specimens of a small spiriferoid shell closely resembling this species are quite common, but of smaller size than those from the soft shales of the Hamilton group, and having greater affinities with a small form closely resembling it, occurring commonly in the sandy layers of limestone at the old Incline Plane near Ithaca, N. Y. The form is transversely elliptical, once and a half to twice as wide on the hinge-line as the length from beak to base; valves gibbous or strongly convex, with a moderately elevated and incurved cardinal area. Surface of the valves arcuate, divided in the middle by a moderately wide and deep sinus on the ventral valve, and by a corresponding fold on the dorsal, which is flattened or slightly grooved along the middle. They are also marked on each side of the center by six or seven strong, subangular plications. The surface of the casts show strong evidence of numerous coarse concentric lines crossing the plications, which arch strongly backwards in crossing them.

The internal casts offer but very slight evidence of an internal longitudinal septum in the ventral valve required in *Spiriferina*, in this respect resembling the New York specimens of the species.

Formation and locality. In the Hamilton group beds, at Brown Deer, near Milwaukee, Wisconsin.

Genus ATRYPA, Dalman.

Atrypa reticularis L. and A. spinosa and A. hystrix, Hall.

Plate XXVI. Figs. 5–8.

Specimens representing these three forms of Atrypa, are comparatively common among the collections of the survey, from the Hamilton group. Those representing *A. reticularis* have much the character of specimens from the soft shales of the formation in New York, being finely marked and the dorsal valve strongly convex, with numerous strong, concentric growth lines imbricating the radii. Those referred to *A. spinosa* Hall, are more coarsely marked, the radii presenting a somewhat knotty appearance at the crossing of the concentric lines, while the valves are more nearly equally convex than those of the last; and the shell is usually wider above, presenting a somewhat square-shouldered appearance, seldom or never possessed by either of the above species. The *A. hystrix* is lenticular in profile, the valves being nearly equally convex, and marked by only a few, very coarse, usually bifurcating plications, which are crossed by distant and strong concentric undulations, marked at the junction of the plications by strong nodes corresponding to the bases of the spines. These specimens have precisely the features of the specimens from the higher beds of the series at Rockford, Iowa; being slightly more regular in their growth than those from the Chemung group of New York.

It is a very interesting fact connected with the distribution of species, finding these three forms of the genus so characteristically represented, at an isolated outcrop of the formation, particularly one so slightly developed as is this one; and to find them associated with other species also, which, in other geographical areas, are confined to different or distinct geological horizons, separated by deposits of great thickness, as they are in New York, between the Hamilton shales and the Chemung group above. It tends to show the continuance and preservation of specific forms through a long lapse of time, and over great geographical areas, where the conditions were favorable for their preservation, and their distribution through forced migrations, by gradual changes of conditions, instead of extinctions, over areas, by sudden changes of circumstances.

Formation and locality. In the Hamilton group, at Washington street bridge, Milwaukee, Wisconsin.

GENUS LEIORHYNCHUS, Hall.

LEIORHYNCHUS KELLOGGI?

Plate XXVI. Fig. 9.

Leiorhynchus Kelloggi — Hall (?); Pal. N. Y., Vol. IV, p. 361, Pl. LVI, Figs. 1-12.

Shell of moderate size, transversely oblate in outline and moderately convex in profile, giving a rather rounded lenticular section. Dorsal valve about three-fourths as long as wide, and presenting an almost regularly oval figure, the beak not projecting beyond the general contour; central third of the valve elevated to form the mesial fold, which is not conspicuous on the posterior third of the valve, but is marked by four low, but slightly angular plications, one of which, on the specimen figured, bifurcates, giving five on the front part of the valve; sides of the valve marked by from three to five slightly raised and faintly marked plications. Features of the ventral valve not clearly seen, as the specimens are much distorted by compression. The internal casts are marked by the characteristic mesial septum in the dorsal valve, which on one individual has extended beyond the middle of the length.

The specimens present the features of the species, as shown on the Ohio specimens originally used, and also retain, to some extent, markings of the long radiating fibrous shell structure, which appears to be a usual character of the genus. The plications shown on the figured specimens are somewhat more strongly developed than are those of the types of the species; but as those are all partially exfoliated, they are consequently somewhat reduced in strength.

Formation and locality. In the Hamilton group, at Washington street bridge, Milwaukee, Wisconsin.

LAMELLIBRANCHIATA.

Genus MODIOMORPHA, H. & W.

Modiomorpha concentrica.

Plate XXVI. Fig. 10.

Pternea concentrica — Conrad; Ann. Rept. Geol. Surv. N. Y., p. 116, 1838.
Cypricardites concentrica —Conrad; Ann. Rept. Geol. Surv. N. Y., p. 52, 1841.
Modiola concentrica — Hall; Geol. Rept. 4th Dist. N. Y., p. 196, Tab. 78, Fig. 9.
Cypricardites oblonga — Conrad; Ann. Rept. Geol. Surv. N. Y., p. 52, 1841.
Modiomorpha concentrica—H. & W.; Prelim. Notice Lamellib. Shells of the Up. Held., Hamilton and Chemung groups, etc., p. 73 (distributed without author's name).
Modiomorpha concentrica — Meek & Worthen.

The specimens representing this shell are below the usual size and in a rather poor state of preservation, but possess the usual features of the species. The form is transversely elongate, ovate or subovate, and very compressed. The anterior end is short and narrowed in front of the beaks; while the posterior portion gradually expands in height from the beaks for about two-thirds of the length, from which point, the margin is rapidly rounded and declines to the postero-basal extremity; basal line slightly convex posteriorly, and slightly emarginate opposite the beaks; the latter feature is small, compressed and directed forward. Umbonal ridge rounded but not conspicuous. Surface of the shell marked by numerous regular, closely arranged concentric ridges, which are most distinct along the umbonal ridge.

Formation and locality. In the Hamilton group, at Brown Deer and at White Fish Bay, near Milwaukee, Wisconsin.

Genus Palæaneilo, H. & W.

Palæaneilo constricta.

Plate XXVI. Figs. 13 and 14.

Nuculites constricta — Conrad; Jour. Acad. Nat. Sci. Phil., Vol. VIII, p. 249, Pl. XV., Fig. 8.
Palæaneilo constricta — H. & W. (Con.); Prelim. Notice Lamellib. Shells of the Up. Helderberg, Hamilton and Chemung groups, etc., p. 7 (distributed without author's name), 1869.

Shells of small size, seldom attaining a length of more than three-fourths of an inch. Form irregularly ovate transversely, the length nearly twice the height; largest anterior to the middle, and rapidly narrowing posteriorly. Anterior end rounded; basal line full and somewhat protruding near the middle of its length, between which point and the posterior extremity it is distinctly and broadly sinuate. Posterior extremity narrow, the margin rounded, and the longest point a little above the middle of the height of the valve; hinge-line slightly arcuate, more abruptly bent at the beak, the posterior side nearly twice the length of the anterior, and both marked by numerous small, curved teeth, the number not ascertained on any of the specimens in hand. Surface of the shell moderately convex on the middle and at the anterior end, but compressed posteriorly. Posterior to the middle, and corresponding to the umbonal angle of other shells, there exists a broad, shallow depression or sulcus, which extends from behind the beak to the constriction of the postero-basal border; as in all species of the genus yet noticed. The surface markings consist of fine regular lines parallel to the margin, covering the anterior and middle portions of the shell, but becoming obsolete on the posterior portion and in the sulcus.

The shells of this species are somewhat variable in their proportions of length and breadth, and in the depth and distinctness of the posterior sulcus and basal constriction; dependent on the greater or less extension of the posterior extremity of the valves. The species has been recognized in several distinct geographical regions, and these variations are noticed at each of the localities.

Formation and locality. In Wisconsin it has been noticed only on the lake shore at White Fish Bay, near Milwaukee.

PALÆANEILO NUCULIFORMIS.

Plate XXVI. Fig. 12.

Leda nuculiformis — Stevens; Am. Jour. Sci. & Arts, 2d Series, Vol. XXV, p. 262, 1858.
Leda Barrisi—Wh. & Whitf.; Proc. Bost. Soc. Nat. Hist., Vol. VIII, p. 298.
Palæaneilo Barrisi — H. & W.; Prelim. Notice Lamellib. Shell of the Up. Helderberg, Hamilton and Chemung groups, etc. (distributed without author's name), 1869.

A single right valve of this species has been noticed among the collections of the survey, having a length of three-fourths of an inch, and presenting the usual characters shown on those from the Burlington sandstones and from the Marshal sandstones of Michigan. The form is elongate-elliptical, the length nearly twice and a half the height; beak small and inconspicuous, situated at about, or a little within the anterior third of the length; anterior end the largest, and rounded; the posterior end narrowed from the beak and the extremity more sharply rounded, the longest point being a little above the middle of the height, the basal line rounding upward from just behind the center; hinge-line gently curved and marked by numerous small teeth. Surface of the shell marked by somewhat regular concentric lines of growth.

The original specimens of the species were from the Marshal sandstones near Battle Creek, Michigan; and were described as coming from coal measure strata, in consequence of which they were overlooked in the description of *Leda Barrisi;* but several years afterward, in looking over the type collection of Mr. R. P. Stevens, his specimens were noticed and recognized as specifically identical with those from the Burlington sandstone, and to have come from strata other than coal measures. The form described as *Nucula Iowensis* in the same paper with *Leda Barrisi* was also recognized under the name *Nucula Houghtoni* Stevens, and as these names antidate *Leda Barrisi* and *Nucula Iowensis* these latter will take their place as synonyms.

It is of considerable interest to find this species, which in Ohio, Michigan and Iowa, is found in rocks which are considered as of Waverly age, here associated with so many forms of undoubted Hamilton age; and it shows conclusively the close connection and uninterrupted passage of the fauna of this earlier period into that of the later, and if the Waverly group proves to be of Lower Carboniferous age, as is claimed for it, a passage of the fauna of one into that of a subsequent AGE. It also proves a connecting link between the formations around Milwaukee and those of Michigan on the opposite side of the lake.

Formation and locality. In the Hamilton group, at White Fish Bay, near Milwaukee, Wisconsin.

PALÆANEILO EMARGINATA.

Plate XXVI. Fig. 11.

Nuculites emarginata — Conrad; Ann. Rept. Geol. Surv. N. Y., 1841, p. 50.
Palæaneilo emarginata — (Con. sp.) — H. & W.; Prelim. notice, Lamellibranch. shells of the Up. Helderberg, Hamilton and Chemung groups, etc., p. 7 (distributed without author's name), 1869.

Shell small, strongly convex, very transverse, with dorsal and basal margins straight and parallel; anterior end short and rounded; posterior end narrowed from below and extended along the cardinal line, the extremity pointed or slightly rounded; posterior basal margin sharply and deeply constricted or emarginate, corresponding to a deep, sharp sulcus which crosses the surface of the shell from behind the beaks to this point, producing a strongly marked feature. Beaks small and inconspicuous, situated near the anterior extremity. Surface of the shell ornamented by very distinct, regular, raised lamellose lines or ridges, parallel to the margin and marking stages of growth. Entire length of the shell equal to about twice the height.

The Wisconsin specimens of this species are somewhat smaller than those from New York, and are usually slightly flattened; in which condition they present an appearance somewhat intermediate between the *P. emarginata* and *P. filosa* (Conrad, sp.) of the Chemung group of New York, but when compared with small individuals of the first named species they are found to correspond very closely.

Formation and locality. In the Hamilton group, at Washington street bridge, Milwaukee, and at White Fish Bay, Wisconsin.

CEPHALOPODA.

GENUS GOMPHOCERAS, Sowerby.

GOMPHOCERAS ? FUSIFORME, n. sp.

Plate XXVI. Fig. 16.

Shell rather below a medium size, very moderately expanding from below upward to near the middle of the outer chamber, as seen on the type specimen, above which it again decreases to the aperture somewhat more abruptly than below. Section circular, or very nearly so, the slight flattening of the specimen probably due to compression. Septa not distinctly defined in the specimen, but apparently about one-sixteenth to one-twelfth of an inch apart, and but slightly concave. Siphuncle not observed.

The aperture of the specimen is narrowly sinuate on one side, but does not appear to have been contracted and trilobed as is usual with specimens of the genus from older rocks. This feature is noticeable in many species of this group of shells from rocks of the Devonian age, and it is probable they may require a different generic designation if it is found to be a prevailing feature of those of this period.

Formation and locality. In the Hamilton group, at White Fish Bay, near Milwaukee, Wisconsin.

GOMPHOCERAS BREVIPOSTICUM, n. sp.

Plate XXVI. Fig. 15.

Shell rather below a medium size, very rapidly expanding from below upward, the rate of increase more rapid toward the base of the outer chamber than in the earliest stages of growth, and again decreasing in the same rate to near the middle of the chamber, and gently contracted above to the aperture. The rate of increase in the type specimen in a length of two inches below the point of greatest diameter, is from a little less than five-eighths of an inch to one inch and seven-eighths; septa moderate, those preserved being about one-eighth of an inch apart; siphuncle lateral in the specimen; aperture sharply sinuate on one side, at a distance of one-fourth of the circle from the position of the siphuncle. No evidence of the lobed contraction of the aperture, as in the Silurian examples of the genus, exists.

The specimen is flattened by compression, so that the apparent expansion is probably somewhat greater than natural.

Formation and locality. In the Hamilton group, at White Fish Bay, near Milwaukee, Wisconsin.

CRUSTACEA.

Genus PHACOPS, Emmerich.

PHACOPS RANA.

Plate XXVI. Figs. 17–19.

Calymene bufo, var. rana — Green; Mon. Am. Trilobites, p. 42, 1832.
Phacops rana (Green) — Hall; 15th Rept. State Cab., p. 93, 1862; Illust. Dev. Foss., 1876, Pl. VII and VIII.
Phacops rana (Green) — M. & W., Geol. Rept. Ill., Vol. III, p. 447, Pl. XI, Fig. 1.

The few imperfect fragments of this species which the collection contains, are sufficiently characteristic to leave no reasonable doubt of their specific identity. They consist of two separated pygidial plates, and a nearly entire thorax, but no heads have been examined; consequently, the most reliable features of the species have not been noticed. The portion of the thorax preserved, consists of parts of eleven segments, and is a little wider than long, the greatest width being at about the fourth segment from the anterior end, from which point it gently contracts, with a slight curvature, to the pygidium, some parts of which are visible. The axial lobe is moderately elevated, regularly tapering backward and slightly narrower than the lateral lobes. Lateral lobes flattened on the surface for nearly two-thirds of their width; outside of the flattening they are rounded and rapidly declining to the margin. Articulation strongly convex and moderately arched forward in the centre of the axis and gently inclined backward across the flattened portion of the lateral lobe, and more strongly bent at the angle of the lobe, but rounded forward at the extremities of the pleura.

The pygidial plate is transversely subelliptical, with obtusely pointed lateral extremities, and a moderately convex surface. Axis narrow, scarcely more than one-fourth of the entire width of the plate, even on the anterior end, rapidly narrowing posteriorly in the cast, pointed at the extremity, which terminates a little within the outer margin. Axis marked by about eight rings exclusive of the anterior articulating projection; lateral lobes marked by five on the cast, and possibly there may have been six showing on the outer crust. The specimens all being casts, the surface features of the crust cannot be determined.

Formation and locality. In the Hamilton group, at Washington street bridge, and at White Fish Bay, near Milwaukee, Wisconsin.

SUPPLEMENTARY SPECIES.

Genus DIKELLOCEPHALUS, Owen.

Dikellocephalus lodensis.

Plate XXVII. Figs. 12 and 13.

Dikellocephalus Lodensis— *Whitfield; ante*, p. 188; also Ann. Rept. Wis. Geol. Surv. 1880, p. 51.

This species was first founded upon a single detached cheek. Since that time I have received other material which illustrates the species more fully, and from which the following description is drawn.

Body broadly ovate in outline, the width across the upper part of the thorax being about two-thirds as great as the entire length, the whole being distinctly trilobed. Cephalic shield, as shown by the left movable cheek, and an isolated glabella and fixed cheeks referred to the same species, has been broadly subsemicircular. Glabella depressed convex, half as long again as wide across the middle, slightly narrowed anteriorly and rounded on the anterior end, but presenting a somewhat squarish aspect in front. Two pairs of glabellar furrows mark its surface, the posterior pair unite in the center and form a continuous line across the glabella, of nearly equal strength with the occipital furrow and parallel to it; the anterior pair are faintly marked, each one extending only about one-third of the width of the glabella. Occipital ring broad, round on the surface and projecting somewhat beyond the sides of the glabella at the dorsal furrows. Dorsal furrows very distinct, and continued with equal strength in front of the glabella. Anterior limb of moderate width, though considerably exceeding that of the occipital ring. Fixed cheek rather narrow, not very prominent. Eye lobes wider than the fixed cheeks above and below and convex on their surfaces, the channel bordering the eye narrow and deep. Posterior limbs long and narrow, the occipital furrow strongly marked along their surfaces. From the dorsal furrows at the antero-lateral angles of the glabella, small furrows cross the fixed cheeks in an obliquely upward direction, separating the fixed cheeks from the frontal rim.

The movable cheeks are elongate, subtriangular in form, with a gently convex surface; the ocular rim is large and the outer margin strong and thickened and is extended backwards from the genal angle into long, round spines, which reach to the extremity of the sixth thoracic segment.

Thorax composed of ten segments, which gradually decrease in size from in front backward. Axial and lateral lobes subequal in width, the pleura strongly recurved and pointed at their extremities, and longitudinally divided by an oblique furrow which rises near the upper edge at the dorsal furrow and terminates below the middle on the outer flattened or free portion. Axial lobes of the segments marked at their outer ends by broad bosses or tubercles.

Pygidium transverse and broadly elliptical with a strong central axis, which is marked by four elevated rings, exclusive of the large terminal one; lateral lobes marked by four ribs each, which are deeply divided by longitudinal furrows, all of which terminate considerably within the margin of the plate.

The surface of the cheek plate within the marginal rim, the axial lobes of the thoracic segments and the primary divisions of the pleura, as well as the corresponding parts of the pygidium are thickly covered with raised, rounded granules of moderate size, giving a distinctly verrucose surface to these parts of the crust. The occipital ring and the space between the furrows on the sides of the glabella also show indications of the same structure, though much less distinctly than the other parts of the body. (The specimen shows evidence of recent abrasion, and in several places has been scraped with a knife or other sharp instrument, enough to have destroyed such ornamentation, had it existed; but the granules have been much less distinct than on the other parts.)

The specimens from which the above description is drawn consist of an isolated glabella and fixed cheeks very nearly perfect, and an individual in which the pygidium, thorax and the left movable cheek are preserved intact and quite complete; the central plate of the head and right movable cheek only being absent, thus making perhaps the most complete individual of a *Dikellocephalus* yet obtained in this country.

The principal point of distinction between this species and *D. pepinensis* rests in the granulose surface structure. I have examined a large number of separated glabellas, movable cheeks and pygidia from La Grange mountain, Minn., Owen's typical locality for his species, and from Mazomanie, Wis., but have not been able to detect on any of them the slightest indication of this granulose structure. Other points of distinction may be found in the structure of the central plate and glabella. The anterior or third pair of furrows are not at all discernible, and the second pair are slightly nearer the anterior end of the glabella. The fixed cheeks are a little wider, and the furrows passing from the anterior angles of the glabella across the fixed cheeks is a feature not possessed by the glabellas from the other localities. The movable cheeks are proportionally longer, and the spines of the posterior angles more slender, but not nearly so long as in the *D. pepinensis*. The pygidium is very similar to that of Owen's species, but is quite perceptibly broader in proportion to its length.

It may be possible that the glabella and fixed cheeks above described do not belong to this species; but so far as I am aware, it is the only form of these parts found associated at the locality, not already determined. The fact that there are so few granules on its surface, and those quite obscure, while the movable cheek and other parts found in juxtaposition are so thickly covered, is rather an evidence against their union. At the same time, there is another form of movable cheek, possessing a very similar facial suture; in that respect corresponding as nearly to the glabella in question as the one associated with the thorax and pygidium; but it has a much broader marginal border and strong, broad spine, while the broader occipital ring would require a wider and stronger lateral posterior limb than that of this glabella. It has therefore been thought best to consider it as of a distinct species and to place the glabella with this species until evidence to the contrary is obtained.

The example of this species retaining the parts in position will serve to throw more light on the characters of the genus *Dikellocephalus* than has been hitherto possessed, especially in regard to the number of segments composing the thorax, which are stated by Dr. Owen under the original description as probably eight. The position of the fixed cheek and pygidium in this specimen leaves no doubt whatever of the number in this species being ten, and ten only; at least at this stage of development; while it may be possible that some species may have had but eight.

Formation and locality. In the upper part of the Potsdam formation at Prairie du Sac, Wis., found and presented by R. E. Stone, Esq., of that place.

Dikellocephalus crassimarginatus, n. sp.

Plate XXVII. Fig. 14.

Dikellocephalus Pepinensis? Hall; 16th Rept. State Cab. N. Y., pl. 11, Explanation Fig. 2.

The movable cheek, for which the above name is proposed, is usually nearly as wide from the lower angle of the ocular sinus, as the length from the line of the posterior occipital margin to the frontal projection of the marginal rim; which gives the plate a much greater width than is the case of that found with the body of *D. Lodensis*. The marginal rim is also very wide and heavy in appearance, being fully one-fourth of an inch in the widest part of the specimen figured. The spine at the posterior angle is about as long as the body of the plate; is very wide at its origin and tapers rapidly to the point. Ocular sinus large; occipital ring, as shown on the plate, proportionately broad and convex. The line of the facial suture is very similar to that of *D. Lodensis*, differing only in the greater distance across the occipital ring.

The specimen figured in the 16th Rept. State Cab. N. Y. *loc. cit.* was referred with doubt to *D. Pepinensis*, being associated with that species at La Grange Mountain, Minn., but it is evidently not of the same species as the common form found in those beds and associated with the glabellas and pygidia of that species; nor is there any other part yet known that can with satisfaction be classed with it. But as it is apparently not of extremely rare occurrence, I have thought it best to treat it so that it may be spoken of and referred to in a definite manner. The surface of the cheek near the ocular sinus is marked by faint wavy lines in curves, nearly parallel to the border of the sinus.

Lingulella Stoneana, n. sp.

Plate XXVII. Figs. 6 and 7.

Lingula aurora var. Hall; 16th Rept. State Cab. N. Y., p. 127, pl. 6, Figs. 6–8.

Associated with the above two species of *Dikellocephalus* on the same blocks are impressions of the *Lingulella* which was published in the 16th Rept. State Cab. under the name *Lingula aurora* var. retaining all the peculiarities of the specimens from Mazomanie which led to their identification as a variety. Their persistence in specimens from other localities would seem to give them sufficient weight to be considered as of specific importance. I therefore propose to recognize it as such under the above name given in honor of R. E. Stone, Esq., the discoverer of the specimens of *Dikellocephalus* above described.

The peculiar surface ornamentation of this species seems to be one that characterizes many forms of this genus in the primordial formations. It is caused by a series of concentric lines which cross the shell in a direction different from the ordinary lines of growth, sometimes assuming a nearly opposite direction; and are consequently an independent feature depending on a series of changes in the mantle of the animal during the formation of the shell; as in the case of *Lucina divaricata* and many other forms of Lamellibranchiate shells.

Genus LINGULA, Brey.

Lingula elderi, n. sp.

Plate XXVII. Figs. 1–5.

Shell oblong and subquadrangular in outline, with nearly or quite parallel lateral margins, which are but very slightly curved; anterior and posterior extremities subequal, the upper end being slightly angular at the apex and on the shoulders, while the front or anterior end is broadly rounded. Valves rather strongly convex, the dorsal or shorter valve being a little the most convex and the valve as shown by the cast frequently marked by a slight flattening, or even by a depressed longitudinal line along the middle of the front half. Surface of the shell, as seen on fragments adhering to the casts, nearly smooth, being marked only by fine concentric lines of growth; and its substance thick.

The interior of the shell of this species as shown by the internal casts appears to correspond more nearly to that of the recent forms of the genus than any other Silurian or Devonian species I have ever examined. In fact the muscular scars and vascular lines would seem to correspond exactly with those of *L. anatina* Lam., as given by Allany Hancock, Esq., in his excellent memoir published in the Phil. Trans. 1858, so far as the different elements of the scars can be detected. Of course there are variations in the position of different scars and somewhat in the lines of the pallial sinuses, and vascular ramifications, but not more so than one would expect to find in different species of the same genus. All the muscles have left their imprint on the internal casts in a remarkable manner, even the pallial sinuses with their interior and exterior ramifications are shown, and even their posterior prolongations with their ramifications are shown, on the dorsal side of two individuals.

I have not been able to trace all of the elements of the muscular system, nor to detect the divisions between those forming the larger scars; some of which in the recent forms are seen to be composed of three or four elements; but where they are impressed on the shell and leave the trace of their advance over its surface in the process of growth, this would scarcely be possible in the fossil.

In the dorsal valve the impression of the pallial sinuses (p s) are deeply marked and are widely separated, leaving the area within them very considerable; the central or inner ramifications (1) are very distinct, and the outer ones also for a short distance from the main branches, while the posterior branches show the lateral ramifications (2) only on the outer side. The divaricator muscular scar of the dorsal valve (d) is very large and curved forward at the sides, being situated well back near the apex of the valve. It cannot be positively traced on the ventral side, most of the specimens being imperfect at this point. The anterior adductor scars (a a) are small and situated near the center of the valve, while the posterior abductors (p a) are large and situated outside of and posterior to them so as to inclose their posterior ends. The adjustor muscles (a d) are distant from each other, and placed just within the posterior third of the length of the shell. Two elements can be detected in each scar on some individuals, but they are usually obscure.

On the ventral valve the lines of the pallial sinuses are nearer together on the anterior half of the shell than on the dorsal, the same as shown in *L. anatina*, but spread out rapidly toward the middle, and, on the posterior half, occupy nearly the same relative position as on the other side. Near the center of the valve are seen a pair of large scars (p a), which have advanced from behind their track, forming a strong feature on the cast, as it originates just in front of the position of the divaricator muscular scar (d), and gradually widens as it advances until it occupies fully one-half of the width of the cast near the middle of its length. In the central line of these scars there is an elevated ridge, which terminates in a slightly prolonged tongue, and seems to represent the central adjustors (c a). The large scars outside of these are probably the posterior adductors and external adjustors combined. Posterior to these and distant from the median line are other scars, which are long and narrow, which have also left their track as they have advanced. Two elements are represented on each side, and mark the place of the posterior adjustors and anterior adductors (p a and a a). Between the lines formed by the advance of the scars of the adjustor muscles and those of the central area, on each valve, there is a narrow smooth impressed space, which unites with the line of the pallial sinuses at the junction of the anterior and posterior branches, seen on all the specimens, and for which I have not been able to satisfactorily account, as it lies within the area of the muscular scar, and consequently within the walls of the perivisceral chamber. The area of attachment of the muscular walls of the perivisceral chamber has not been detected, unless it be combined with the scar of the posterior branches of the pallial sinuses, which really seems to be the case. If this is so, the posterior branches of the sinuses can have had ramifications on but one side instead of on both, as in the case of *L. anatina*. This would be a marked specific but not a generic character.

It has been thought and argued by many persons that the genus Lingula, as represented by *L. anatina* Lam., was not represented in the older Palæozoic rocks, if in any of the rocks of that age, and for this reason there has been a disposition to class all the Linguloid shells of that age under other generic names, but the beautifully preserved markings of these casts, I think, have proved beyond doubt that we have it represented in the Trenton period by at least one unquestionable species.

Formation and locality. In the Trenton limestone ("buff limestone"). The specimens figured were presented to me several years since by Dr. Elder, formerly of New York city, who collected them near Rochester, Minnesota. I have also received specimens from Mr. N. S. Ainslie, of that place, and have collected several imperfect specimens near Beloit, Wisconsin.

Genus DINOBOLUS, Hall.

Dinobolus parvus, n. sp.

Plate XXVII. Figs. 8—10.

Shell, as represented by the internal cast, the only condition under which the species has been observed, small, subcircular in outline and lenticular in profile, the dorsal valve being considerably more convex than the ventral, and both valves the most ventricose in the upper part. In the cast the dorsal valve is characterized by a proportionally large depressed area of a broadly ovate form, extending from the upper portion to below the middle of the length, most deeply sunken toward the front, where it is slightly prolonged in a rounded tongue-like extension, and along the middle of the area a slightly raised and rounded ridge is distinctly shown. Indications of separate muscular scars are seen in the upper part of the area. A similar depressed area of a subtriangular form represents the scars in the ventral valve, and occupies nearly the upper half of the length and is as wide across the base as the length; from the lower central portion a broad, shallow, rounded groove extends to the front of the cast; and a narrow slit marks the center of the impression. In a cardinal view the peduncular groove is shown to have been large and the cardinal process of considerable strength. Other muscular scars not visible; surface shown to have been strongly marked with concentric undulations. The characterizing marks of the species are the small size and the groove extending from the base of the muscular scar of the ventral valve to the front border.

Formation and locality. In the Galena or lead-bearing limestone layers at Whitewater, Wisconsin.

Genus HOLOPEA, Hall.

Holopea obesa, n. sp.

Plate XXVII. Fig. 11.

Shell large, robust, extremely ventricose and natica-like; with strongly rounded, almost inflated volutions, about five in number, the last one of which forms more than one-half the entire height of the shell, and expands very rapidly. Height of the shell about equal to the greatest diameter across the body whorl; giving an apical angle of about ninety degrees. Suture line very distinct, and in the cast deep and strongly marked, leaving the volution distinctly rounded on the summit. Base of the last volution round and the shell deeply umbilicated. The aperture has been broadly ovate and distinctly modified by the intrusion of the preceding volution. The surface of the shell has been marked by strong irregular growth lines, which have a strong backward direction in crossing from the suture to the base of the volution. There are also slight evidences of the existence of faint revolving lines on the body of the last volution.

The species is one of a group of large forms of the genus, characterizing the horizon of the Calciferous sandstone or Lower Magnesian limestone formation, which appear to have very close affinities with each other. The present species is most nearly allied to *H. turgida* (=*Pleurotomaria turgida*, Hall, Pal. N. Y., Vol. I, pl. 12, p. 3, figs. 9 and 10), from which it differs in the more erect form and less obliquity of the volutions, as well as in the more elevated spire. I should infer from the description given in Pal. Foss. Can. Vol. I p. 28 of *H. Proserpina*, Billings, that there was great similarity between it and New York species, the principal points of difference being in the proportions of height and breadth. *H. ovalis*, Bill., *loc. cit.*, p. 351, fig. 2, is more elongated than this one and the volutions less ventricose; while *H. Hageri* of the same work, p. 29, fig. 27, has much the same form, but the upper volutions are flattened in the direction of the spire.

Formation and locality. The specimen in our possession, and from which the description is taken, is an imperfect internal cast in white chert, stained by iron. It was found loose at River Falls, Wisconsin. Its characters are the same as those of the loose cherty nodules of the Lower Magnesian limestones commonly found in the drift material of that part of the state.

NOTE A.—In Vol. 5 of the Palæontology of New York (dated December 15, 1879, distributed in December, 1880, see Am. Jour. Sci., Vol. XX, p. 489), at page 139, there occur some remarks, by the author, on the limestones at the Falls of the Ohio, and their relations to the Hamilton Group of New York. By reading these remarks one would be led to infer that the discovery that the limestones near Milwaukee are of the age of the Hamilton Group of New York, is there for the first time recognized. This very erroneous idea may be readily corrected by reference to the Report on the Geol. Survey of Wisconsin for the years 1873 to 1877, pp. 79 and 85; but is more satisfactorily explained on p. 395, where Prof. T. C. Chamberlin has a chapter on the "HAMILTON CEMENT ROCK." On page 397 and succeeding pages, lists of the fossils from these beds, as recognized by myself in the collections of the survey at Beloit College in 1877, are given, which show positively what age the beds belong to, and were positively recognized as, at that time. For the authority for the lists, see p. 262 of the same report under the head of "Organic Remains." R. P. W.

GENERAL LIST OF THE FOSSILS

Recognized within the state, including those described in this volume; and showing the formations in which they occur.

Genera and Species.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
PLANTÆ.									
Palæochordia, sp. undet	*								
Phytopsis tubulosa, Hall			*						
Cruziana, sp. und	*		*	*					
Palæophychus cæspitosum, Hall			*						
P. duplex, Hall ?	*								
P. plumosus, Whitf	*								
P. simplex, Hall	*								
P. tubularis, Hall	*								
P. sp. undet	*		*		*				
Buthotrephis gracilis, Hall			*						
B. succulens, Hall			*	*					
B. sp. undet			*	*		*			
Fucoids, gen. and sp. undet		*							
Sphenothallus, sp. undet								*	
PROTOZOA.									
PETROSPONGIA.									
Astylospongia, sp. undet			*	*					
Stromatopora concentrica, Goldf						*	*		
S. sp. undet		*				*			
FORAMENIFERA.									
Receptaculites globularis, Hall				*					
R. hemisphericus, Hall						*			
R. infundibuliformis, Hall						*			
R. Iowensis, Owen				*					
R. Oweni, Hall				*					
Ceryonites dactyloides, Owen's sp						*			
RADIATA.									
ZOOPHYTA.									
ALCYONARIA. *(Graptolitidæ.)*									
Oldhamia ? sp. undis			*						
Buthograptus laxus, Hall			*						
Dendrograptus Hallianus, Prout	*								
Dictyonema Neenah, Hall			*						
Diplograptus Peosta, Hall			*						
Climacograptus typicalis, Hall ?				*					
C. sp. undet				*	*				
Graptolitic bodies, gen. and sp. undet			*	*					

General List of the Fossils — continued.

Genera and Species.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
ZOANTHARIA-TABULATA.									
Chætetes atritus, Nich					*				
C. briareus, Nich					*				
C. discoideus, James			*	*	*				
C. fusiformis, Whitf					*				
C. Jamesi, Nich					*				
C. lycoperdon, Say?			*	*	*				
C. pulchellus, Nich			*						
C. sp. undet			*	*	*				
Monticulipora Dalei, Ed. & H			*						
M. mammalata, D'Orb					*				
M. multituberculata, Whitf					*				
M. Ortoni, Nich					*				
M. pavonia, D'Orb					*				
M. punctata, Whitf					*				
M. rectangularis, Whitf					*				
M. ramosa, D'Orb					*				
M. rugosa, Ed. & H					*				
M. sp. undet					*				
Dekaya aspera? Ed. & H					*				
Favosites favosus, Gold						*			
F. Gothlandicus, Gold.?						*			
F. Niagarensis						*	*		
F. occidens, Whitf							*		
F. sp. undet			*			*			
Astrocerium constrictum, Hall						*			
A. venustum, Hall						*	*?		
Columnaria alveolata, Gold			*						
C. sp. undet			*						
Alveolites irregularis, Whitf					*				
A. sp. undet					*		*		
Cladopora reticulata, Hall						*			
C. reticulata? with finer cells						*			
C. sp. undet							*		
Heliolites macrostylus, Hall						*			
H. pyriformis, Guttard?						*			
H. spinopora, Hall						*			
Halysites agglomeratus, Hall						*			
H. catenulatus, Linn						*	*		
H. c. var. labyrinthicus, Goldf						*	*		
H. c. var. micropora, Whitf						*	*		
Thecia minor, Rominger						*			
T. major, Rominger						*			
Cœnites lunatus, Nich. & Hinds						*			
ZOANTHARIA-RUGOSA.									
Syringopora compacta, Billings						*			
S. Dalmani, Billings						*			
S. retiformis, Billings						*			
S. verticillata, Goldf						*			
Diphiphyllum cæspitosum, Hall						*	*		
D. sp. undet							*		
Eridophyllum, sp. undet						*			
Cystostylus infundibulus, Whitf						*			

GENERAL LIST OF THE FOSSILS — continued.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
ZOANTHARIA RUGOSA — con.									
Cystostylus typicus						*			
Strombodes pentagonus, Goldf						*	*		
S. sp. undet						*			
Zaphrentis, sp. resemb. Z. gigantea						*			
Z. (Polydilasma) turbinata, Hall sp.						*			
Z. Racinensis Whitf						*			
Z. sp. undet			*	*		*	*		
Amplexus annulatus, Whitf							*		
A. fenestratus, Whitf						*			
A. Shumardi, Ed. & H						*			
A. sp. undet						*	*		
Omphyma stokesi, Ed. & H., ?						*			
Aulacophyllum, sp. undet						*			
Cyathoxonia Wisconsensis, Whitf						*			
Chonophyllum magnificum, Bill							*		
C. Niagarensis, Hall						*			
C. sp. undet						*	*		
Cystiphyllum Niagarense, Hall						*			
C. Niagarense ?							*		
Cyathophyllum, sp. undet									*
Streptelasma calyculum, Hall						*			
S. corniculum Hall			*	*					
S. multilamellosum, Hall				*					
S. profundum, Conrad			*						
S. sp. undet			*	*	*	*			
Calceola? sp.?			*						
ECHINODERMATA.									
CYSTIDEA.									
Pleurocystites squamosus, Bill				*					
Glyptocystites Logani, Bill				*					
Holocystites abnormis, Hall						*			
H. alternatus, Hall						*			
H. cylindricus, Hall						*			
H. ovatus, Hall						*			
H. scutellatus, Hall						*			
H. Winchelli, Hall						*			
Gomphocystites clavus, Hall						*			
G. glans, Hall						*			
Echinocystites nodosus, Hall						*			
Crinocystites ornatus, Hall						*			
C. sp. ?						*			
Hemicosmites subglobosus, Hall						*			
Apiocystites imago, Hall						*			
A. sp. undet				*					
CRINOIDEA.									
Cryptodiscus sp. ?						*			
Platycrinus sp. undet						*			
Saccocrinus Christyi, Hall						*			

General List of the Fossils — continued.

Genera and Species.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
CRINOIDEA — continued.									
Saccocrinus semiradiatus, Hall						*			
Metocrinus verneuili, Troost						*			
Eucalyptocrinus cœlatus, Hall						*	*		
E. cornutus, Hall						*			
E. cornutus, var. excavatus, Hall						*			
E. crassus, Hall						*			
E. obconicus, Hall						*			
E. ornatus, Hall						*	*		
E. sp. undet						*			
Macrostylocrinus striatus, Hall						*			
Caryocrinus ornatus, Say						*			
Cyathocrinus Cora, Hall						*			
C. pisiformis, Rœmer						*			
C. Waucoma, Hall						*			
C. sp. ?			*						
Poteriocrinus, sp. undet			*	*					
Schizocrinus nodosus, Hall			*	*					
Homocrinus, sp. undet			*	*					
Rhodocrinus rectus, Hall						*			
Glyptaster occidentalis, Hall						*			
G. pentangularis, Hall						*			
Glyptocrinus armosus, McChes. sp						*			
G. nobilis, Hall						*	*		
Lampterocrinus inflatus, Hall						*			
Icthyocrinus subangularis, Hall						*			
Lichenocrinus, sp. ?.					*				
Stephanocrinus gemmiformis, Hall						*			
MOLLUSCA.									
MOLLUSCOIDEA.									
BRYOZOA.									
Alecto inflata, Hall					*				
Aulopora (?) arachnoidea, Hall					*				
Palæschara, sp. undes					*				
Lichenalia concentrica, Hall						*			
Sagenella membranacea, Hall						*			
S. sp. ?						*			
Cornulites-like tubes			*						
Constellaria polystomella, Nich					*				
Clathropora flabellata, Hall						*			
Fenestella elegans, Hall						*			
F. granulosa, Whitf					*				*
F. sp. undet						*			
Polypora incepta, Hall						*			
Retopora, sp. undes					*				
R. sp. undet			*		*	*			
Ptilodictya recta, Hall			*	*					
P. sp. undet			*	*					
Stictopora elegantula, Hall			*	*	*				
S. fragilis, Bill					*				
S. ramosa, Hall			*						

General List of the Fossils — continued.

Genera and Species.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
BRYOZOA — con.									
Stictopora sp. undet			*	*					
Heiopora sp. undet					*				
Fistulipora lens, Whitf					*				
F. rugosa, Whitf					*				
F. solidissima, Whitf					*				
F. sp. undes					*				
Trematopora, annulifera, Whitf					*				
T. granulata, Whitf					*				
T. sp.?			*	*	*	*			
BRACHIOPODA.									
Lingula ampla, Hall	*								
L. attenuata, Hall			*						
L. Maquoketa					*				
L. mosia, Hall	*								
L. quadrata, Eichwald?			*	*					
L. obtusa, Hall			*						
L. palæaformis, Hall									*
L. Winona	*								
L. sp. undes				*					
Lingulella aurora, Hall	*								
L. aurora var., Hall	*								
L. Iowensis, Owen				*					
Lingulepis pinnaformis, Owen sp	*								
Discina inutilis, Hall	*								
D. marginalis, Whitf									*
Trematis sp. undet			*			*			
Schizocrania filosa, Hall sp			*						
Obolella polita, Hall	*								
Pholidops truncata, Hall				*					
Crania antiqua, Hall					*				
C. scabiosa, Hall				*					
C. sp. undes			*						
Dinobolus Conradi, Hall						*			
Monomerella prisca, Bill							*		
M. sp. undet				*					
Trimerella grandis, Bill						*			
Orthis bellarugosa, Hall			*	*					
O. biloba, Linn						*			
O. borealis, Bill			*						
O. disparalis, Conrad			*						
O. elegantula, Dalman						*	*		
O. Ella, Hall			*						
O. equivalvis, Conrad			*	*					
O. flabellula, Sowerby						*			
O. hybrida, Dalman						*			
O. impressa, Hall									*
O. Kankakensis, McChes					*				
O. lynx, Eich			*	*	*				
O. oblata, Hall								*	
O occidentalis, Hall					*				
O. pectinella, Conrad			*	*	*				

General List of the Fossils — continued.

Genera and Species.	Potsdam.	Lower Magnesian	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
BRACHIOPODA — con.									
Orthis plicatella, Hall	....	....	*	*	....	....	....	....	....
O. perveta, Conrad	....	....	*	*	....	....	....	....	....
O. Pepina, Hall	*	....	....	....	....	....	....	....	....
O. subcarinata, Hall	....	....	....	....	....	....	....	*	....
O. subequata, Conrad	....	....	*	....	....	....	....	....	....
O. subquadrata, Hall	....	....	*	....	*	....	....	....	....
O. testudinaria, Dalman	....	....	*	*	*	....	....	....	....
O. tricenaria, Conrad	....	....	*	*	*	....	....	....	....
O. sp. undet	....	....	*	*	*	*	....	....	....
Hemipronites Americana, Whitf	....	....	....	*	....	....	....	....	....
Streptorhynchus cardinale, Whitf	....	....	....	....	*	....	....	....	....
S. deflectum, Hall	....	....	*	*	....	....	....	....	....
S. deltoideum, Conrad	....	....	*	*	....	....	....	....	....
S. filitextum, Hall	....	....	*	....	*	....	....	....	....
S. planoconvexum, Hall	....	....	*	....	....	....	....	....	....
S. planumbonum, Hall	....	....	*	....	*	....	....	....	....
S. sinuatum, Emmons	....	....	*	....	....	....	....	....	....
S. subtentum, Hall	....	....	*	....	....	....	....	....	....
S. subplanum, Conrad	....	....	....	....	....	*	....	....	....
S. sp. new and undet	....	....	*	....	*	*	....	....	....
Strophomena alternata, Conrad	....	....	*	*	*	....	....	....	....
S. antiqua, Sowerby	....	....	....	....	*	....	....	....	....
S. camerata, Conrad	....	....	*	*	*?	....	....	....	....
S. camura, Conrad	....	....	*	....	....	....	....	....	....
S. incrassata, Hall?	....	....	*	*	....	....	....	....	....
S. Kingi, Whitf	....	....	....	....	*	....	....	....	....
S. nitens, Bill	....	....	....	....	*	....	....	....	....
S. patenta, Hall	....	....	....	....	....	*	....	....	....
S. profunda, Conrad	....	....	....	....	....	*	?	....	....
S. recta, Conrad	....	....	....	....	*	....	....	....	....
S. rhomboidalis, Wahl	....	....	....	....	....	....	*	....	....
S. semifasciata, Hall	....	....	....	....	....	*	....	....	....
S. tenuistriata, Hall	....	....	*	....	....	....	....	....	....
S. tenuilineata, Conrad	....	....	*	....	....	....	....	....	....
S. Thalia, Bill	....	....	....	....	*	....	....	....	....
S. unicostata, M. & W.	....	....	....	....	*	....	....	....	....
S. Wisconsensis, Whitf	....	....	....	....	*	....	....	....	....
S. new and undet. sp	....	....	*	*	*	*	....	....	....
Strophodonta demissa, Conrad	....	....	....	....	....	....	....	....	*
S. inequistriata, Conrad	....	....	....	....	....	....	....	....	*
S. perplana, Conrad	....	....	....	....	....	....	....	....	*
S. striata, Hall	....	....	....	....	....	*	....	....	....
Skenidium insignum, Hall?	....	....	....	....	....	*	....	....	....
Leptæna Barabuensis, Winchell	*	*	....	....	....	....	....	....	....
L. sericea, Sowerby	....	....	*	*	*	....	....	....	....
L. tranversalis, Dalman	....	....	....	....	....	*	....	....	....
Chonetes coronata, Conrad	....	....	....	....	....	....	....	....	*
C. deflecta, Conrad	....	....	....	....	....	....	....	....	*
Productella spinulicosta, Hall	....	....	....	....	....	....	....	....	*
Spirifera angusta, Hall	....	....	....	....	....	....	....	....	*
S. (Cyrtina?) aspera, Hall	....	....	....	....	....	....	....	....	*
S. audacula, Conrad=S. medialis, Hall	....	....	....	....	....	....	....	....	....

General List of the Fossils—continued.

Genera and Species.	Potsdam.	Lower Magnesian	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
BRACHIAPODA—con.									
Spirifera euritunes var. fornacula, Hall									*
S. gibbosa, Hall						*			
S. granulifera, Hall									?
S. mucronata, Conrad									*
S. nobilis, Barr						*			
S. meta, Hall						*			
S. pennata, Owen									*
S. plicatella, Sowerby						*			
S. plicatella var. radiata, Sowr						*	*		
Cyrtina? aspera, Hall									*
C. Hamiltonensis, Hall									*
Spiriferina? zigzag, Hall									*
Trematospira hirsuta, Hall									*
Meristella (Charionella) Hyale, Bill							*		
M. nucleolata, Vanux								*	
Retzia sp. undet							*		
Atrypa hystrix, Hall									*
A. nodostriata, Hall						*			
A. reticularis, Linn						*			*
A. spinosa, Hall									*
A. sp. undet							*		
Zygospira modesta, Hall			*	*	*				
Z. recurvirostra, Hall			*	*					
Rhynchonella Anticostensis, Bill			*	*					
R. capax, Conrad			*	*	*				
R. cuneata, Dalman							*		
R. Indianensis, Hall						*			
R. Janea, Bill					*				
R. Neenah, Whitf			*	*	*				
R. neglecta, Hall						*	*		
R. perlamellosa, Whitf					*				
R. pisum, H. & W							*		
Leiorhynchus Kelloggi, Hall									*
Leptocœlia planoconvexa, Hall						*			
L. plicatula, Hall						*			
Triplesia primordialis, Whitf	*								
Eichwaldia reticulata, Hall						*			
Camarella hemiplicata, Hall's sp			*	*					
C. ops, Bill			*						
Pentamerus bisinuatus, McChes						*			
P. fornicatus, Hall						*			
P. oblongus, Murch						*	*		
P. pergibbosus, H. & W						*	*		
P. ventricosus, Hall						*	*		
P. sp. undet						*	*	*	
Gypidula multicostatus, Hall						*	*		
G. occidentalis, Hall						*	*		
Stricklandinia Galtensis, Bill						*			
S. multilirata, Whitf							*		
Anastrophia interplicata, Hall						*			
Rensellæria, sp. undet							*		

General List of the Fossils — continued.

Genera and Species.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
MOLLUSCA-VERA.									
LAMELLIBRANCHIATA.									
Pterinea aviculoidea, Hall	...	...	...	...	...	...	...	*	...
P. brisa, McChes	...	...	...	...	...	*	...	...	...
P. demissa, Conrad	...	...	...	...	*	...	...	...	...
Pteronites, sp. undet	...	...	...	...	...	...	...	...	*
Ambonychia acutirostra, Hall	...	...	...	...	...	*	*	...	...
A. attenuata, Hall	...	...	*	...	...	...	...	...	...
A. lamellosa, Hall	...	...	*	*	...	...	...	...	...
A. planistriata, Hall	...	...	*	...	...	...	...	...	...
A. radiata, Hall	...	...	*?	*	...	...	...	...	...
A. recta, Hall	...	...	*	*	...	...	...	...	...
A. sp. undet	...	...	*	...	...	...	...	...	...
Tellinomya alta, Hall	...	...	*	...	...	...	...	...	...
T. Iphigenia, Bill	...	...	*	...	...	...	...	...	...
T. levata, Hall	...	...	*	...	...	...	...	...	...
T. nasuta, Hall	...	...	*	...	...	...	...	...	...
T. ventricosa, Hall	...	...	*	...	...	...	...	...	...
T. sp. undet	...	...	*	*	...	...	...	...	...
Cypricardites Canadensis, Bill	...	...	*	...	...	...	...	...	...
C. Niota, Hall	...	...	*	...	...	...	...	...	...
C. megambonus, Whitf	...	...	*	...	...	...	...	...	...
C. rectirostris, Hall	...	...	*	...	...	...	...	...	...
C. rotundatus, Hall	...	...	*	...	...	...	...	...	...
C. subtruncatus, Hall	...	...	*	...	...	...	...	...	...
C. ventricosus, Hall	...	...	*	...	...	...	...	...	...
C. sp. undet	...	...	*	...	...	...	...	...	...
Cleidophorus neglectus, Hall	...	...	...	...	*	...	...	...	...
Palæoneilo constricta, Conrad's sp	...	...	...	...	...	...	...	...	*
P. emarginata, Conrad's sp	...	...	...	...	...	...	...	...	*
P. fecunda, H. & W	...	...	...	...	...	...	...	...	?
P. nuculiformis, Stevens' sp	...	...	...	...	...	...	...	...	*
Leptodomus (Amphicœlia) Leidyi, Hall's sp	...	...	...	...	...	*	...	...	...
L. (Amphicœlia) neglectus, McChes	...	...	...	...	...	*	...	...	...
L. undulatus, Whitf	...	...	...	...	...	*	...	...	...
Megalomus Canadensis, Hall	...	...	...	...	...	...	*	...	...
Modiolopsis dictæus, Hall	...	...	...	...	...	*	...	...	...
M. faba, Hall	...	...	*	...	...	...	...	...	...
M. Nilesi, M. & W	...	...	...	...	...	*	...	...	...
M. plana, Hall	...	...	*	...	...	...	...	...	...
M. recta, Hall	...	...	...	...	...	*	...	...	...
M. superba, Hall	...	...	*	...	...	...	...	...	...
M. sp. undet	...	...	*	...	...	*	...	...	...
Modiomorpha concentrica, Conrad's sp.	...	...	...	...	...	...	...	...	*
Schizodus? sp. undet	...	...	...	...	...	*	...	...	...
GASTEROPODA.									
Palæacmæa Irvingi, Whitf	*	...	...	...	...	...	...	...	...
Metoptoma Barabuensis, Whitf	...	*	...	...	...	...	...	...	...
M. patelliformis, Hall	...	...	...	...	*	...	...	...	...
M. perovalis, Whitf	...	...	*	...	...	...	...	...	...
M. recurva, Whitf	...	*	...	...	...	...	...	...	...

GENERAL LIST OF THE FOSSILS — continued.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
GASTEROPODA — con.									
Metoptoma retrorsa, Whitf.		*							
M. similis, Whitf.		*							
Platyceras primordialis, Hall	*								
P. Niagarensis, Hall						*			
Platyostoma Niagarensis, Hall							*		
Euomphalus macrolineatus, Whitf.						*			
E. Strongi, Whitf.		*							
E. vaticinus, Hall	*								
E. (Straparollus?) mopsis, Hall						*			
Straparollus Hippolyte, Bill.							*		
S. solaroides, Hall							*		
S. sp. undet		*							
Straparollina, sp.?						*			
Ophileta? (Raphistoma) primordialis, Winchell	*								
O. uniangularis, Vanuxem		*							
O. sp.? (casts only)		*							
Helicotoma planulata, Salter			*						
H. sp. undet				*	*				
Holopea elevata, Hall							*		
H. Guelphensis, Bill.							*		
H. harmonia, Bill.							*		
H. magniventra, Whitf.							*		
H. obliqua, Hall			*	*					
H. paludinæformis, Hall			*	*					
H. (Pleurotomaria) turgida, Hall		*							
Holopea Sweeti, Whitf.	*								
H. sp?		*							
Cyclonema (?) elevatum, Hall						*			
C. pauper, Hall						*			
C. sp. resembling C. pauper							*		
C. percarinata, Hall			*	*					
C. sp. ?						*			
Raphistoma lenticularis, Sowr.			*	*					
R. Niagarensis, Whitf.						*			
R. Nasoni, Hall			*						
R. sp. ?			*	*					
Trochonema ambiguum, Hall			*						
T. Beachi, Whitf.			*						
T. Beloitense, Whitf.			*						
T. fatua, Hall						*	*		
T. lapicidum, Salter					*				
T. umbilicatum, Hall			*	*					
T. sp. undet			*	*					
Zenophora trigonostoma, Meek						*			
Loxonema Leda, Hall						*			
L. magnum, Whitf.							*		
Eunema (Murchisonia) pagoda, Salter?			*						
Subulites elongatus, Conrad			*	*					
S. ventricosus, Hall							*		
Clisospira occidentalis, Whitf			*						
Pleurotomaria advena, Winchell	*								
P. Axion, Hall						*	*		
P. depauperata, Hall			*						

General List of the Fossils — continued.

Genera and Species.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
GASTEROPODA — con.									
Pleurotomaria Galtensis, Bill							*		
P. Halei, Hall						*	*		
P. Hoyi, Hall						*			
P. Idia, Hall						*			
P. Laphami, Whitf						*			
P. occidens, Hall						*			
P. niota, Hall			*						
P. Racinensis, Whitf						*			
P. perlata, Hall						*			
P. subconica, Hall			*						
P. sp. undet			*	*		*			
Murchisonia bellicincta var. major, Hall				*					
M. bicincta, Hall			*	*					
M. Boydi, Hall							*		
M. Chamberlini, Whitf							*		
M. Conradi, Hall						*			
M. gracilis, Hall			*	*					
M. helicteres, Salter			*						
M. Hercyna, Bill							*		
M. Laphami, Hall						*			
M. Logani, Hall							*		
M. longispira, Hall							*		
M. macrospira, Hall							*		
M. mylitta, Bill							*		
M. (Eunema) pagoda, Salter			*						
M. tricarinata, Hall			*						
M. turritiformis, Hall							*		
M. ventricosa, Hall			*						
M. sp. undet			*	*		*			
Fusispira elongata, Hall				*					
F. ventricosa, Hall				*					
F. sp. undes				*					
Maclurea Bigsbyi, Hall			*						
M. cuneata, Whitf				*					
M. subrotunda, Whitf				*					
HETEROPODA.									
Bucania bidorsata, Hall			*						
B. Buelli, Whitf			*						
B. trigonostoma, H. & W						*			
B. punctifrons, Hall			*						
Bellerophon antiquatus, Whitf	*								
B. bilobatus, Sowr			*						
B. Wisconsensis, Whitf			*						
Cyrtolites compressa, Conrad			*						
C. Dyeri, Hall				*					
Scævogyra elongata, Whitf		*							
S. obliqua, Whitf		*							
S. Swezeyi, Whitf		*							

GENERAL LIST OF THE FOSSILS — continued.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
PTEROPODA.									
Ecculiomphalus undulatus, Hall	....	....	*	....	....	....	....	....	....
Pterotheca attenuata, Hall	....	....	*	....	....	....	....	....	....
Hyolithes Baconi, Whitf	....	....	*	....	....	....	....	....	....
H. primordialis, Hall	*	....	....	....	....	....	....	....	....
Conularia Trentonensis, Hall	....	....	....	*	....	....	....	....	....
CEPHALOPODA.									
Orthoceras abnorme, Hall	....	....	....	....	....	*	*	....	....
O. alienum, Hall	....	....	....	....	....	*	....	....	....
O. amplicameratum, Hall	....	....	....	*	....	....	....	....	....
O. anullum, Conrad	....	....	*	....	....	....	....	....	....
O. annulatum, Sowerby	....	....	....	....	....	*	*	....	....
O. (Actinoceras) Beloitense, Whitf	....	....	*	....	....	....	....	....	....
O. capitolinum, Safford	....	....	*	....	....	....	....	....	....
O. Carltonense, Whitf	....	....	....	....	....	....	*	....	....
O. columnare, Hall	....	....	....	....	....	*	*	....	....
O. crebescens, Hall	....	....	....	....	....	*	....	....	....
O. Hoyi, McChes	....	....	....	....	....	....	*	....	....
O. junceum, Hall	....	....	*	*	....	....	....	....	....
O. Laphami, McChes	....	....	....	....	....	*	....	....	....
O. medulare, Hall	....	....	....	....	....	*	....	....	....
O. Niagarense, Hall	....	....	....	....	....	*	....	....	....
O. multicameratum, Hall	....	....	*	....	....	....	....	....	....
O. planoconvexum, Hall	....	....	*	*	....	....	....	....	....
O. primogenium, Hall	....	*	....	....	....	....	....	....	....
O. verebrale, Hall	....	....	....	....	....	*	....	....	....
O. Wauwatosense, Whitf	....	....	....	....	....	*	....	....	....
O. sp. undet	....	....	*	....	....	*	....	....	*
Actinoceras (Orthoceras) Beloitense, Wh.	....	....	*	....	....	....	....	....	....
Ormoceras tenuifilum, Hall (?)	....	....	*	....	....	....	....	....	....
O. sp. undet	....	....	*	....	....	*	....	....	....
Endoceras annulatum, Hall	....	....	*	....	....	....	....	....	....
E. proteiforme, Hall	....	....	*	....	....	....	....	....	....
E. (Cameroceras) subannulatum, Whitf	....	....	*	....	....	....	....	....	....
E. sp. undet	....	....	*	....	....	....	....	....	....
Huronia annulatum, Hall	....	....	....	....	....	*	....	....	....
Discoceras (Gomphoceras) conoideum Hall	....	....	....	....	....	*	....	....	....
Gomphoceras fusiforme, Whitf	....	....	....	....	....	....	....	....	*
G. breviposticum, Whitf	....	....	....	....	....	....	....	....	*
G. scrinium, Hall	....	....	....	....	....	*	....	....	....
G. septoris, Hall	....	....	....	....	....	*	....	....	....
G. sp. undet	....	....	*	....	....	*	*	....	....
Cyrtoceras annulatum, Hall	....	....	*	....	....	....	....	....	....
C. articameratum, Hall	....	....	....	....	....	....	*	....	....
C. brevicorne, Hall	....	....	....	....	....	*	....	....	....
C. camurum, Hall	....	....	*	....	....	....	....	....	....
C. corniculum, Hall	....	....	*	....	....	....	....	....	....
C. dardanum, Hall	....	....	....	....	....	*	....	....	....
C. eugium, Hall	....	....	*	....	....	....	....	....	....
C. infundibulum, Whitf	....	....	....	....	....	*	....	....	....
C. laterale, Hall	....	....	....	....	....	*	*	....	....
C. loculosum, Hall	....	....	*	....	....	....	....	....	....

General List of the Fossils — continued.

Genera and Species.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
CEPHALOPODA — con.									
Cyrtoceras macrostomum, Hall			*						
C. Neleus, Hall			*						
C. planodorsatum, Whitf.			*						
C. rectum, Whitf.							*		
C.? rigidum, Hall						*	?		
Oncoceras abruptum, Hall			*						
O. Alceus, Hall			*						
O. brevicurvatum, Hall			*						
O. Lycus, Hall			*						
O. mumiaformis, Whitf.			*						
O. Orcas, Hall						*			
O. Pandion, Hall			*						
O. plebium, Hall			*						
Gonioceras anceps, Hall			*						
G. occidentalis, Hall			*						
Phragmoceras Hoyi, Whitf.						*			
P. Hoyi, var. compressum, Whitf.						*			
P. labiatum, Whitf.						*			
P. Nestor, Hall						*			
Gyroceras convolvans, Hall			*						
G. duplicostatum, Whitf.			*						
G. Hercules, W. & M.						*			
G. sp. undet			*			*			
Nautilus occidentalis, Hall						*			
N. sp. undet						*			
Lituites multicostatus, Whitf.						*			
L. occidentalis, Hall			*						
L. Ortoni, Meek						*			
L. Robertsoni, Hall			*						
Trochoceras costatum, Hall						*			
T. Desplainense, McChes						*			
T. Gebhardi, Hall							*		
ARTICULATA.									
ANNELIDÆ.									
Arenicolites Woodi, Whitf	*								
Serpulites Murchisoni, Hall	*								
Ortonia, sp?						*			
Worm-like tubes		*	*						
CRUSTACEA.									
ENTOMOSTRACA.									
Leperditia alta, Conrad								*	
L. fabulites, Conrad			*						
L. fonticola, Hall						*			
Beyrichia, sp. undet			*		*				

GENERAL LIST OF THE FOSSILS — continued.

GENERA AND SPECIES.	Potsdam.	Lower Magnesian.	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
TRILOBITA.									
Pemphigaspis bullata, Hall	*								
Agnostus disparalis, Hall	*								
A. Josepha, Hall	*								
A. paralis, Hall	*								
Aglaspis Barrandi, Hall	*								
A. Eatoni, Whitf.	*								
Ellipsocephalus curtus, Whitf.	*								
Dikellocephalus Barabuensis, Whitf.		*							
D. Eatoni, Whitf.		*							
D. Lodensis, Whitf.	*								
D. Minnesotensis, Owen	*								
D. Minnesotensis, var. limbatus, Hall	*								
D. Miniscaensis, Owen	*								
D. Miniscaensis var., Hall	*								
D. misa, Hall	*								
D. Osceola, Hall	*								
D. Pepinensis, Hall	*								
D. spiniger, Hall	*								
Chariocephalus Whitfieldi, Hall	*								
Triarthrella auroralis, Hall	*								
Conocephalus (Agraulos) anatinus, H.'s sp.	*								
Conocephalus binodosus, Hall	*								
C. calymenoides, Whitf.	*								
C. diadematus, Hall	*								
C. (Arionellus) dorsalis, Hall's sp.	*								
C. eos, Hall	*								
C. (Ptychaspis) explanatus, Whitf.	*								
C. Hamulus, Owen	*								
C. Iowensis, Owen	*								
C. minor, Shumard	*								
C. nasutus, Hall	*								
C. optatus, Hall	*								
C. Patersoni, Hall	*								
C. Perseus, Hall	*								
C. ? quadratus, Whitf.	*								
C. Shumardi, Hall	*								
C. Winona, Hall	*								
C. Wisconsensis, Owen	*								
Crepicephalus? Gibbsi, Whitf.	*								
C. onustus, Whitf.	*								
Arionellus bipunctatus, Shumard	*								
A. convexus, Whitf.	*								
A. sp. undet	*								
A. (Conoceph.) dorsalis, Hall	*								
Agraulos (Conoceph.?) anatinus, H.'s sp.	*								
A. (Bathyurus?) Woosteri, Whitf.	*								
Ptychaspis Barabuensis, Winchell	*								
P. (Conoceph.) explanatus, Whitf.	*								
P. granulosus, Owen	*								
P. Miniscaensis, Owen's sp	*								
P. minuta, Whitf.	*								
P. striata, Whitf.	*								
P. sp. undet	*								

General List of the Fossils — continued.

Genera and Species.	Potsdam.	Lower Magnesian	Trenton.	Galena.	Hudson River.	Niagara.	Guelph.	Lower Helderberg.	Hamilton.
TRILOBITA — con.									
Calymene Clintoni, Hall						*			
C. Niagarensis, Conrad						*			
C. senaria, Conrad			*	*	*				
Asaphus Barrandi, Hall			*						
A. gigas, D'Kay			*						
A. Iowensis, Owen			*						
A. homalonotoides, Walcott			*						
A. Susæ, Calvin			*						
A. sp. undet			*		*				
Illænus armatus, Hall						*			
I. crassicauda, Wahl			*						
I. cuniculus, Hall						*			
I. Daytonensis, H. & W.						*			
I. imperator, Hall						*			
I. insignis, Hall						*			
I. Ioxus, Hall						*			
I. Iowensis, Owen				*					
I. Madisonianus, Whitf						*			
I. oratus, Conrad			*						
I. pterocephalus, Whitf						*			
I. taurus, Hall			*	*					
I. sp. undet			*	*	*	*			
Illænurus convexus, Whitf		*							
I. quadratus, Hall	*								
Harpes, sp. undet				*					
Ceraurus Niagarensis, Hall						*			
C. pleurexanthemus, Green			*						
C. sp. undet			*			*			
Encrinurus ornatus, H. & W.						*			
E. sp			*			*			
Sphærexochus Romingeri, Hall						*			
Sphærocephalus sp. undet				*					
Dalmania callicephalus, Hall			*	*					
D. nicta, Hall			*						
D. vigilans, Hall						*			
D. sp.?			*						
Phacops rana, Green									*
P. sp. undet						*			
Prœtus undet. sp				*					
Lichas phlyctonodes, Green						*			
Bronteus acamas, Hall						*	*		
B. Laphami, Whitf						*			
VERTEBRATA.									
PISCES.									
Rhynchodus excavatus, Newberry									*
Plate of Placoderm									*

PART IV.

THE ORE DEPOSITS

OF

SOUTHWESTERN WISCONSIN.

BY T. C. CHAMBERLIN.

HISTORICAL REVIEW.

In Volume II of this series of reports, the late lamented Moses Strong described the general geology and topography of the lead region, and presented statistics in relation to the mines and mining operations. For reasons there in part indicated, he did not, however, enter upon a systematic discussion of the forms and methods of deposition of the lead and associated ores, nor of the theoretical considerations that relate to the subject. This, by Mr. Strong's preference, falls to the writer, and will constitute the central subject of this report. While, for completeness and convenience, topographical and geological facts may be passed in review, it will be only because of their relationship to the special subject under discussion, and only those features will usually be selected which seem to have a bearing upon the elucidation of the metalliferous deposits.

I desire to ask, at the outset, the patience and pardon at once of both the professional and non-professional reader; of the former, for the introduction of some elementary statements for the convenience of the latter, and of the latter, for the use of some chemical and other technical terms that are necessary to a precise discussion of the subject.

The origin of the lead, zinc, and associated ores of the Mississippi Valley has very naturally been the theme of much speculation and discussion, though less often the subject of careful and systematic investigation. Dr. Percival seems to have been the first competent geologist who gave the subject a sufficient amount of special study to entitle his opinions to deferential consideration. Dr. Owen had indeed preceded him, and was possessed of acknowledged ability, but he was not permitted, by the limitations of time and the legal requirements imposed upon him, to give these deposits thorough personal examination.

He has not left us any clear and definite statement of his views, which, at the best, must have been based upon general considerations, but he indicated a belief in the derivation of the ores from beneath, and implied that they were in some way due to the fact that they are "based upon a syenitic and granitic platform lying somewhere between one thousand and two thousand feet below."

Dr. Percival gave the fall of 1854 and the spring and early summer of 1855, to a minute and critical study of the forms and geological relations of the lead deposits, and he has left us, in his two preliminary reports for those years, a large amount of valuable data. Probably at no time in their history, have the mines been more extensively or actively worked than during the period of Dr. Percival's investigations; and his observations, at that stage of their development, are of much service to all subsequent investigators. They would, doubtless, have proved much more valuable, had their gifted author lived to complete his examinations, and to make a report embodying a complete exposition of his observations and opinions, properly illustrated. The want of adequate maps and figures — very pardonable in an annual report of progress — is yet much to be regretted, since they would have added clearness and definiteness to some statements that are now somewhat ambiguous, as all merely verbal descriptions are liable to be.

Dr. Percival seems to have arrived at his general conclusions as to the descent of the deposits very early in the course of his examinations, indeed even before his investigations on behalf of the state were commenced, for he says:

"I have also employed, in preparing this report, such facts as I had collected the former year, in the employment of the American Mining Company (N. Y.), in exploring different localities in the same district, and particularly in examining the different strata, in reference to the probable descent of the mineral through them. On this point, of so much importance to the mining interest, I had then ascertained a series of facts which seemed to prove that all the limestones, from the surface of the upper magnesian [Galena limestone] to a considerable depth, at least, in the lower magnesian, were good lead-bearing rocks. My researches this year have enabled me to add many convincing proofs to what I had before ascertained, the whole showing a regular descent of the mineral through all the rocks, within the limits above indicated, except the upper sandstone."

He very candidly adds:

"I have had no opportunity, this season, of extending my researches in the lower magnesian, its outcrop occurring chiefly in the northern part of the district, which I have not yet visited."

The following paragraph also deserves a place here:

"From the short time that I have been employed by the state, it cannot be expected that I should prepare a complete report. In this, I have had in view the immediate interests of the mineral district, and I have endeavored to give it a practical bearing. My object has been to give general views of more immediate importance, and rather to point out the method I design to pursue than to give the results of a survey. Local details, and such as have no direct bearing on my present object, are reserved to another occasion."

The passage above quoted indicates the views Dr. Percival held with reference to the downward extension of the metallic deposits. Precisely what he meant by "a *regular descent* of the mineral through all the rocks," I do not find more definitely indicated than in the following statements from p. 68 of his first report:

"I have thus been able to trace the mineral in a series of crevices and openings from the summit of the upper magnesian to the depth of 60 to 70 feet in the lower magnesian, and have found all the beds of limestone good mineral-bearing rocks, each with one or more openings, besides vertical or pitching sheets or veins. The small depth to which mining has been extended does not allow one to trace the mineral through the whole of the extent downward in any one instance, but wherever circumstances permit of examination, the order of succession in the openings is found to be regular, and in multiplied instances vertical crevices and veins have been found passing down from one opening to another. It is then probable that the series is generally continued through the whole downward extent indicated, subject only to such interruptions as are more or less common in all veins. The arrangement appears most analogous to that of the lead mines in the North of England, where the veins traverse different beds of limestone, separated by beds of other rock (sandstone or grit, shale, and toadstone or amygdaloid), but the mineral is chiefly confined to the limestone, the other beds being generally considered barren, and where there is a similar combination of vertical crevices and veins with more or less extensive flats, corresponding to the flat sheets and openings in the mineral district."

It should be borne in mind that this was written at a date when something of indefiniteness of ideas concerning the English deposits was doubtless pardonable; but in 1861 Wm. Wallace published an elaborate discussion of the lead deposits of Alston Moor, abundantly illustrated by maps and sections. From this and other authorities it appears that both in the Alston Moor district and in Derbyshire, the leading districts of the north of England, the fissures are of an altogether different character from the crevices of Wisconsin, being due to extensive breaks and dislocations of the strata. The displacement of the beds sometimes amounts to a fault of 200 feet. In Wisconsin, displacements, except of the most trivial character, have not been found. But it is more important to observe that, notwithstanding the English fissures traverse the strata to great depths, and penetrate igneous rocks, there is no "regular descent of the mineral."

Mr. Wallace says:[1] "In Alston Moor the veins have been the most productive in situations furthest removed from Plutonic action, the richest deposits having been effected in the upper part of the Mountain Limestone, where no igneous rocks are found, either in the form of dykes or sheets intermingled horizontally with the stratified rocks. The lower part of the strata in this district comprehends a stratum of

[1] On the Laws which Regulate the Deposition of Lead Ore in Veins, by Wm. Wallace, 1861, p. 99.

Basaltic Greenstone, and also a Basaltic dyke, but the veins generally have contained very little lead ore where these rocks form their sides or walls. Doukeburn east and west vein has been proved to contain scarcely any ore for a considerable distance on each side of the Basaltic dyke. So far as this district is concerned, there is nothing to support the theory that lead is due to exhalations from beneath or to matter injected in a fluid state among the consolidated sedimentary rocks."

By the expression, "good lead-bearing rocks," Dr. Percival would seem to imply that in his view the ore deposit was dependent on the character of the inclosing rock; but, on the other hand, he indicates a belief that the crystalline rocks ("primary and igneous") were influential agencies. These implied views are, perhaps, not necessarily inconsistent, but their harmony is not evident, and before any safe, practical considerations can be drawn, the precise influence of each agency ought to be shown. Undoubtedly Dr. Percival would have discussed the subject more fully had his life been spared; but justice to the practical issues involved forbids us from giving undue weight to the opinions of even one so much respected, unless fully supported by data and reasons, especially so since some views then prevalent in respect to metallic deposits have been discarded in the light of the developments of the quarter century that has intervened.

Dr. Percival seems to have been the first to study critically the surface arrangement of the lead-bearing crevices, and to associate them in groups and series. So far as the grouping into "diggings and districts" is concerned, we have no occasion, even now, to change or modify in any important respect the groups of crevices described by him; but in his attempt to arrange these districts into great series or belts, he can scarcely be regarded as eminently successful, since no subsequent investigator seems to have been impressed with the force of his groupings. Probably no one else has been more successful, while some have certainly been less natural and more arbitrary. The fact seems to be that there is no very conspicuous and natural arrangement of the diggings into great series, although there is an obscure tendency to an irregular belt-like arrangement, but this is not sufficiently definite to admit of unequivocal interpretation, if studied simply from surface mapping.

Dr. Percival noted the existence of several points within the district where the strata were lifted above their normal position, which he designated "centers of elevation." In his last year's work he also recognized the existence of corresponding depressions. Both of these he appears to have attributed wholly to disturbance of the strata, and not at all to irregularity of original deposition, and to have emphasized its amount in some measure beyond what a more critical study would warrant. As this undulatory character of the strata forms an element in my own theory of the method of deposition of the ores, I am not indisposed to accept as pronounced views of the undulations of the strata as the facts will permit. But it is quite certain that a portion of the present undulation is due to original deposition on an uneven ocean bed, and the remaining portion to subsequent disturbance. The amount of this disturbance, while noteworthy, was not by any means very great, and Dr. Percival's reference of sudden changes in the height of beds to faults was doubtless a misconception, they being really due to the abrupt irregularity of the strata, now known to be a common feature of these formations. These apparent faults and disturbances seem to have been important elements in Dr. Percival's theory of the origin of the deposits, for he says:

"The opinion expressed in my former report, that the mineral was derived from beneath, is strengthened not only by the general results of my observations in the diggings, but by the appearance of disturbance in the strata, particularly along the line of the great body of mineral traversing the middle of the district, and by the relation in the bearing of that body to the extensive ranges of primary and metamorphic rocks towards the northeast, indicating that the mineral may have arisen from a mass of such rocks beneath the secondary strata."[1]

It is unfortunate for this theory, however, that not one of these "centers of elevation" is the center of a heavy ore deposit, while on the other hand, it is quite certain that some, and apparently most of the deposits, lie in depressions of the strata, as will appear in the fuller discussion of the subject in the body of the report.

Dr. Percival clearly perceived and fully set forth the important distinctions between the character of the north-south and the east-west crevices.

Whatever of adverse judgment has been implied in this brief sketch of Dr. Percival's views has been introduced reluctantly, and purely from a feeling that it was but just to him to review his work, and, on the other hand, but just to the practical issues involved to dissent from what seemed, in the light of continued exploration and more recent investigation, to be untenable. But I do not allow this to detract from the just and high esteem in which Dr. Percival will always be held.

In the year 1859, Prof. J. D. Whitney began an investigation of the lead formations of Wisconsin, having previously studied the adjacent deposits of Iowa. In his report of 1862, he presented an able and elaborate discussion of the subject, giving an extended description of

[1] An. Rep. 1856, p. 63.

the forms and relations in which the ores are found, together with his views as to their origin. Our space will manifestly not permit a minute review of this report of 358 pages, nor indeed is it greatly demanded, since the report itself is well known and quite widely accessible. Prof. Whitney differed quite radically from Drs. Owen and Percival in his views of the source of the deposit. Instead of derivation from beneath, due, in some unexplained way, to disturbances of the strata that, at best, were but slight, Prof. Whitney maintained that metallic salts were held in solution in the waters of the ancient ocean, from whence the lead-bearing strata were deposited, and that they were thrown down by the action of organic matter, or the sulphuretted hydrogen arising from its decomposition, and so were mingled with the accumulating sediment. Afterwards the metallic materials, thus disseminated through the strata, were concentrated in fissures and openings, forming the present deposits. The crevices, Prof. Whitney attributed to the ordinary jointing that is common to almost all rocks, and to the elevatory movements to which the region has been subject.

The views of Prof. Whitney have been very generally accepted by the scientific world, though they have been less cordially received by the people of the lead region, since the practical inferences from them are thought to be less encouraging in regard to the permanence of mining. The people have, however, generally recognized the fact that it is more important to know the truth than to be beguiled into useless expenditures by a flattering hypothesis.

There are, however, certain features of Prof. Whitney's theory that are not quite satisfactory. He assumes that the general oceanic waters of the early geological periods were more highly impregnated with metallic salts than in later ages, and that, on the introduction of life, and its death and decay, there arose chemical agencies which caused the deposition of these metallic salts, mingled with the accumulating sediments. If this be true, it is a logical inference, (1.) That the metallic depositions would correspond to the introduction and distribution of life; (2.) That the ores would appear in the strata when life first appeared; (3.) That they would be abundant or sparse, according to the luxuriance of life; (4.) That they would continue prevalent in the life-bearing beds till the oceanic supply was exhausted, when they would cease. But as far down as the Huronian formation of the Lake Superior region, and the still lower Laurentian of Canada, there are great beds of carboniferous shale, graphite, and limestone, indicating, it is confidently believed, an abundance of life. A section of the Huronian strata in the Menominee region probably contains more carbonaceous matter than a similar section of the entire

Silurian strata of Wisconsin. But noteworthy deposits of lead and zinc are not prevalent in these strata, as the theory would seem to demand. Again the Upper Silurian and Devonian beds are very prolific in organic remains, but in this country they are nearly destitute of the ores under consideration, while in the still later and not more fossiliferous Lower Carboniferous limestones are found the great deposits of southwestern Missouri, and the north of England, and minor accumulations elsewhere, and even in the Triassic beds of Silesia, Carinthia and elsewhere important deposits occur.

On the other hand, the great deposits of eastern and central Missouri lie in beds which correspond to our Lower Magnesian limestone, and are, like it, almost destitute of well preserved fossils.

Still further it is to be noted that even the lead bearing strata themselves do not carry the ores throughout their entire horizontal extent, though often more fossiliferous than in the lead bearing districts, and still further, even in the productive regions the ores are found in abundance only in circumscribed areas. In short, there is no such uniform and specific correspondence between the prevalence of organic remains in the strata, and the richness of lead and zinc deposits as to make that appear to be the sole-determining agency. Prof. Whitney was not unaware of this objection, as indicated by the following quotation:[1]

"Another question which will naturally be asked in reference to the views advanced above is this: Why, if the metalliferous solutions from which the ore deposits of the Lead Region were thrown down, were diffused through the oceanic waters, there was not a precipitation of the metallic sulphurets over every part of the valley of the Upper Mississippi? or why is the productive mining ground confined to a limited area, while over a vast extent of country, for all that can be seen on the surface, there is no reason why equally important deposits should not exist?

"To this we reply that we believe that it would be found that, were the earliest highly fossiliferous formations everywhere exposed, they would be found, to a considerable extent, impregnated with the sulphurets of lead, zinc, iron, etc.; and in proof of this we refer to the fact that the Silurian, and especially the Lower Silurian rocks, are much more metalliferous than any other series of strata occupying the same area and with the same thickness. But these are not commonly exposed, being almost everywhere covered by other groups. Where metalliferous ores do exist in the upper strata, nothing forbids the belief that they may have been derived from previously deposited masses below, carried up in solution by thermal springs or otherwise. If the original conditions under which the ores were deposited in the lower rocks were not favorable to their segregation in large masses, as was the case in the Lead Region, where the rocks were intersected by numerous fissures — then the deposition would take place in a more diffused manner, and we might have a mass of strata impregnated with ore, in small particles, which would thus be liable to oxidation, and would easily be dissolved out and transferred to the upper strata by thermal springs rising through them from beneath."

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[1] Geol. of Wisconsin, 1862, pp. 405, 406.

It is true that there are extensive areas over which the Silurian strata are concealed, and we can have no knowledge of their metalliferous character; but it is equally true that there are other extensive areas over which they are abundantly exposed, and their poverty in lead and zinc ores does not admit of rational doubt. In the matter of segregation we may freely admit that there may be instances where the metallic material remains diffused throughout the rock-mass, and fails to be concentrated owing to unfavorable conditions; but when we have made all due allowance for this, we still find large areas over which the conditions for concentration are seemingly as favorable as those of the lead districts. In the presence of so great richness in certain limited areas, and so great poverty over the much vaster areas of the same and similar formations elsewhere, I cannot convince myself that this reply, though it has some force, is at all adequate. The suggestion that the ores in the upper strata may be derived from beds below, through the agency of thermal springs, seems to me especially unfortunate, as it yields the very basis of the theory held by Prof. Whitney; for, if the Carboniferous lead deposits may be due to thermal springs, much more so, we may fairly reason, the lower Silurian deposits, which lie nearer the thermal rocks below. If warm springs gave rise to the lead and zinc ores of the Sub-carboniferous limestone of southwestern Missouri, much more rationally might the Lower Magnesian ores of eastern and central Missouri, which lie almost in contact with granitic and porphyritic rocks, be so explained. It is evident that the farther we recede from the crystalline rocks, the more inapplicable does the thermal theory, as a general proposition, become.

Before any theory of these deposits can be complete and satisfactory, it must assign a reason why they occur where they do, and not elsewhere, both in respect to their vertical and horizontal distribution. And this applies quite as forcibly to any hypothesis, based on disturbance of the strata or thermal springs, as to oceanic precipitation, for the same strata, which in the lead region are metalliferous, are found to be much more disturbed and to have been much more subjected to heat in the mountainous regions of this and the European continent through stretches of hundreds of miles without producing notable mineral deposits. If simple disturbance of strata made lead mines, they would be as plenty as mountains.

These criticisms do not so much affect the general theory of oceanic derivation as the special phase of it maintained by Prof. Whitney, which, otherwise than in its failure satisfactorily to account for the localization of deposits, is strongly grounded in evidence and justifies the favorable estimate it has quite generally received at the hands of competent scientists. The cause of the localization of deposition, however, stands before the theory of oceanic derivation as its supreme difficulty.

Mr. J. Murrish, in a report as commissioner for the survey of the lead district, made in 1871,[1] maintained that a north and south "axis of physical disturbance" passed through the district near the fourth principal meridian, and that this was crossed by several east and west belts characterized by upheaval, and that the "mechanical force" and thermal agencies connected with these disturbances gave origin to the ore. He attempted to marshal the ore districts into four east and west belts identical with those of disturbance. How far these views accord with the facts of the case the reader will be able to judge by consulting the ample data bearing upon the subject of upheaval, or by inspection of the accompanying crevice maps, on which the ranges are laid down with as much precision as practicable.

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[1] Document accompanying governor's message, 1871.

THE ORE DEPOSITS OF SOUTHWESTERN WISCONSIN.

CHAPTER I.

DATA RELATING TO THE ORE DEPOSITS.

It is proposed in this chapter to present, with as great precision as can be commanded consistent with the requisite brevity, the essential facts that relate to the lead, zinc and associated ore deposits of southwestern Wisconsin, and the immediate inferences that spring from them, reserving, in the main, theoretical considerations for the following chapter.

I. The Nature of the Minerals under Consideration.

A. *The Grouping of the Ores.* It is convenient to speak of these ore formations simply as lead deposits, but in a critical study of the subject, it is important to observe that we have to deal rather with a *group* of minerals than with any single ore. Indeed, at present, zinc is industrially the more important resource, and copper is now being mined with reasonable profit, it is claimed.

The association of ores, though a common, is always an interesting phenomenon, and, in this instance, in the judgment of the writer, has a significance which gives it something of importauce. Viewing the lead region as a whole, the mineral group embraces ores of lead, zinc, iron, copper and manganese, and the minerals calcite and barite. Silver is almost universally found in galena, but in this region the amount present is so minute as to render it notable for its comparative absence. Fluor spar, a not uncommon associate of lead ores, has not been found in the Wisconsin region. Quartz, though abundant in the inclosing beds, in the form of chert, is rare in the crystallized form as an immediate attendant of the ores. Antimony and arsenic, that frequently attend them, have not been observed; so likewise nickel and cobalt, which occur in association with the lead deposits of Missouri, have not been detected in the upper Mississippi region.

It is not to be understood that these minerals are constantly associated with each other throughout the lead region, for, in some localities, little besides lead ore is found; at others, only two or three of the group named. The special distribution of the several minerals will claim attention presently, but it will be helpful first to consider the ores of lead, zinc, iron, copper and manganese, with calcite and barite, as constituting the mineral group presented by the Wisconsin lead region.

In comparison it is interesting to note that the eastern Missouri district presents a somewhat more numerous group, embracing ores of lead, zinc, iron, copper, nickel and cobalt, the last two associated with a little arsenic, and the minerals barite and calcite.

These, like the Wisconsin ores, are poor in silver. This group differs from our own mainly in the presence of nickel, cobalt and arsenic, and in a greater prevalence and preponderance of barite as gangue matter.

The central Missouri lead region affords the same general association of minerals as the Wisconsin district, while that of southwestern Missouri differs in the absence of barite and copper, the presence of greenockite (cadmium sulphide) and of a notable quantity of bitumen, with the predominance of dolomite, only feebly present elsewhere as gangue material.

Quartz is present in all these regions, but not in such form or abundance as to indicate that it has any intimate connection with the special causes of deposition.

In the meager published descriptions of northwestern Arkansas, I find only lead, zinc and calcite noted, suggesting a close alliance with the adjacent Missouri region. In the northeastern district, copper and iron pyrites are added, while in the central region the group remains essentially the same as the last, but a portion of the galena is highly argentiferous. None of the deposits of Arkansas, however, have been developed to a sufficient extent to lend these discriminations much trustworthiness.

In the lead districts near the mouth of the Cumberland river, in Kentucky and Illinois, the lead ore has, for its principal gangue, fluorite and, as accessory associates, blende, calcite and bituminous matter.

If it were our province to discuss lead deposits in general, there would be found, by going beyond the limit of the Mississippi basin, an exceedingly interesting variety of mineral associations, yet possessing, on the whole, a striking similarity. It would appear that zinc is almost universally associated with lead ores, where these occur in magnesian limestone; that iron usually accompanies them, and that the so-called gangue matter is usually either calcite, dolomite, barite, or fluorite. The presence of calcite and dolomite is not especially suggestive, since they largely constitute the material of the inclosing rock, but the presence of barite and fluorite, which are not by any means prevalent in the rocks of the surrounding regions, deserves consideration.

In the districts above cited, barite is confined to the Silurian deposits and fluorite to the Subcarboniferous, but any suggestion of an explanation or generalization on the basis of geological age will be found untenable on a wider view. For barite, as well as fluorite occurs in the Subcarboniferous deposits of Derbyshire, Cumberland and elsewhere, while fluorite is found in the Silurian deposits of New York and at other points in the lower formations.

B. *The Nature of the Minerals.* In a rational study of metalliferous deposits, the precise character of the ores and their mineral associates is of the very highest importance. It is not uncommon to find theories, popularly prevalent, and even occasionally finding their way into official reports, that are wholly inconsistent with the nature of the minerals whose origin they are designed to explain. Veins are sometimes thus held to be filled by igneous injection with minerals that cannot take the fused state together without wholly losing their chemical composition and character. Deposits of mixed ores and spars are sometimes attributed to gases arising from below, notwithstanding the fact that some of the group take the gaseous form only under the most extraordinary circumstances, and the further fact that to volatilize and deposit them in the observed order would require incredible conditions, and the still more decisive difficulty of volatilizing and depositing them simultaneously in the observed form and position, owing to the wide differences in their temperatures of solidification. Other like inconsistencies are met with. The chemical composition, crystalline form and microscopic structure of the minerals involved may be such as to forbid the belief that they originated in certain ways, and these must therefore be rejected in arriving at a rational conclusion as to the manner of their formation. Hence at the outset, there is need for a critical study of the minerals with which we have to deal.

The Wisconsin lead region presents for our special consideration the following minerals: (1) of lead ores, the sulphide, galena, the carbonate, cerussite, and the sulphate, anglesite; (2) of zinc ores, the sulphide, sphalerite or blende, the anhydrous carbonate, smithsonite, and the hydrous carbonate, hydrozincite; (3) of iron ores, the sulphides, pyrite and marcasite, the carbonate, siderite, and the oxides hematite and limonite; (4) of copper ores, the mixed sulphide, chalcopyrite and the carbonates, malachite and azurite; (5) of manganese ores, the oxide, pyrolusite; (6) of lime compounds, the simple carbonate, calcite, the calco-magnesian carbonate, dolomite and the sulphate, gypsum; and (7) of barium salts, the sulphate, barite. A few other minerals will claim attention for special reasons.

It will very much simplify and facilitate our subsequent discussions to distinguish among these minerals two classes, the first including those that retain the form in which they were originally deposited, and the other embracing those that owe their present chemical character to changes that have taken place since deposition. To illustrate, all the lead was, undoubtedly, at first deposited in the form of the sulphide, galena, and the carbonate and sulphate have been derived from this by subsequent chemical change. All the zinc was originally blende, the "drybone" and "bloom" being derived from it. The evidence of this will appear subsequently.

Grouping on this basis, the first class will embrace the lead sulphide, galena, the zinc sulphide, sphalerite or blende, the iron sulphides, pyrite and marcasite, the copper-iron sulphide, chalcopyrite, the lime carbonate, calcite, the lime-magnesian carbonate, dolomite, and perhaps the barium sulphate, barite. To these there is probably to be added a manganese sulphide, though none is now known to exist. In short it may be stated that all the metals were at first deposited as compounds of sulphur; and the spars as carbonates or sulphates.

The second class will include the remainder of the previous list, or in other words, the oxides, carbonates, and sulphates of the metals.

CLASS I.—*Minerals in the form in which they were originally deposited.*

Galenite. *Galena, Lead Sulphide, Sulphuret of Lead, "Mineral."* This is a simple compound of lead and sulphur, in the ratio of 86.6 to 13.4. When perfectly pure the former figure represents the amount of metallic lead in the ore. It very rarely is absolutely free from foreign substances, but in the region under consideration, it attains a very high degree of purity, and the derived metal ranks as the highest grade of "soft lead." The only foreign ingredient that deserves more than passing notice is silver, and that not on account of its amount, but rather its almost entire absence. It is asserted by high authority that all galena is more or less silver-bearing, but the amount contained varies greatly, and this variation has both a practical and a theoretical importance. If the content of silver ranges from six ounces per ton, or thereabouts, upwards, it may be profitably extracted.

The recent remarkable developments in the west have made us very familiar with argentiferous lead ores of high grade. The word "carbonates" has come to have a magical sound. But these carbonates were beyond question derived from silver-bearing galenas.

It has been observed that galena, occurring in veins in crystalline rocks, usually contains a notable percentage of silver, while that formed in unchanged sedimentary strata is very poor in silver. This rule is not, however, universal, and I doubt not that a more exhaustive study of the subject would show that the amount of silver is more intimately connected with the source and method of deposit, than with the character of the inclosing rock. I incline to the opinion that the lead ores, in the course of their history, have undergone solution and redeposit a greater or less number of times, and that, during these processes, owing to the somewhat different affinities of the two metals, they have been in some degree separated. Under this view, the *circumstances* of solution and redeposit would be influential factors, as well as the number of times it was repeated. If the ores were dissolved from deep-seated strata, and simply brought toward the surface, through fissures, and redeposited, no great amount of separation would probably take place. If, on the other hand, the solutions were mingled with the oceanic waters, and, after being borne to various distances, deposited with earthy sediments, again to be taken up and redeposited in crevices and openings, much larger opportunities for the disassociation of the metals would be afforded. If these views be tenable, the amount of separation might be stated as being dependent not only upon the number of times solution and redeposition have taken place, but also upon the circumstances and conditions under which these changes occurred. The original proportion of the two metals is presumed to have been quite varying, but whatever it may have been, these changes might be competent, in some cases, to bring about a nearly complete dissassociation of the two metals, leaving the galena almost entirely free from silver. This view would lead to the presumption that the Wisconsin lead ores had undergone repeated transformations or extended transportation.

The following tables show the amount of silver in the leading lead deposits in the world, in connection with the geological horizon and character of the inclosing rock, so far as at command:

TABLE SHOWING THE AMOUNT OF LEAD AND SILVER IN GALENA FROM DIFFERENT AMERICAN LOCALITIES.[1]

LOCALITY.	Per cent. of lead.	Per cent. of silver.	Ounces of silver in ton of ore.	Geological formation.	Nature of rock.
Upper Mississippi Region.					
Wis., Rockville	....	0.0004	1/8	Galena Limestone...	Dolomite.
Wis., Mineral Point	....	0.0101	3	Galena Limestone...	Dolomite.
Ills., Marsden Lode	....	0.0002	1/14	Galena Limestone...	Dolomite.
Ills., Rosiclare	....	0.0283	9½	Galena Limestone...	Dolomite.
Missouri Region.					
Mo. Granby Mines	84.9	0.0031	1	Lower Carboniferous.	Dolomite.
Central Missouri	86.	trace	.....	Lower Magnesian ...	Dolomite.
Madison Co	12.8	0.0124	4	Archæan	Porphyry.
Ark., Newton Co	76.	0.010	3¼	....	....
Ark., Marion Co	86.	0.028	7⅖	....	....
Ark., Lawrence Co	86.	0.003	1	....	....
Ark., Carroll Co	86.	0.010	3¼	....	....
Ark., Pulaski Co	77.	0.880	287	....	....
Other States.					
Ky., Princeton	80.	0.0017	5/9	....	....
N. H., Shelburne	....	0.147	48	Palæozoic	....
Penn., Chester Co	....	0.0413	13.5	Palæozoic	Metamorphic.
Penn., do. (Pyromorphite)	71.	0.0054	1⅚	Palæozoic	Metamorphic.
North Carolina	17.	0.0250	11⅕	Palæozoic	Talcose Slate.

[1] Compiled by I. M. Buell.

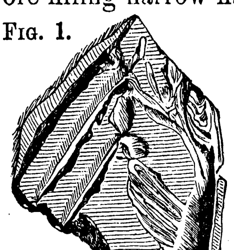
TABLE SHOWING THE AMOUNT OF LEAD AND SILVER IN GALENA FROM DIFFERENT FOREIGN LOCALITIES.

LOCALITY.	Per cent. of lead.	Per cent. of silver.	Ounces of silver per ton.	Geological formation.	Nature of rock.
England.					
Wensleydale (Yorkshire)	80.5	0.0030	1	Carboniferous	Limestone.
Alston Moor (Northumbld)	80.	0.0143	4⅝	Carboniferous	Limestone.
Weardale (Durham)	83.6	0.0120	3 9/10	Carboniferous	Limestone.
Somersetshire	69.8	0.0410	13⅖	.....	.....
Alport (Derbyshire)	82.	0.0040	1⅓	Carboniferous	Limestone.
Shropshire	85.3	0.0016	½	Lower Silurian	.....
Teign Valley (Devonshire)	79.	0.0146	4¾	Devonian	Limestone.
Leicestershire	81.	0.0050	1⅖	.....	.....
Cornwall	78.2	0.0478	15½	Devonian	Limestone.
Isle of Man	79.	0.1477	48¼	Lower Silurian	Slates.
Beer Alston (Devonshire)	.....	0.3399	110	Devonian	Calcareous slate.
Cardiganshire	.....	0.2480	80	Lower Silurian	Slates.
France.					
Pontgibaud	32.4	0.4000	130	.....	Granite, schists.
Pallieres	40.	0.1100	35	.....	.....
Brittany	77.	0.1588	51⅞	.....	.....
.....	80.5	0.3348	109	.....	.....
German Empire.					
Freiberg (Saxony)	40	0.1500	49	Palæozoic	Gneiss, schistose.
Commern	62.5	0.0168	5½	Triassic	Bunter sandstone.
Harz	74.6	0.1000	32	Palæozoic	Breccia.
Harz (Clausthal)	75.1	0.9570	312½	Palæozoic	Breccia.
Tarnowitz, Silesia	75	0.0247	8	Triassic	Muscelkalk.
Freidrich, Silesia	78.5	0.0476	15	Triassic	Muscelkalk.
Obernhof, Nassau	.....	0.2327	75	Silurian	Argillaceous slate.
Bohemia, Przibram	40.75	0.2680	87.5	Lower Silurian	Schist and sandstone.
Gladenbach, Hessen	83.5	0.1400	45 5/7	.....	.....
Spain.					
Carthagena	35.0	0.0801	26.6	.....	Schists and slates.
Sierra Almagrera	.....	0.4654	150	Lower Silurian	Micaceous slate.
.....	84.2	0.0230	7 5/9	Lower Silurian	Limestone.
Other Countries.					
Portugal	83.4	0.0120	4	.....	.....
Portugal	55.	0.2480	81	.....	.....
Bottino (Tuscany)	79.7	0.4570	149	.....	.....
Argenteira (Tuscany)	72.7	0.6850	221	.....	.....
Sardinia	79.8	0.0129	4⅕	.....	.....
Sweden, Sala	75.2	0.7690	251	Azoic	Limestone.
Switzerland	58.6	0.1500	49	.....	.....
Turkey	61.3	0.0400	13	.....	.....
India (Himalaya)	60.	0.0270	8⅘	.....	.....
Siberia, Zerinofsk	.....	0.1000	32⅝	.....	.....
Siberia, Nertschinsk	Lead.	1.8560	606	.....	Limestone.
Australia (Sulphate)	38.	0.1000	32	.....	.....
Peru	56.	1.3595	444	.....	.....
Peru, La Providentia	.....	3.4840	1138	.....	.....
West Indies (St. Kitts)	83.9	0.0055	1.8	.....	.....
Greenland	82.5	0.1800	58⅘	.....	.....
Hudson's Bay (Whale R.)	83.8	0.0164	5⅜	.....	.....

The galena of our lead region shows a marked tendency to crystallize in its most simple fundamental form, the cube. Not infrequently, however, the corners are cut away, as it were, by the planes of the octahedron, and this modification sometimes extends so far as to produce nearly or quite perfect octahedral forms. Perfect octahedrons are, however, very rare and seem only to be found in soft, shaly layers, in the yielding clay of which they were enabled to grow symmetrically. The finest specimen yet seen by me came from Crow Branch and is in the possession of J. H. Evans, Esq., of Platteville. Where the ore forms in close crevices or other confined situations, it is, of course, prevented from taking, externally, a distinct crystalline form; but its cubic cleavage shows that it is definitely crystalline in structure. This prevalent tendency to complete and simple crystallization is perhaps attributable to the exceptional purity of the ore and its exceedingly slow, undisturbed growth.

The cubes are habitually large and clustered, and are then graphically designated "cog mineral," but not infrequently, small cubes, styled "dice mineral," prevail. Large, illy defined masses are known as "chunk mineral," and "sheet mineral" designates thin layers of ore filling narrow fissures, usually vertical.

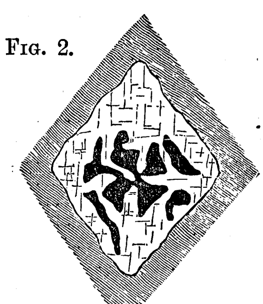
FIG. 1.



RETICULATED GALENA.

Among its most interesting crystalline features are the forms known as "reticulated" galena. In one variety the crystal, instead of being solid within, is formed of alternate plates and spaces, parallel to the exterior, or of bands lying in the axes of the crystals, the remainder of the interior being occupied by angular spaces; or of combinations of these, or of less regular spaces, bounded by faces that are corrugated with minute ridges conformable to the lines of crystallization. Prof. Whitney mentions these cavities as being lined with minute crystals of lead sulphate,[1] and hence attributes the phenomenon to the removal of a portion of the interior of a once solid crystal by solution; the material along the axes being thought to have the power of resisting the decomposing agent for a longer period than the rest of the crystal. I do not, however find the lining of lead sulphate to be by any means universal, or even general, a portion of the filling being car-

FIG. 2.



SHOWING CAVITIES IN GALENITE-CRYSTAL. THE SHADED BORDER REPRESENTS INCLOSING BLENDE, THE BLACK, CAVITIES IN GALENA.

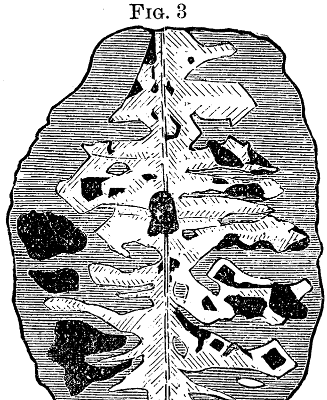
[1] Geology of Wisconsin, 1862, page 193.

bonate, and in a large number of cases, the walls of the interior cavities possess a seemingly fresh leaden gray surface that has a very considerable reflecting power in certain attitudes, and in other cases, it presents brilliant specular surfaces without any indication of corrosion. A large specimen, from the Marsden lode, near Galena, when sawed open, exhibited a somewhat irregular cavernous interior, which possessed the curious crystalline angles and corrugations previously referred to. A portion of these had an external opening and were corroded and coated with a secondary lead compound, but the remainder presented a brilliant specular surface.

These reticulated forms also occur in the center of stalactitic aggregations of galena and blende, the reticulated cavities taking the place of the central cylindrical opening, common to stalactites. In some cases the bright metallic surface presents the appearance of an encrusting film and does not take a sharply defined crystalline form, but I have not succeeded in demonstrating that this is its true nature. It seems possible that such bright metallic surfaces might be produced by the simple *solution* of the lead sulphide, but scarcely by any form of chemical corrosion or transformation. If the lustrous surface is due to a film of comparatively recent deposition, the cavities might still be due to earlier decomposition, and the harmony of seemingly incompatible facts be made, at least, conceivable.

There is a form, likewise styled reticulated galena, that seems to owe its origin in part to the primal mode of its crystallization. It appears to have grown up along an extended octahedral axis by accretions to the adjacent faces, the result being an elongated prism capped by a pyramid. After this elongated crystal had attained certain very moderate dimensions, and apparently while it was yet growing, there sprang out thickly along its length, a series of lateral crystals that grew in a similar manner, but at right angles. These are imbedded in blende and seem to have grown simultaneously with it, and to have been modified by their struggles with the competitive mineral, resulting in mutual encroachments, which produced, in the galenite crystals, successive contractions and enlargements of an irregular and unsymmetrical sort. Subsequently the interior seems to have been, in part, redissolved, after the manner above

FIG. 3

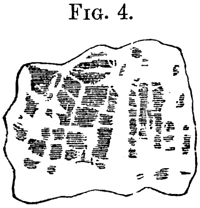


"RETICULATED GALENA."
SHADED PORTION REPRESENTS INCLOSING BLENDE, LIGHT PORTION, GALENA, BLACK PORTION, CAVITIES. OBLIQUE LINES ON LIGHT PORTION REPRESENT CORRODED LAMINÆ.

indicated, mainly along the central axes, but also on the margins and in irregular ways. The total result is, that, being imbedded in blende, and dependent on its irregular fracture for exposure, most specimens present a very complicated aspect. Its theoretical interest lies mainly in the fact that it is one of the evidences of the strictly contemporaneous deposition of lead and zinc ores. Another curious form consists of an elongated rectangular prism capped by sloping pyramidal faces. To give a definite conception of dimensions, a specimen one foot long, one inch wide and one-half inch thick may be taken as a type. The pointed end has suggested the name "pick mineral," the form being not unlike the rectangular point of that instrument. Its special peculiarity consists of a small round perforation, of the size of a knitting needle, passing through the entire length of the specimen, but neither precisely at its center nor in a straight line. The perforation closely resembles those common to stalactites and probably has the same origin, the elongated crystal being stalactitic in mode of formation, but of this I cannot speak confidently, as I have never seen the specimens in place, and presume, from what I can learn, that they have only been found in the loose residual clay of the "openings," which would indicate that they had fallen from above, but from what exact position is uncertain. I am trustworthily informed that they were formerly very common at the Yellowstone diggings. The specimen which I have made the type of this description is in the possession of J. M. Smith, Esq., of Mineral Point. Mr. W. T. Henry, of the same place has several very large specimens that have a similar but more symmetrical form. The cross section of these is nearly a square, sometimes three to four inches on a side, the length of the specimens being from one to two feet.

The external surface of the lead ore as found in our region is generally dull, rough, and coated with the oxide or carbonate, resulting from chemical change at the surface. This change is usually confined to the immediate surface, but sometimes penetrates to a considerable depth, and occasionally throughout, completely replacing the galena.

FIG. 4.



GALENA PARTIALLY CHANGED TO LEAD CARBONATE. THE BLACK REPRESENTS THE GALENA.

The form of the masses of galena is often much modified by erosion. The original cubes have been much worn, often resulting in odd and fantastic shapes. These eaten and worn forms clearly indicate that, since the original formation, circumstances have changed. Whereas then the conditions favored deposition, they have since caused corrosion and removal. This also necessitates the belief that the removing agency, which was, undoubtedly, the common drainage of the region, might, on meeting a reversal of conditions, redeposit its burden. But there are many exceptions to this rough and corroded condition of the ore. Some of it presents a decidedly fresh aspect. Of this sort there are two varieties; the one has a fresh, leaden-gray surface, reflecting only in certain attitudes, and the other presents a brilliant, metallic, specular face. This necessitates the belief that either these fresh forms are or have recently been in process of formation, or that they have long escaped the incessant, though slow, changes, by which, as we shall presently see, they have been almost universally surrounded.

The eroded forms are found mainly at and above the permanent water-level.

It is important to consider what are the *possible* ways in which the several ores may be formed, since that may be decisive in respect to some theories of deposition. Galena is sometimes found in connection with furnaces, where it seems to be produced simply by the vaporization of the ore and its redeposit in the cracks and cavities of the cooler parts of the furnace. Numerous experiments have shown that galena may be sublimed and again condensed in the crystalline form, or produced by gaseous combination. It may also be formed by passing steam over lead sulphide at a white heat, and afterwards suitably condensing it. It may also be produced from solutions of lead compounds through the action of decomposing organic matter, and other agencies.

So far, then, as the galena itself is concerned, it is permissible to suppose that it might have originated (1), through the condensation of its own heated vapor; or (2), through the agency of steam; or (3), from water solutions by the agency of decomposing animal or vegetable matter. But when we come to consider its associated minerals, we may find ourselves shut up to a narrower choice.

Sphalerite, *Blende*, *Black Jack*, *Zinc Sulphide*, *Sulphuret of Zinc*. This mineral, commonly known among the miners as "Jack," is a simple compound of zinc (67 parts) and sulphur (33 parts). When essentially pure, sphalerite is transparent and has a fine resinous luster and white or yellow color. But in the Wisconsin lead region it almost universally contains a sufficient amount of iron to render it dark and opaque. It belongs to the same fundamental system of crystallization as galena, but instead of growing in cubes and octahedrons, it usually takes the dodecahedral form and cleavage. Fine crystals are abundant, but they are almost universally of modified or irregular forms. These are formed especially in shale, whose yielding substance permits their growth, or in cavities, or crevices, where the deposition is sparse. When the deposit is massive, the blende is usually disposed in compact layers or assumes a rudely botryoidal form, with a radiant internal structure, often marked with concentric bands of lighter and darker hues. In certain situations it takes the form of stalactites, traversed along the center by an irregular opening, along which some galena is often distributed. These special forms will be subsequently described.

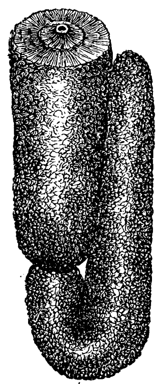
A very interesting form occurs at Mifflin, known as "Strawberry Blende." It consists of an aggregation of small crystals, which have evidently grown out from a common center, projecting their points in all directions, forming a sort of burr, or berry-like accretion, not inaptly named "Strawberry Jack." Galena sometimes forms a part of the aggregation, and must have grown simultaneously with the blende. These "berries" were formed in soft clay — a circumstance that favored their symmetrical development.

Blende may be produced artificially from solutions of its compounds, especially the sulphate, through the agency of decomposing animal matter. It seems also to have been produced by volatilization and recondensation, as in the case of galena. It has also been produced by gaseous combination and by subjecting heated zinc oxide, or silicate to sulphur vapors. It is not impossible, therefore, that in some instances blende may have a vaporous origin, and the practical question is, whether the conditions under which we find our deposits were such as to admit of this method of formation, and hence the critical attention of the reader is invited to those conditions as they shall hereafter be sketched.

The forms which the ore presents should also be kept before the mind, such especially as "Strawberry Blende" and "Speckle Jack," formed throughout soft rock, and, even more particularly, the stalactitic growths.

Pyrite, *Yellow Iron Pyrites*, "*Mundic*," "*Fools' Gold*," *Iron Bisulphide*, "*Sulphur*," *Sulphuret of Iron*. This mineral of many names is commonly known among the miners as "sulphur." It consists of iron and sulphur in the atomic ratio of one to two, or by weight of 46.7 of iron and 53.3 of sulphur. It attracts universal attention by its bright, brassy color and splendent metallic luster. The name "fools' gold" suggests a long chapter of high human expectations, passing off, like the mineral, in acrid smoke, when tried by fire. Pyrite crystallizes on the cubic basis and takes a multitude of modified forms. In our region, it almost always appears in aggregations where the forms of the several constituent

FIG. 5.

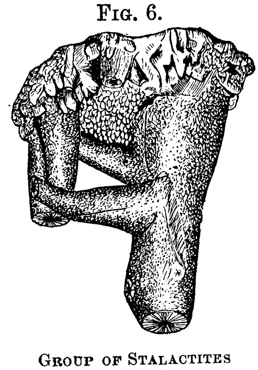


STALACTITE OF PYRITE RECURVED UPON ITSELF.

crystals are constrained and obscured by the encroachment of their neighbors. These aggregated crystals often diverge from a common point, giving rise to a beautiful radiate structure, and where the individuals are densely crowded, the axial lines of growth induce a fibrous texture, though this is more especially characteristic of marcasite. Pyrite occasionally takes a stalactitic and stalagmitic form. In the former case the crystals are gathered about a small central tube that extends the entire length of the stalactite, growing out at right angles from it, giving a beautiful crystalline surface. A singular specimen of this kind, in my possession, consists of a stalactite reflexed upon itself as shown in the adjoining cut. The two adjacent portions are firmly grown together. Its situation and attachments when found are unknown.

Figure 6 represents an interesting group of irregular stalactitic growths of pyrite attached to a base of blende, from Marsden Mine, Galena, in the possession of R. D. Salisbury.

FIG. 6.



GROUP OF STALACTITES ATTACHED TO BLENDE.

Pyrite very often occurs as an incrustation, either of the walls of cavities, adhering directly to the rocks or coating various minerals previously deposited, thus the same sheet frequently overlies galena, blende and calcite, enwrapping all in a common resplendent sheet of crystals. The incrusted minerals present perfect, unchanged surfaces showing that the conditions under which the pyrite was deposited were not incompatible with their preservation, as certain heights of temperature and the presence of certain heated gases would be. Pyrite also occurs abundantly in sheets beneath and between the other ores, and in accumulations apparently replacing them in their lateral extension, and also in isolated and scattered aggregations.

Iron pyrites may be formed artificially by the slow deoxidation of iron sulphate by organic matter in waters containing carbonate or other salts of iron in solution. Pyrite is abundantly found in the most recent sediments as well as in the medieval and most ancient strata, and it is certain that it has been formed under the ordinary conditions furnished by accumulating sediments, and in these instances not due to thermal agencies of any kind. Its prevalence in bituminous coal, oil-bearing limestone, and pyroschists is *prima facie* evidence of the absence of heat, and its distribution throughout massive and impervious beds of clay make it irrational to attribute its origin to thermal waters. It will scarcely be questioned by any competent student of the subject, that, at least, the vast majority of pyrite found in the sedimentary strata was formed under the ordinary circumstances of those formations, and without such special agency as heated gases or vapors, thermal waters, physical disturbances or volcanic influence. Pyrite does not habitually volatilize when heated, but undergoes decomposition, giving off sulphur and leaving a magnetic residue which, when formed at moderate temperatures, is allied to pyrrhotite. Indeed, pyrrhotite, and not pyrite, is the form of iron sulphide, if any, that would presumably be formed through the influence of igneous agencies, and its occurrence in nature in the lava of Vesuvius and mainly in crystalline rocks perhaps lends some support to this suggestion. Nevertheless, experiments seem to show that heated vapors and gases may combine to form pyrite, and that some metalliferous deposits may arise from such a source, with or without the aid of steam.

In the case in hand the question is: Could the forms above indicated, *e. g.* the stalactites, have been formed by either gases, vapors or *ascending* hot waters?

Pyrite frequently replaces fossils, retaining, very perfectly, their form and surface markings. These are quite common among the shaly deposits in the zinc-bearing beds of the lead region.

Marcasite, *Iron Bisulphide, White Iron Pyrites.* As this mineral is not generally distinguished from pyrite, the same popular terms, "sulphur," "mundic," etc., are applied to it. It has the same composition as pyrite, their main difference being in crystallization, the pyrite being cubic, and the marcasite, orthorhombic, and in physical properties, the marcasite being usually whiter and much more prone to decomposition. It has a greater tendency to take the fibrous, radiated, crested and saggitate forms. At several localities in the lead region it is much disposed to assume small, internally radiant, hemispherical forms, completely inclosed in blende, or in a combination of blende, galena and pyrite.

Aside from these peculiarities, the remarks upon pyrite are generally applicable to marcasite.

Chalcopyrite, *Copper Pyrites, Yellow Copper Ore, Copper-iron Sulphide.* This ore consists of a double sulphide of copper and iron, the three ingredients weighing nearly the same, namely: sulphur 34.9, copper 34.6, and iron 30.5. It somewhat closely resembles iron pyrites, but differs from it in being softer, so that it may be cut with a knife, while pyrite is so hard as to strike fire with steel. It usually has a deeper yellow color, more inclined to be iridescent and to tarnish, but these color distinctions are of uncertain value as tests.

Its crystalline system is tetragonal, but it is still very closely isomorphous with pyrite which conforms to the cubic system. In the lead region this mineral is mainly found in massive forms and these largely changed to the carbonates, malachite and azurite. Theoretically, chalcopyrite can probably be formed in either of the general methods heretofore named.

Manganese Sulphide, *Alabandite?* From the presence of manganese oxides in forms that are evidently secondary, and the fact that the oxides of the associated metals are unquestionably derivatives from original sulphides, it is highly probable that there was, and doubtless, in the deeper lodes still is, some compound of manganese and sulphur. No specimens of it have been identified so far as known.

Calcite, *Calc Spar, Tiff, Calcium Carbonate, Carbonate of Lime.* This mineral derives its main importance in this discussion from the fact that it is so abundantly and so intimately associated with the preceding ores. It is at times deposited beneath, between and upon them all, and, perhaps we shall be justified in concluding, strictly contemporaneously with them all. Our final views of the method of deposit must therefore be such as to permit of the deposition of this mineral simultaneously with the others. Calcite consists of a simple combination of carbonic acid and lime, forming usually transparent and white crystals. At Linden and some other localities, beautiful pink specimens are found, and gray, cream and amber colors are not uncommon. It crystallizes according to the rhombohedral system, and perhaps surpasses all other minerals in the number of modified forms which it assumes. In the lead region the varieties popularly known as "dog-tooth spar" and "nail-head spar" are the most pronounced. Occasionally large openings in a lode, lateral cavities and even small caverns are brilliantly lined with these spars. A fine instance of this was found at the Linden Mine, from which W. T. Henry, Esq., raised and distributed a series of magnificent specimens. At Crow Branch, where the calcite grew in a soft, clayey shale, the crystals and crystalline aggregates assumed a very great variety of odd, unusual forms, due apparently, to the half-yielding, half-confining nature of the clay matrix. Agaric mineral or "rock milk" occurs at some of the mines as a coating on the walls, having been formed since the excavations were made, and undoubtedly still in process of deposition.

In regard to the origin of calcite, it is one of the most familiar facts of historic mineralogy that it has been and is being formed almost everywhere throughout calcareous rocks, by deposition from common lime-bearing water at the usual temperatures and under the ordinary circumstances that prevail in the superficial strata of the earth. It is also a well-known, though a less familiar fact, that it is formed from thermal waters. On the other hand it is an equally familiar fact that calcite cannot — unless it be under the most extraordinary circumstances — be vaporized, but that on heating, it decomposes, the carbonic acid passing off as gas, leaving caustic lime as an infusible residue. It may not be entirely safe to say that, under extraordinary conditions of heat, pressure and confinement, aided by superheated steam, a deposit of calcite *might* not be formed from the vaporous state, but such an instance must be placed among phenomenal occurrences, and, I think, will be admitted to be quite inapplicable to the case in hand, when all the attendant circumstances are duly considered.

Dolomite, *Pearl Spar, Brown Spar, Bitter Spar, Magnesian Carbonate of Lime, Calcium-Magnesium Carbonate.* This is a double carbonate of lime and magnesia in the ratio of 54.35 to 45.65 and, like calcite, crystallizes in the rhombohedral system. It resembles calcite, but may be conveniently distinguished from it by its more feeble effervescence in cold hydrochloric acid. Notwithstanding the fact that the lead-bearing formations are composed of highly magnesian limestones, indeed almost massive dolomites, pure crystalline dolomite is not abundant in the ore-bearing crevices and openings, nor indeed in the Silurian formations of the state. This seems to be due to the greater solubility of the magnesian carbonate by virtue of which it remains in solution in the depositing liquid while the lime carbonate crystallizes out.

Quartz, *Silica.* This is one of the most common of minerals, occurring in almost every formation in greater or less quantities. No extensive formation is known in which its chemical equivalent, silica, is not present, and nothing is wanting to the production of quartz but the conditions necessary to concentration and crystallization. Such conditions are almost universally furnished by hot waters and the widely distributed alkalies. If thermal waters were the agency that deposited the ores and associated minerals of the lead region, it would be presumable that quartz would form a prominent constituent of the deposit, especially as the surrounding and underlying formations, as well as those in which the waters are supposed to have been heated, contain an abundance of it. As a matter of fact, however, it is so rare as to be notable for its absence. The lead-bearing crevices and openings frequently lie in beds thickly charged with cherty flints, in the very cracks of which the ores are often deposited, while below lie the upper and lower silicious sandstones aggregating a thousand feet in thickness, through which any supposed hot waters would pass in reaching the lead-bearing horizon. The absence of quartz under such circumstances presents a difficulty of some magnitude.

Barite, *Barytes, Heavy Spar, Barium Sulphate, Sulphate of Baryta.* Composition: sulphuric acid, 34.33; baryta, 65.67. Barite crystallizes in the orthorhombic system, but, in the lead region, it almost always appears in massive aggregations, occupying the same situations and relations to the ores that calcite does, indeed, in many instances, it seems to be literally replacing it, the calcite being gradually dissolved away and the barite taking its place. It is only abundant at a few localities, and it is an interesting fact that in its distribution it is essentially confined to the eastern portion of the region. In respect to the possibilities of its origin, nothing opposes the view that it might under supposable conditions be formed either from cold or hot solutions. There are difficulties in the way of supposing it to have been volatilized or to arise from gaseous combinations, since barium sulphate is not, under ordinary conditions, volatile, its tendency under heat being to reduce to the sulphide which is competent to resist a high degree of heat.

Class II.—*Secondary Minerals.*

The foregoing constitutes an essentially complete list of the minerals that seem to have been originally deposited in the crevices, chambers and soft strata of the lead-bearing formations, where we now find them. Certain portions of the deposits have, however, undergone transformations since, and have given rise to a class of derivative minerals to which the following belong.

Sulphur. Native sulphur, though not abundant, is occasionally found in the lead region in the pulverulent or minutely crystalline form in crevices or small cavities in the mines. It is undoubtedly due to the decomposition of the iron sulphides, pyrite and marcasite.

Melanterite, *Copperas, Iron Vitriol, Green Vitriol, Sulphate of Iron, Iron Sulphate.* This well known substance is occasionally found in the vicinity of decomposing marcasite, or pyrite, from whose oxidation it unquestionably arises. It is also abundant in heaps of exposed pyritiferous debris from the mines, where it forms rapidly. In such situations it usually takes the form of an efflorescence of fine white fibrous crystals, or a light-colored, filmy coating.

This, of course, is soon dissolved and washed away, or is further oxidized into the iron rusts.

Alum. Among the efflorescent material attending the decomposition of the iron sulphides there are yellowish coatings and minute fibrous crystallizations, of bitter astringent taste, that are probably iron-alum, but I have not tested them.

Hematite, *Red Iron Ore, Red Ocher, Peroxide of Iron, Ferric Oxide.* This mineral, in the form of red ocher, and occasionally as a pseudomorph after pyrite, is present in connection with the lead deposits, but not in sufficient quantity to give it of itself any importance. It is mainly of interest, as showing the changes the lode minerals have undergone. The presence of bright red ocher is regarded by the miners as an unfavorable sign, indicating, as they express it, that "the ore has been burnt out," a not inappropriate expression, if its real significance be rightly understood, since the pyrite seems to have been "burned," in the chemical sense of oxidation, first to iron sulphate and then to red ocher. How much of this red ocher is really the hematitic variety, known as turgite, is not fully ascertained.

Limonite, *Brown Hematite, Yellow Ocher, Hydrated Sesquioxide of Iron, Hydrous Ferric Oxide.* This occurs more abundantly than hematite, taking the form of yellow or brown ocher and rust. It consists of iron oxide chemically combined with water, and owes its origin, so far as this region is concerned, mainly to the oxidation of the iron sulphides, pyrite and marcasite, whose forms it often retains.

Siderite, *Spathic Iron Ore, Black Tiff, Iron Carbonate.* It is merely worth noting that this ore of iron occurs occasionally, and is known as "black tiff." Whether it belongs to this group of derived minerals, or was originally deposited in the fissures in the present form, I am unable to judge from the little known about its occurrence, but incline to the former view.

Cerussite, *White Lead Ore, Lead Carbonate.* This ore of lead occurs in small well-formed crystals attached to galena, and also as a white coating replacing the exterior of galenite crystals and occasionally taking the place of the entire mass. In the latter cases, it is manifestly due to the change of the lead sulphide to the lead carbonate, probably through the intermediate state of the sulphate, which would doubtless be the immediate result of the oxidation of the sulphide and which, in turn, might be reacted upon by the alkaline or earthy carbonates held in solution in the percolating waters, thus producing the carbonate. The crystalline forms may be supposed to have the same origin, save that the sulphate served to transfer, somewhat, as well as to transform the changing ore.

Anglesite, *Lead Sulphate.* This mineral is of rare occurrence and is, undoubtedly, in all cases formed from the sulphide, galena, by oxidation. It would doubtless be more abundant but for the fact that when lead sulphate is formed from the sulphide in the presence of water carrying the earthy carbonates, as lime and magnesia, the latter react upon the lead sulphate forming lead carbonate (cerussite) and lime or magnesian sulphate. As these earthy carbonates are abundant in the waters of the region, it is not remarkable that we should find the lead carbonate instead of the lead sulphate as the usual product of the change. We do, however, occasionally find it in cavities in the interior of galenite crystals, where there has been little exposure to general circulation. It is too rare, however, to merit attention beyond the interest it possesses as a way-mark of the changes the ore has undergone.

Smithsonite, "*Dry Bone,*" *Zinc Carbonate.* Composition: carbonic acid 35.2, zinc oxide 64.8. When pure the ore would, therefore, yield 52 per cent. of metallic zinc.

This ore very rarely appears in the lead region in its crystalline form — rhombohedral — but assumes various shapes according to the circumstances of its situation. The most common is an irregular cellular structure not unlike the open porous part of the interior of bones, whence the miners' name "dry-bone." A more exact comparison could be made with the tufaceous forms assumed by lime when deposited from calcareous springs or seepings. It also forms coatings and crusts over the surface of surrounding rock or ore and thus frequently simulates a crystalline form it does not possess. It not unfrequently thinly coats calcite crystals, after which, the latter are slowly dissolved away and smithsonite takes its place, forming a species of pseudomorph. These are quite common near Mineral Point. More rarely, similar pseudomorphs after galena and other minerals are found. It occasionally presents the characteristic forms of blende, but this is due to derivation from the blende rather than replacement, as in the preceding cases, indeed these pseudomorphs after blende are among the proofs that the smithsonite in general is derived from the blende. Other evidences are found in the fact that, with the greatest frequency, the exterior of a mass is found to be smithsonite and the interior blende, and the line of junction is such as to force the conviction that the blende is changing into the smithsonite. Equally convincing is the fact that the "dry-bone" is found almost exclusively above the permanent water level, where atmospheric agencies are active, and oxidation finds suitable conditions, while in the same crevice, below the water level, blende is found, the two occupying the same relations to the other minerals of the crevice, thus indicating clearly that they are but parts of what was originally a continuous sheet. In the change of the lead and iron sulphides to oxides, or carbonates, the material was scarcely moved from its original position, except such part of it as was entirely carried away, but in the change from zinc sulphide to zinc carbonate, the product was often in part removed slightly so as to be distributed over surrounding objects, as previously indicated; in other words, there was slight transportation, as well as chemical transformation. This seems to imply an intermediate state between the zinc sulphide and the zinc carbonate, and this satisfies the theoretical presumption, that the zinc sulphide would first become, by oxidation, zinc sulphate, a very soluble compound, which, through the agency of the earthy and alkaline carbonates, present in the waters, would be changed to zinc carbonate and redeposited, some little transportation taking place in the meantime.

The smithsonite is usually somewhat impure from the presence of iron oxide and earthy substances. The iron was probably derived from that contained in the blende, which doubtless underwent chemical transformation at the same time as the zinc and in a similar manner. Some may, however, have been derived from other sources in common with the earthy impurities.

Hydrozincite, *Zinc Bloom, Hydrocarbonate of Zinc.* Composition: carbonic acid 13.6, zinc oxide 75.3, water 11.1, though the proportions somewhat vary. When pure it contains about 60 per cent. of metallic zinc. This mineral is intimately associated with the preceding, and differs from it chemically in containing water as a constitutional ingredient. It occurs as incrustations, mainly on smithsonite, and usually has a more close texture and clear translucent light color, and is more inclined to the stalactitic and botryoidal forms. But it is often difficult to distinguish it by physical properties from smithsonite. It is often mistaken for the silicate of zinc, calamine, a name which was indeed formerly applied to it. Its origin is closely similar to that of smithsonite.

Goslarite, *Zinc Sulphate.* This substance has only a theoretical interest, as I am not aware that any specimens of it have ever been collected in the Wisconsin lead region, and from its highly soluble nature there is no reason to think it exists permanently. There is little doubt, however, that it is formed in the decomposition of blende, and is a transition product in the chemical metamorphosis of that mineral into smithsonite and hydrozincite.

Malachite, *Green Copper Carbonate.* Composition: carbonic acid 25.6, copper oxide 69.2, water 5.2. When pure it yields 57.22 per cent. of metallic copper. Just as the zinc and lead carbonates are formed from blende and galena by oxidation, so malachite is derived from copper pyrites. In the lead region it occurs mainly in small earthy masses, associated with the chalcopyrite, from which it is derived, and associated with it in such a way as to leave no doubt as to its derivation. It may be distinguished from the green earths, which are often popularly mistaken for it, by its pure verdigris color, by its complete solution in nitric acid, by the intense blue color of the nitric solution on adding ammonia and by the coating of copper that forms on any clean surface of iron or steel — as a knife blade — thrust into the solution.

Azurite, *Blue Copper Carbonate, Blue Malachite.* Composition: carbonic acid 25.5, copper oxide 69.2, water 5.2. When pure it contains 57.22 per cent. of metallic copper, or in other words is identical in composition with malachite. This beautiful mineral occurs in clusters of small crystals lining drusy cavities of the mixed copper ores in the Mineral Point region, being intimately associated with malachite and chalcopyrite, from the latter of which it has, unquestionably, been derived, in a manner analogous to the preceding carbonates.

Gypsum, *"Plaster," Lime Sulphate, Hydrous Calcium Sulphate.* This mineral is of rare occurrence in the region, being only known to occur occasionally as the filling of small fissures. It has some theoretical interest, however, since the decomposition of the metallic sulphides has, doubtless, given rise to considerable quantities. But, being slightly soluble, it has been borne away, except in the rare instances of its preservation. This involves the solution and removal of an equivalent quantity of limestone, which, in part, accounts for the openings in which the ores are found.

Pyrolusite, *Wad, Black Manganese Oxide.* Composition: manganese, 63.3; oxygen, 36.7. A black pulverulent substance, often called "black ocher," is occasionally found in the mines. It sometimes forms coatings on calcite, or other minerals, and occasionally fills small fissures, but rarely occurs in any notable quantity. In its minutely divided state, it is very light, and thus is liable to give the impression of being the residual "ash" of some mineral, supposed to be consumed. This is not, however, what is commonly known among the miners as "mineral ash," or, at least, not the only substance so known.

Professor Whitney remarks on the scarcity of manganese in the lead region, as well as the Lake Superior district, as something noticeable, an observation to which some little interest may attach from its harmony with the general tenor of our views, as hereafter expressed.

II. The Areas Within Which These Minerals are Found.

1. *The General Area.* The West Platte Mound is a notable elevation, standing nearly on the fourth principal meridian and about eighteen miles from the southern limit of Wisconsin. If one were to stand upon this mound and sweep a circle with a radius of forty miles, it would cover all the notable lead mines of the upper Mississippi valley. The trivial exceptions would be those near Exeter and Monroe. If this circle were compressed on the north, the southeast and the southwest, so as to be somewhat triangular, it would more correctly represent the form of the productive area. If the circle were reduced to a radius of thirty miles, it would still include all the richer mines.

This territory embraces the southwest corner of Wisconsin and the adjacent portions of Iowa and Illinois, but by far the greater portion lies in the "Badger" state. The center of productiveness of this area lies somewhat to the south of the center of geographical distribution.

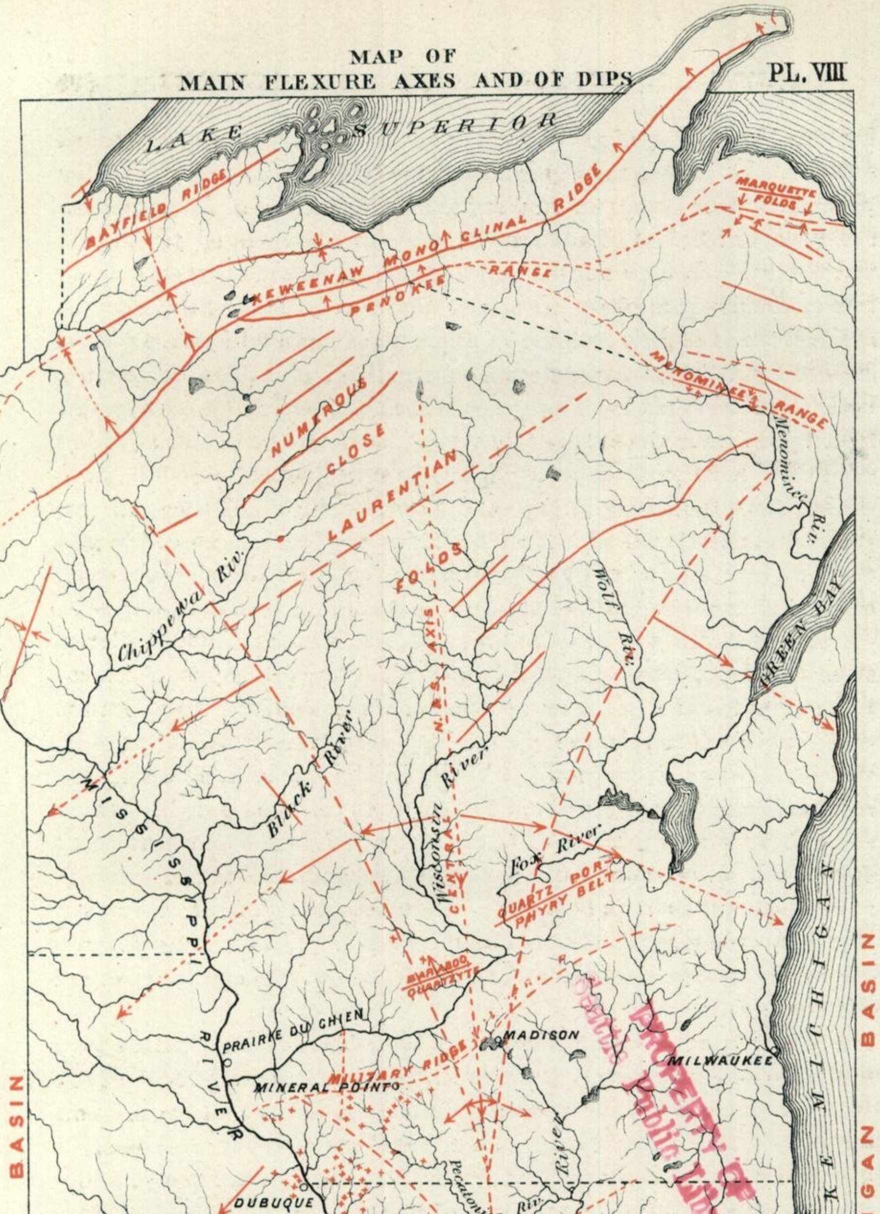
To the south and southwest, for aught that is known, the lead deposits may extend beyond these limits, for the lead bearing strata are concealed by later formations. To the north they *may have once extended* farther, for the strata have been mainly worn away. From the fact that the lower formations of *that* region are more metalliferous there than elsewhere, and from general considerations, that will appear in the sequel, there is reason to believe that they did so and that the primitive lead region extended considerably north of the Wisconsin river. To the east, the deposits gradually dwindle away, till only a few pounds and, at length, but an occasional hand specimen of galena, or blende, is found, though the lead-bearing strata stretch onward without notable change of character. The same may be said, essentially, in respect to the southeasterly and northwesterly extensions.

If a metalliferous disposition in the lower strata is any ground for presumption, it is not improbable that the original region of deposit may have been elongated to the northward, but further than this, I know of no evidence that the primary deposition extended beyond the area above indicated.

2. *Other General Areas.* Before discussing more minutely the Wisconsin lead region, it may be serviceable to glance over the continental basin with which this region is intimately united in geological

MAP OF
MAIN FLEXURE AXES AND OF DIPS

PL. VIII



Axes of flexure. Direction of dip. + Mines.

history, and bring into view the several similar metalliferous areas. The most noteworthy of these lie in Missouri, and — disregarding some scattering deposits of little consequence — may be regarded as constituting three quite well defined districts. These lie respectively in the southeastern, the central and the southwestern portions of the state. Recent discoveries have extended the latter into the adjacent portions of Kansas. South of these areas, scattered through the northern portion of Arkansas, there are detached and feeble deposits that, as yet, at least, have assumed little importance. The most southern, and perhaps the most important, lies near Little Rock, in the center of the state. Near the mouth of the Cumberland river, there are a few deposits in Kentucky and Illinois that form a somewhat isolated and interesting, though economically unimportant, group. Slight deposits also occur near Franklin, Kentucky. In eastern Tennessee and northwestern Georgia there are a number of scattered deposits, though none of them possess much richness, nor are they clustered geographically or geologically, so as to constitute a well defined metalliferous district. In eastern Pennsylvania, northern New Jersey and eastern New York, there is a line of scattered mines running nearly north and south, parallel to the belt of metamorphic rocks of the region. There are also a few deposits clustered about the base of the Adirondack highlands. In a similar way, a few lodes are distributed along the margin of the Archæan districts of Canada.

The distribution of all these is presented to the eye on plate 000. The smaller deposits of the Appalachian and Canadian regions are necessarily somewhat exaggerated, relatively, for the sake of distinct presentation.

3. *The Special Districts within the Lead Region.*— Returning to a more careful consideration of the Wisconsin Lead Region, it is but reiterating an old and established fact to observe that the mines are not promiscuously distributed over the whole territory, but are clustered into districts, or "diggings." The country between these districts has thus far proved nearly, or wholly, unproductive and has received the name "barren" territory. The occurrence of occasional dispersed mines and small deposits or "indications" of ore has led some to the hope, if not belief, that these intermediate areas would in the course of future developments prove productive. While it is not at all improbable that the present mining districts may be extended, and new ones discovered, yet in a candid discussion of the subject, we must face the fact that within the last twenty-five years or more, no new districts have been developed and no very marked extension of the limits of previous mining districts has resulted from continued exploration.

Indeed, it is asserted that all the present "diggings" were discovered within five years of the first earnest mining operations. If the mines were situated in portions of the strata better exposed than elsewhere, that might be presumed to account for these facts, but in reality the productive areas are no better exposed than the unproductive, nor any differently exposed. The whole region is free from glacial drift and is only covered by a moderate depth of residual clay, so that the strata are readily accessible in all parts of the region. And, furthermore, this clay being derived from the decomposition of the rock itself, often indicates the metalliferous character of the rock, by containing "float mineral," or other evidence of ore deposits, so that, even where the clay has considerable depth, we are not entirely without some indication of the character of the subjacent rock. As the strata are furthermore carved into deep valleys throughout the whole region, thus affording abundant means of observation and exploration, it is quite certain that the present practical limitation of the mines to circumscribed districts, accords with the real facts of deposit, and that there are really productive and unproductive areas. This is not saying that all the productive areas have yet been discovered, but the negative experience of a score or more of years will not permit us to found any views, either theoretical or practical, on any other assumption than that our present knowledge represents the truth, viz.: that the ores are only found in richness in certain limited areas, while the rest of the region is but little more metalliferous than areas of the same strata elsewhere. This being admitted, the locations, arrangement and geological relations of these mining districts become subjects of importance, and give rise to some knotty problems, among which not the least difficult are the causes of this localization of the deposits and the reasons why the given localities were the favored ones — questions we shall attempt to answer during the course of the discussion.

If we resume our central station on Platte Mound, we shall find no mines in our immediate vicinity, but, within two miles to the southwestward, diggings appear, and four miles distant is the center of the rich Platteville district. This, embracing the village in its midst, extends thence two miles northward and, with intervals, about three miles southwestward. To the east and west there are detached lodes, and to the southeast a scattering line of mines stretches away to Elk Grove and Strawberry diggings, somewhat more than six miles distant. Five miles south of Platteville lie the Big Patch diggings, and about three and one-half miles west on the opposite side of the Platte valley are the circumscribed Whig diggings, while three miles beyond are the unimportant Brush Ridge deposits. Between all these and the central Platteville district there are intervals that have as yet proved unproductive.

If, still retaining our position on the mound, we lift our vision across both the Platte valleys and extend it to the vicinity of the Mississippi, it will rest upon the Potosi district that, in productiveness, has held a high rank. Its air line distance is about seventeen miles. The main mines are closely gathered about Potosi village. The Dutch Hollow diggings on the northeast are separated by only a slight interval. About a mile north of these are the mines of British Hollow and these lead off to the northeast, toward the minor diggings of Rockville, Pin Hook and Red Dog. Taken with Potosi, these form an elongated district stretching northeast and southwest about six miles in length and two in maximum width.

About eleven miles northwest of this, and about twenty-four miles nearly due west from Platte Mound is the Beetown district, embracing the Muscalunge, Nip-and-tuck and Hacketts diggings, as well as those of Beetown proper. These are somewhat closely connected by intermediate minor deposits. An interval of about three miles lies between the easternmost of the Beetown lodes and the unimportant ones of Hurricane Corners, and about two miles north of these lodes and four miles from the former are the isolated Pigeon diggings. Westward from Beetown are occasional small mines reaching as far south as Cassville, and north to Glen Haven and Gutenberg on the west side of the Mississippi. But none of these have attained importance, and the Beetown district may be considered the most westerly heavy deposit of the lead region.

Looking northward from the mound about nine miles, may be seen the ore district about the head of Crow Branch, which only embraces a few scattered ranges. Fourteen miles north are the Wingville mines, a thick little cluster of lodes. Three miles farther north is the concentrated patchy deposit of Centerville, and four miles farther, or twenty miles from the mound, the rich ranges of Highland. These are the most northerly productive mines in the region.

Sweeping a little to the eastward, Mifflin, with its single group of rich ranges, lies within seven miles of our elevated station, and nearer at hand the unimportant South Mifflin diggings. Beyond, and more easterly, lies Linden, twelve miles distant, a group not well defined. To the westward, and northward from the main Linden lodes, less important mines extend three miles or more, while to the southeastward there are at intervals of a mile or less diggings that connect the Linden with the Mineral Point district, six miles distant. Among these intermediate mines, those of Diamond and Lost Groves are the more important.

The Mineral Point district, one of the most important of the region, centers within the city limits. Thence it extends about two miles south, but is quite sharply limited on the east and west. Northwestward, as already stated, scattering lodes connect it with the Linden diggings. In a similar way, detached groups of mines lead north to Van Meter's Survey, a notable cluster of rich ranges. Passing an interval of less than two miles, we are within the Dodgeville district. This really consists of two sub-districts, one lying within and northwest of the city; the other beginning about a mile east and extending thence eastward and northward about four miles. About two miles farther east are the Porter's Grove diggings, and about ten miles beyond the Moundville mines. In the interval there are some detached "patches" and small diggings. The Moundville mines lie near the base of the West Blue Mound, and mark the extreme northeasterly extension of the productive lead deposits. They are distant thirty-three miles from our center of view on Platte Mound.

Looking to the eastward about eleven miles, are the mines near Calamine, which consist of several groups of small ranges scattered along the Pecatonica, nearly as far south as Darlington. Northeast of Calamine are a few mines on Duke's Prairie, and five miles east of this are the Yellowstone diggings, which scatter on to the vicinity of Blanchardville. More to the south are the detached deposits near Argyle, and, still farther, the compact Wiota district. Still more distant to the east are the Monroe and Exeter mines, the most easterly of the lead region, the latter being forty-five miles due east of Platte Mound.

Still retaining our elevated outlook and turning to the southeast, we see, at a distance of sixteen miles, the rich, interesting Shullsburg district. The ridge just beyond the town is thickly dotted with heaps of debris, marking the rich deposits of that favored location. A little detached from these, on the northeast, are the Irish diggings, that stretch away toward Stump Grove, three miles from Shullsburg. West of the place, mines occur at short intervals as far as the Benton and New Diggings districts. Beyond Shullsburg are the isolated Stopline diggings, and over the line, in Illinois, those of Apple River, and still farther, the abandoned lodes of Babel, marking essentially the limit of deposit in that direction, at a point about twenty-eight miles from Platte Mound.

Turning directly to the south, we look down upon the minor mines near Elk Grove, already alluded to in connection with the Platteville district. Beyond, over an interval of about three miles, lie the interesting deposits at Meeker's Grove. Four miles beyond, Swindler's Ridge, the nucleus of the Benton district swells up into a well rounded prominence. It is hard to set definite limits to this district, since mines are scattered at intervals eastward all the way to Shullsburg, southeastward to New Diggings and thence onward to White Oak Springs, and southwestward to Hazel Green and beyond. These districts may perhaps properly be regarded as one complex district with several rich centers. Swindler's Ridge, already alluded to, the rich group of mines immediately south of the village of New Diggings, and the remarkable cluster near Hazel Green, may be regarded as such centers, all having yielded very rich returns. Around and between these, mines of less average richness are dispersed, in a manner that does not present any conspicuous natural grouping.

Passing over the state line into Illinois, there is a thick cluster of lodes about Vinegar Hill, on the west side of Fever river, while on the east side, there is a more disconnected line of mines, stretching southeasterly to Council Hill station and a little beyond.

Following down the Fever river, we encounter the notable mines in the vicinity of Galena, and beyond, the famous Marsden lode.

A dozen miles southeast from Galena, over an interval occupied by Upper Silurian rocks, is the Elizabeth district, lying in the valley of Apple River. This constitutes the most southerly group of mines, being a little over thirty miles from the Platte Mounds.

Again resuming our station on the west mound and turning to the south-southwest, and looking directly over the little cluster of mines, extravagantly dubbed Big Patch, at a distance of about fourteen miles, we see a very regular parallel group of lodes known as the Upper Menomonee district. South of these, two miles, are the Lower Menomonee diggings, and beyond these only a slight interval, and even this occupied by a few ranges, lie the Fairplay mines, notable like the Upper Menomonee ranges for their prevailing parallelism. From the extremity of these, it is less than five miles across the Mississippi to the well-known Dubuque mines. Beyond these the galena limestone is buried beneath later formations and is inaccessible, so that, whatever may be its metalliferous character, the Dubuque district is the practical limit of the mining area to the southwest.

We have thus swept rapidly over the ore field for the purpose of picturing to our minds the general distribution of the metalliferous deposits. But we have not paused to consider the special nature of the ores, nor their individual distribution, a subject which now claims our attention.

III. The Special Distribution of the Several Ores.

1. The lead ores are prevalent throughout the entire district recognized as the lead region. On the north they do not reach as far as the iron and copper deposits, that we shall find reason to associate with the already recognized district. But within the lead region proper there is no sub-district, indeed I am not aware that there is a single lode, that does not contain some galena, though in many cases it is greatly subordinate to the zinc ore. The general distribution which has already been sketched will therefore represent the areal disposal of the lead ores.

2. *Distribution of the Zinc Ores.* In considering the zinc-producing areas, a qualifying circumstance should be borne in mind. In the main these ores occur in lower beds than the galena, or, to be more specific, in the lower layers of the Galena limestone, and in the Trenton that lies beneath it. These lower horizons are not exposed in many of the districts, and have not been reached in mining, and, consequently, nothing is known as to their metalliferous character. For aught that has yet been demonstrated, these lower horizons may be productive in zinc in districts where mining in the upper strata has, thus far, only produced lead; so that, what may be said, concerning the distribution of the zinc ores, will be understood as referring to demonstrated deposits only, and subject to possible — and I think probable — extension, by the development of deposits in the lower beds.

The zinc ores develop their greatest importance in the northeastern portion of the region, the shipments from Mineral Point much exceeding those from all other districts combined. Besides the deposits in the immediate vicinity of Mineral Point, there are very important mines at Mifflin, Linden and Dodgeville, with some of lesser account in the intermediate region. In the extreme northern portion of the mining region are found the deposits of Highland and Centerville. On the western side of the area deposits have been developed in the Beetown and Pigeon districts, though most of the mines of that region do not reach the usual zinc-bearing beds. On the south border, the great Marsden mine, below Galena, produces mostly blende, and, with others in that region, completes the evidence that the zinc ores are not, as formerly supposed, confined mainly to one side of the region. At Shullsburg, New Diggings, Benton, Hazel Green, Meeker's Grove, Platteville, British and Dutch Hollows, Crow Branch, and other points in the interior of the region, zinc has been found in quantity.

It appears, therefore, that it occurs in notable amount in all the leading mining districts, except Potosi, Fairplay and Dubuque, and in these, the lower beds, where it commonly abounds, have not been exploited. The progress of mining has shown the ores of zinc to be more widely and richly prevalent than has been heretofore supposed, and the evidence justifies the belief that this metal occupies the lower beds throughout the entire region. It, doubtless, does not always sustain a definite relation to the amount of lead formed in the upper horizons, so that it would be unsafe to assume that where there have been rich deposits of lead in the higher beds, there will be found correspondingly rich lodes of zinc in the lower. It certainly would be a great practical point gained if such relations could be established, but at some points there are quite large bodies of zinc ore, where there is an absence of evidence that much lead ever existed in the crevices above, and, on the other hand, there have been notable deposits of lead in the upper beds and but little zinc in the lower, so far as explorations have shown. We shall have occasion to recur to the subject. In this connection it is sufficient to entertain the general view, that, while the richer known deposits are found in the Mineral Point, Highland, and Galena districts, the zinc ores have a wide, if not universal, distribution over the entire region.

3. *Distribution of the Copper Ores.* These, like the zinc ores, usually occur in the lower horizons. Mineral Point is the only locality within the recognized limits of the lead region where they occur in any such amount as to give promise of economic value. But, in small quantities — of no industrial consequence, but of some theoretical interest — copper has been found at Dodgeville, Centerville, Beetown, New Diggings, Buncomb, Shullsburg, Jamestown and near Wiota.

To the north of the lead region, as usually limited, in Crawford, Richland and Vernon counties, there are a number of deposits, worthy of consideration in this connection, detailed mention of which will be found in Mr. Strong's report in this volume, pages 56 and 69–72. Associating these with those of the lead region, though the former occupy a lower geological horizon, it may be broadly asserted that the copper is distributed through the eastern and northern portions of the extended ore region.

4. *Distribution of the Iron Ores.* It is not to be inferred from the discussion of the iron ores here, or elsewhere in this report, that they exist in any such amount, or in such form, as to be valuable as sources of iron, except in the region north of the Wisconsin river. While the pyrite and marcasite may be utilized as sources of sulphur

compounds, they are here considered, not on account of their industrial but of their theoretical importance. While iron, mainly as sulphide, is widely distributed throughout the Silurian formations, yet in this region it exists in unusual quantity and in such close association with the lead and zinc ores as to require attention in any comprehensive study of the metalliferous deposits.

Like the zinc and copper, it abounds mainly in the lower beds and, furthermore, its distribution is very closely similar to that of the zinc. Most abundant in the Mineral Point, Linden, and South Galena districts, it also abounds in the zinc-producing mines of Mifflin, Dodgeville, Highland, Beetown, Crow Branch, Shullsburg, Meeker's Grove and, less notably, elsewhere, indeed quite universally. The close association of iron and zinc suggests that the conditions favoring their deposit were probably identical, and that, therefore, the cause of deposition is to be found in circumstances common to both. It is worthy to be noted here that, as in the case of copper, there exists a considerable region stretching to the northward, wherein iron ore is much more than usually abundant; indeed, so much so, as to become valuable as a source of the metal. The area includes western Sauk, Richland, Vernon and Crawford counties, a district about forty by fifty miles in extent. These deposits lie in lower beds than most of the known deposits of the lead region proper, but, the higher beds being wanting, we still regard them as significant of a common metalliferous area.

5. *Distribution of Heavy Spar.* As this substance is but very rarely recognized in the Silurian formations of the territory adjacent to the lead region, its presence and distribution are worthy of passing notice. Like the preceding minerals, it is most abundant in the northeastern districts, as Mineral Point, Dodgeville and Linden. It also occurs in considerable quantity at Meeker's Grove and at some points in the Benton district. It has also been observed north of New Diggings and at Scales Mound, Dubuque, and Gutenberg, Iowa.

Recapitulation. It may be said, in summary, that the lead ore is distributed throughout the whole region, as commonly limited, but is gathered somewhat most richly in the southern portion; that the zinc ores, abounding in a lower horizon and presumably less fully discovered, are scattered widely over the region, but gathered most thickly in the northeast; that the copper is sparsely distributed, only attaining notable proportions in the northeast and the region beyond the Wisconsin river; that the iron ores have essentially the same distribution as the zinc and, besides, a northward extension, like the copper ores, and that the baryta predominates in the northeastern section.

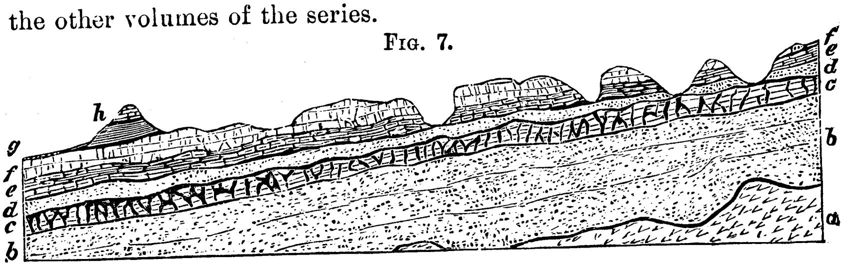
Concerning the region north of the lead district proper, it is to be remarked that the deposits are in lower members of the Silurian group than those chiefly metalliferous in the main lead district, these latter having been removed, but the deposits are still not without significance, since eleven localities bearing lead, seven bearing copper and twenty-four bearing iron in sufficient quantity to be worthy of official notice have been examined in that region.

As similar deposits are not known to exist to the northeast, east and southeast, on the one hand, nor to the west and northwest on the other, though the same strata are exposed, it seems proper to associate the northern portion with the richer metalliferous area. If this be done, it nearly doubles the north and south diameter of the area, and gives the whole an oval outline with its longest axis in the meridian.

IV. The Strata Within Which the Ores are Found.

It only concerns us here to recall the general features of the strata involved in our discussion and such special characteristics as bear upon it. Fuller descriptions may be found in their appropriate places in the other volumes of the series.

Fig. 7.



Profile of Strata of Lead Region. a, Archæan. b, Potsdam sandstone. c, Lower Magnesian limestone. d, St. Peter's sandstone. e, Trenton limestone. f, Galena limestone. g, Hudson or Cincinnati shales. h, Niagara limestone (mound).

A. *1. Galena Limestone (Dolomite).*—The main lead-bearing formation consists of a stratum of magnesian limestone about 250 feet in thickness, lying nearly horizontally and forming the uppermost rock throughout the greater part of the region. From its mineral content it is known as the Galena limestone. The amount of its magnesia is essentially equal to that of the lime, reckoned atomically, rendering the rock really a dolomite. But as this is equally true of the barren areas of the formation on every side, this fact of dolomization seems to have no special significance here, though in Missouri, according to Dr. A. Schmidt (Geo. Survey of Mo., '73, '74, p. 405), there is at least a coincidence, if not a genetic connection, between the dolomization of certain limestones and the deposition of the ores. In our region dolomite crystals of secondary origin, even, are uncommon, except as the lining of small cavities, while calcite is abundant.

The dolomitic rock usually takes an imperfectly crystallized granular form, so that it often presents a sandy appearance, especially where somewhat decomposed.

In addition to the dolomite, there is everywhere present a small ingredient of siliceous and aluminous material. While these are, to some extent, distributed throughout the whole rock, the clayey matter takes mainly the form of thin, shaly seams and partings dispersed through the beds or occupying the bedding joints. On the decomposition of the rock this mainly remains, because of insolubility, forming a residuary clay, which is abundantly displayed in the subsoil of the region and in the crevice filling in the mines. In both these situations, it is more or less mingled with undecomposed grains of dolomite and particles of siliceous sandy material.

The siliceous constituent of the formation is largely prone to assume the form of chert, or flint, nodules which tend to arrange themselves in layers or belts at certain horizons. These layers of flint are fairly constant over considerable districts, and serve as mining guides, but no single arrangement for the entire lead region has yet been discovered, and the local variation is so great as to make it doubtful whether a typical or standard section could be constructed, were the fullest data obtainable. The same is true of certain shaly seams, which, like the "gray shale" at New Diggings, furnish valuable local guides, but are not recognizable in distant mining districts. There is oftentimes a close association of the ore-bearing openings with these flint layers, but, so far as I can discern any causal connection, it consists simply in the fact that the flint layers, in these cases, favor the formation of "*openings*," which afford a suitable place for the deposition of the ores; and not that the flints have in themselves any direct agency in causing the deposition. The connection is nevertheless instructive, and, as a local guide, is valuable. The interesting Muscalunge mines at present furnish perhaps the best illustration of this, the "twelve-foot opening," the "false opening," and the "sixty-five foot opening" are each closely associated with layers of chert. The first, at some points, is quite productive, the second rarely so, while the third, which lies immediately above a layer studded with chert nodules, is the main productive horizon. The accompanying large map of these mines, Atlas Plate No. XL, will show the regularity and persistence of this horizon. But it must be prudentially observed that there are many flint beds that are not metalliferous, nor even associated with "openings," and, on the other hand, there are many ore deposits, a majority indeed, that are not associated with these nodules. Their significance as local guides must in the main be determined by observation, but our conclusions will, we hope, somewhat assist in understanding the rationale of practical experience in this regard. The chert, in the general average, is more abundant in the middle and lower portions of the formation. The shaly material is quite decidedly most prevalent near the base of the formation.

The texture of the rock, though universally granular sub-crystalline, varies in compactness, the firmer parts being interspersed with spots of softer, porous, sandy portions which, on exposure, weather out into irregular pits that give the rock a rough, ragged, rotten appearance. These softer portions are frequently replaced in whole, or in part, by cavities and these are frequently lined with calcite, dolomite, and, in the metalliferous districts, by pyrite, blende and galenite—a fact of some significance in considering the origin of the ores. Owing to its granular crystalline texture, the rock, as it disintegrates, usually falls into a dolomitic sand, and, on further decay, gives rise to a loamy clay. Both of these are common constituents of the filling of the lead-bearing crevices.

On the exterior, the Galena limestone is a dirty gray, or buff color. Below the immediate surface, it is commonly a warm buff, while in the interior of large compact masses, and at depths beyond the active penetration of atmospheric agencies, it is bluish gray. It is sufficiently obvious that the whole rock originally possessed the latter hue and that the buff color is due to the peroxidation of the iron disseminated through the rock and thus marks the depth of the effective penetration of atmospheric agencies. Undoubtedly oxygenation has taken place at greater depths, but it has not reached the stage of complete oxidation of the iron compounds, indicated by the bright buff or light gray color. The line dividing the upper buff portion from the lower bluish portion corresponds very nearly to the subterranean water level. As there will be occasion to refer to this subject, it will be convenient to designate the upper portion the zone of oxidation.

Viewed in respect to its massive structure, some portions of the formation seem to be distinctly brecciated, while other portions, not so evidently so, are found, upon more critical examination, to be made up of fragments imbedded in fine material of the same composition. Other portions are more nearly homogeneous. These characters, taken in connection with the variety and broken condition of the fossils, seem to indicate clearly that the rock accumulated in comparatively shallow water, at least within reach of the forcible action of the waves. The beds commonly range from one to four feet in thickness, but are occasionally thinner, especially near the top and bottom of the formation, and, on the other hand, are sometimes consolidated into masses of much greater thickness that do not manifest distinct bedding joints. As just indicated, fossils are comparatively rare. An occasional *Receptaculites Oweni*, popularly known as "lead fossil" or "sunflower coral," or a somewhat more rare *Lingula quadrata* or *Murchisonia bellicincta*, or, in favored situations, an *Orthis* or *Strophomena* constitute the fossil fauna, so far as it is usually identifiable. Fragments of shells are more common, and obscure traces of organic remains are sometimes quite abundant. The cavities of pulverulent portions sometimes give the impression that they have arisen from the decay and removal of large fossils, but this can rarely be proved. The surfaces of certain layers are thickly strewn with the rounded branching forms of sea weeds. The multitude of these would seem to indicate great luxuriance of marine vegetation. This is further rendered probable by layers and seams so highly impregnated with hydro-carbonaceous matter that, when heated, they take fire and burn with a bright flame. There is, of course, no direct proof that this arose from fossilized fucoids, but from the apparent abundance of these remains, this view seems most probable. For the purposes of this discussion, however, it is only material to emphasize the fact that, notwithstanding the rarity of distinct organic remains, there must have been an abundance of life, since the carbonaceous matter could have arisen from no other supposable source. When this is thoughtfully considered, the very absence of distinct fossils, indicating conditions adverse to the preservation and accumulation of organic remains, will enhance our estimate of the amount of life that must have existed during the accumulation of the beds, for, in addition to all that was lost by mechanical comminution and chemical decomposition, a sufficient amount remains to afford notable combustion.

2. *The Mounds.* Above the Galena limestone, save the residuary clays derived from rock-decomposition, we find in the lead region only the "mounds" and remnant patches of Silurian shale. The mounds, around which the popular imagination has gathered much that is mysterious and potential in ore deposition, are simply remnants of higher Silurian strata left by the erosion of the ages that has eaten away the rest of these formations. The basal portion of the mounds is formed of the Hudson river, or Cincinnati, shales and their summits are formed of a protecting cap of highly siliceous Niagara limestone. It is the exceptional hardness of this defensive crown that has caused these portions to withstand the waste of time, while the formation on every side has been eaten away. All that is phenomenal

about these mounds is their isolation and remoteness from the great body of the formation. A few miles beyond the Mississippi on the west and beyond the Illinois line on the south, and, more remotely, to the east, on the farther border of the Rock river basin, the corresponding strata form continuous rock sheets, spreading away in every direction beyond the limits of present consideration, and on the nearer margin presenting their worn and ragged edges toward the lead region. On the skirts of these massive sheets of the formation there lie mounds precisely identical with the isolated ones in the heart of the lead region. That these skirting mounds have been separated from the adjacent beds by the wearing away of the connecting strata is not difficult to comprehend where all stages of disseverance may be seen; but to picture these strata as formerly extending over the whole lead region, embracing the mounds — the only remaining portions — doubtless taxes the popular imagination more than to attribute the mounds to volcanic or geyser action, or at least to some mysterious upheaval. But there is the most positive evidence that they were not due to any of these exceptional agencies, but are simply conspicuous features in that general system of carving by ordinary erosive agents which has given origin to the diversified surface features of the whole region. The Niagara limestone and the underlying shales formerly stretched over the whole of the lead region and have wasted and washed away with the drainage of the ages. No more mysterious agency than rainfall and its accompanying instrumentalities, acting through a vast lapse of time, need be invoked to account for these mounds, and none of the more vigorous agencies usually appealed to has given evidence of existence by the slightest token.

The Sinsinawa mound is about seven miles distant from the main body of the Niagara limestone, across the Mississippi valley. The Platte mounds are about twenty miles farther removed, and the Blue mounds about thirty miles beyond these, or about forty miles from the nearest margin of the main body of the formation. The Hudson river shales occur at intermediate points, as shown on Mr. Strong's maps, and, geologically speaking, bind these together.

While the subject of the mounds is still before us, it may be fitting to remark that, near the Blue mounds, there are some minor lead deposits, but they are not clustered about the mounds nor do they present any evidence of a genetic connection with them, or indicate by any known peculiarity that they are in any way influenced by their nearness. In the immediate vicinity of the Platte mounds there are no mines. The Sinsinawa mound lies adjacent to the Fairplay diggings, but there is nothing in the nature of the crevices, or their metalliferous contents, that suggests any causal relation between them. The richest ore deposits are mainly remote from the mounds and manifest no tendency to cluster about them, as they might fairly be presumed to do, were they in any way causally connected with them.

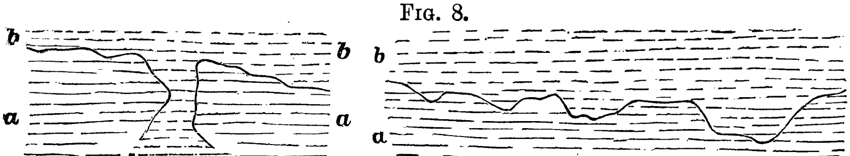
3. *Trenton (Blue and Buff) Limestone.* Below the Galena limestone, and closely united to it, lies the Blue limestone, followed below by the Buff limestone, which together constitute the Trenton group of this region. So consecutively does this merge into the base of the Galena limestone, that it is quite difficult to tell where the dividing plane can be most properly fixed. A general impression of the succession may be gained by conceiving the flints of the Galena to disappear, its texture become more close-grained, its bedding thinner, its dolomite replaced by simple limestone, and the argillaceous matter increased, forming beds of clay and shale, two or three to several feet in thickness at points, besides frequent shaly leaves and partings. In the Buff limestone, at the base, the beds again become thicker, less argillaceous and more magnesian. It is difficult to give a detailed section which shall be fairly representative of the region, because of the local variations of the formation. Mr. Strong gives in volume II, page 695, a general section, subject, of course, to many local variations. The term "opening," in this connection, signifies a clayey shale interstratified with the regular sedimentary beds of the formation. As the word "opening" is also habitually used for actual cavities, and more commonly still for cavities filled with clay and sand, derived from rock-decomposition, and also to broken and decayed portions of rock, the use of the term to designate these interstratified clayey beds is unfortunate, because confusing, but it is too prevalent to be ignored or corrected.

The "Green rock" differs from the Galena above mainly in a more argillaceous appearance, less coarse and rough texture, and in possessing a greenish cast. When sufficiently well marked to be readily identified, it furnishes a serviceable guide in mining. The "Green rock opening" is a group of shaly layers within this. This is not always present and, on the other hand, is sometimes the only portion that possesses a greenish cast.

The "Brown rock" is a granular crystalline magnesian limestone, irregularly stained, of a dark brownish hue and marked by an unusual amount of calcite (tiff) in lumps, seams and imperfect geodes, scattered through the rock. The amount of magnesia falls much short of constituting the rock a dolomite. At the base of the "Brown rock" there is very commonly considerable carbonaceous shale interleaved with limestone.

The "Upper Pipe Clay opening" is the most important of the shale beds designated "openings" both in regard to its thickness and persistence and its mineral-bearing character. At some points it is little more that a clay bed, at others it is a lamellar shale, and at still others, it is largely limestone, and, in all these varieties, it is frequently quite carbonaceous. The typical "Glass rock" is a very pure cryptocrystalline limestone of dark gray, verging toward chocolate hue. It owes its name to its close texture and conchoidal fracture and its brittleness and resonance. Irregular, undulating beds of similar constitution occur at some points above the "upper pipe clay opening" and sometimes lead to a confusion of the two horizons. The term "Glass rock" is also applied to associated limestone that does not possess these characteristics and, as a general term, is used to designate the whole stratum that constitutes the Blue limestone proper. The upper surface of the typical glass rock, near Platteville, shows a smooth eroded upper surface with an occasional fracture of the upper layer through which the subsequent deposit penetrated, as represented in the accompanying figure. The amount of erosion is slight, but is interesting and significant as to the conditions existent at the time of its formation.

FIG. 8.



PROFILES SHOWING EROSION OF GLASS ROCK BEFORE RECEIVING THE NEXT LAYER OF TRENTON LIMESTONE. a, Glass Rock. b, Granular Limestone.

Throughout the bed of Blue limestone, carbonaceous matter is prevalent in the shaly seams and partings, and sometimes becomes a noteworthy constituent of the mass. In some cases, when impregnated with ore, it is burned in heaps for the sake of disintegrating the rock and liberating the disseminated mineral. Three analyses of carbonaceous shale made for Mr. Strong, by Prof. Daniells, showed 15.76, 18.31 and 43.60 per cent. carbonaceous matter. If any are inclined to attribute the lead deposits to igneous agencies, they will do well to consider that this carbonaceous matter yet retains its volatile elements, and that at a moderate temperature — much lower than the fusion point of blende with which it is often impregnated — it gives off combustible gas.

In the Buff limestone ("Quarry rock") lying next below, we again find a dolomitic limestone of more even texture and regular, medium bedding, from which arises the utility that has given it its popular name, "Quarry rock." Within it is found one shaly bed that is somewhat constant and occasionally metalliferous, and to which the name "Lower pipe clay opening," or Buff limestone opening, is applied.

Fossils are exceedingly abundant in the Blue limestone, and not unfrequent in the Buff. The shaly layers and partings, and the surfaces of the beds are most prolific. In the glass rock the preservation of the fossils is most excellent, surpassing that observed in the same, or adjacent formations in this or adjoining states. Among these, brachiopods vastly predominate; *Orthis* and *Strophomena* being the leading genera. It would transcend our purpose in this sketch to enter into detail in regard to the numerous interesting specific forms. It is only important to observe the great abundance and fine preservation of the fossils, indicating that the Trenton sea was prolific in life, and that the strata have not since suffered any such mechanical or thermal disturbance as to destroy or even obscure them. From the fact that the carbonaceous matter sometimes assumes a reddish, flaky, bark-like form, it is presumed to have arisen from acccumulated sea weeds, abundant impressions of which occur in the strata.

The Trenton group varies much in thickness within the lead region, the range being from less than 40 feet to more than 100 feet, with the average probably about the mean between the two. The thickness increases as the formation is traced away from the region, while the Galena correspondingly decreases. The data at hand seem to indicate that this is due to a transition in the character of the lower Galena beds as they pass away from the low flat anticlinal, on the western slope of which the lead region is situated, toward the broad stratigraphical depressions on either hand. I have shown in Volume II that in northeastern Wisconsin the Galena has become so transformed as never to have been recognized heretofore as such, but referred either to the Trenton or Hudson river horizons, and a similar transition is indicated by the reports of the Iowa and Minnesota geologists. There are somewhat definite reasons for thinking that the beds, which I have designated Upper Buff and Upper Blue, in the Rock river valley are the equivalents of beds referred by Prof. Whitney and Mr. Strong to the base of the Galena in the lead region. The average combined thickness of the Trenton and Galena limestones, as indicated by four artesian wells along the shore of Lake Michigan, is a little less than 260 feet, from which it would appear that in the aggregate the strata thin out in that direction.

Viewed comprehensively, it appears that as the strata in question pass over the low flat arch that stretches southward from the Archæan heights of Lake Superior, through the center of the state into

Illinois, the upper portion assumes a coarse, granular, brecciated, thick-bedded, cherty, dolomitic character, with rare and illy preserved fossils, but with abundant evidence in fucoidal markings and carbonaceous shales, if not in the limestone itself, of the existence of a profusion of life in the depositing seas. The lower portion, on the contrary, became even finer in texture in some beds, remained largely non-magnesian and retained its fossils in an exceptionally fine state of preservation and increased the amount of its carbonaceous matter, or, in other words, retained a larger organic element. Bearing upon this point some of Mr. Strong's observations are very suggestive (Vol. II, p. 682). "East of range three east, the presence of the Blue limestone is nowhere so clearly marked as west of this line. It is usually recognized by the outcropping of a quantity of highly fossiliferous fragments, scattered through the soil, having a worn and bleached appearance. East of range three, the fossiliferous Blue limestone was not found. It is replaced by a yellowish limestone containing but very few fossils, and in all respects similar to the Buff limestone. The thickness between the Galena limestone and St. Peters sandstone remains as usual, about fifty feet.

"There are two exceptions to the foregoing general statement. A short distance south of the center of Sec. 18, T. 1, R. 6 E, the Blue limestone reappears in its full thickness, with all its characteristic fossils, but only covers a small area of ground.

"The second exception is situated in the town of Mt. Pleasant, in Green county, in the S. E. qr. of Sec. 11, T. 3, R. 7 E. It is known as the Marble Quarry, so named on account of the fine polish which may be given to the stone. The Blue limestone has here the same thickness, both of the thin and thick beds, as in the western part of the lead region. All the characteristic fossils are present, and in short, it presents all the usual lithological appearances. It appears to have been deposited *in a basin-shaped depression*, as the top of the St. Peters was found to be much lower here than anywhere in the vicinity. Although separated many miles from any other outcrop of the Blue limestone, it is evident that it was deposited under the same conditions as in other localities."

Additional evidence that the Blue limestone develops its most characteristic peculiarities in local basins will be presented a few pages in advance.

4. *St. Peters Sandstone.* Beneath the Trenton limestone lies the St. Peters sandstone. This formation is composed almost exclusively of well-rounded grains of quartz sand of medium or rather coarse size. These are usually but feebly bound together by a very thin

coating of iron oxide or lime carbonate, so that the rock crumbles readily. At some points, however, it is firm enough to be a very serviceable building stone, of which "Redrock," below Darlington, is the most notable example, where the rock is impregnated with an exceptional amount of iron oxide. But, for the purposes of this discussion, the formation may be conceived as an exceptionally pure siliceous sandstone with a minimum of calcareous matter and without interstratified limestone or shale. Its limits above and below are sharply defined, indicating abrupt changes in the conditions of deposition, both at its commencement and close. There was formerly some little doubt as to its marine origin, but its prevalent oblique lamination and other physical characters strongly favored a sub-aqueous rather than a sub-aërial origin. Mr. Strong found ripple marks in it, and Prof. Winchell in Minnesota and the writer in eastern Wisconsin found marine fossils, the former, *lingulas*, the latter, *scolithus* and *fucoids*, so that its marine origin is fully established. Aside from these rare fossils there is an absence of traces of organic life.

In regard to its thickness an error of some importance was very prevalent anterior to our survey. The quotation, "A remarkable fact in connection with the upper sandstone is its uniformity of thickness throughout the whole extent of the Northwest,"[1] may be taken as a typical expression of the view then entertained. While the few measurements that had been made seemed to justify this conclusion, and while, if its local variations were averaged, there would be something of general uniformity of thickness, the statement could scarcely be further from the truth when applied to the local details of the formation. It is exceedingly varying in thickness, owing to the uneven surface of the underlying Lower Magnesian limestone presently to be described. The upper surface undulates somewhat in harmony with the uneven base, but far less in amount and abruptness. Within the lead region the known variation is from about 150 feet down to about one-third of that, while in eastern Wisconsin, it ranges from upwards of 200 feet down to zero, and shows variations of 100 feet within a quarter of a mile. The irregularities seem greatest along the margin of the formation, and become somewhat subdued as it is traced away from the Archæan nucleus, about which the Wisconsin formations gathered.

The sandstone is broken by irregular fissures that manifest a tendency to take oblique directions and do not commonly traverse the formation in regular vertical seams, as is the habit of the adjacent limestones. Owing to the porous nature of the rock, aided by these

[1] Geol. of Wis., 1862, p. 153.

fissures, it is an eminently water-bearing stratum, when it has not been cut into and drained by the channels of streams. It is the source of numerous artesian wells in eastern Wisconsin. These wells have abundantly demonstrated that it is the passage-way of a copious flow of water, and, if we entertain any view of derivation of the ores from below by igneous intrusion, rising vapors, or even thermal springs, we must account for its passage across this underground stream of water. While our limestones are usually charged with water, there is rarely any copious flow through them, but it is quite otherwise with the porous sandstones.

A little lead ore has been found in fissures in the uppermost layer of the sandstone at Crow Branch, as I have personally verified, but it consisted only of thin detached flakes in narrow seams.

5. *Lower Magnesian Limestone.* Descending through the St. Peters sandstone, the Lower Magnesian limestone is encountered. This bears in some respects a close resemblance to the Galena limestone. It resembles and, at the same time, exceeds it in being a coarse, rough, often brecciated, thick-bedded dolomite. It is much more siliceous than the Galena formation, containing not only numerous chert nodules ("flints") but much silica, distributed through the mass or aggregated in clusters of quartz crystals and small irregular geodes. There are occasional shaly seams, and quite rarely, sandy ones. It is quite thoroughly dolomized. Near the base of the formation, where it joins the Potsdam sandstone, it is much mingled with sand, and sometimes there are alternate beds of dolomitic and siliceous rock, showing a gradual and vacillating transition from sandstone to limestone. Some of the sand grains become centers of little calcareous concretions, giving the rock an oölitic structure.

The brecciated condition surpasses that observed in the Galena limestone. This becomes most pronounced in the upper, but not immediately superficial, portion of the formation. The uppermost beds arch over heavy masses of rock composed of limestone fragments imbedded in finer limestone material apparently derived from the wear of the fragments themselves. These appear to have constituted hillocks and ridges over which the later strata were deposited, giving the surface a highly undulating character. During the earlier deposition of the St. Peters sandstone these prominences were somewhat worn and the sandstone deposited on the irregular surface. As the result of these irregularities, the Lower Magnesian limestone varies in thickness from 100 to 250 feet. Mr. Strong observed that it frequently doubled its thickness within a distance of two or three miles.

Crevices, enlarged into openings, somewhat after the fashion of the

Galena limestone, occur in the formation and are sometimes lead-bearing. So far as observed the openings are generally more irregular or cavernous, correspondent to the more uneven structure of the formation. Neither this nor the variation in lithological character seem to the writer important considerations in determining the metalliferous character of the formation.

Distinctly preserved organic remains are rare, but fragments of shells and impressions of sea weeds, if not the limestone itself, indicate the prevalence of marine life in the depositing seas. If any carbonaceous residue, analogous to that of the Trenton and Galena limestones, has been left, it has not been observed.

6. *Potsdam Sandstone.* Beneath the Lower Magnesian limestone, there lies a deep body of sandstone forming the base of our western Palæozoic series. The deep wells on the north of the lead region show that it reaches a thickness of about 1,000 feet. Owing to the irregular surface of the Archæan rocks on which it reposes, no constant depth is maintained, but from the data available an average thickness of 700 or 800 feet is fairly to be inferred.

The great mass of the formation is composed of quartzose sand, cemented to moderate firmness in the upper portions, by thin films of iron oxide or calcareous matter, coating the constituent grains, while in the lower portions and some intermediate beds, it is very loose and incoherent. Within the superior one hundred feet of the formation, there is included a considerable body of arenaceous limestone and calcareous shale, and, at lower horizons, within the upper half of the formation, there are usually some clayey shales. The lower beds are comparatively free from calcareous matter, open, incoherent and coarse-grained. The details of these subdivisions do not concern us here. It is, however, of some theoretical importance to observe, as in the case of the St. Peters sandstone, but with more emphasis, that these are preëminently water-bearing beds, and furnish ready passage for a copious flow wherever a point of exit permits a discharge, as shown by the magnificent fountains at Prairie du Chien, as well as others both north and south of the lead region. Were the overlying rocks to be fractured, there would at once rush up from these water-bearing beds a vast flow of water, rising either to the surface, or to the approximate height of the source in central Wisconsin. That the strata are not thus fissured, is demonstrated by the existence of artesian wells, since a primary condition is that these overlying beds shall be impermeable to water. The force of this suggestion will be apparent to those who have given thoughtful consideration to the problems involved in this discussion.

In the region lying north of the recognized lead region, the upper portion of this formation embraces some deposits of iron and copper that possess much interest and indicate that the formation is here more metalliferous than elsewhere.

7. *Archæan Formations.* The foregoing Silurian strata repose upon a firm crystalline floor, the Archæan rocks. The uppermost of these are presumably the Huronian quartzites and quartz porphyries, that project above the surface in the Baraboo ranges and are probably continuous with similar prominences to the northeast; with the Barron county and the Sioux quartzites to the northwest and with the Missouri quartz porphyries to the south. Still beneath these there should be found the yet greater body of the Laurentian schists and granites. These constitute the "platform of syenite rocks," to which Dr. Owen ascribes formative potency in the origin of the lead deposits. In any attempt to form a definite specific hypothesis, involving the derivation of the ores from a platform lying a thousand or more feet below, it should be borne in mind that these rocks were metamorphosed and upheaved into their present positions, in all essential particulars, *ages before the Potsdam sandstone was spread upon them.* How much more, then, before the metalliferous limestones were formed, not to say, fissured and filled! No vague ideas of disturbance, or of the heat of upheaval can have weight with a thoughtful mind at this stage of science, unless it takes due consideration of the historical facts relating to the formations involved and the possible forces that can have participated in the ore deposition at the time, and under the conditions, existent when the deposit took place. The great metamorphic formations are, broadly considered, metalliferous and may fairly be looked upon as ultimate or immediate sources of ore-derivation, but some definite conception of ways and means is obligatory upon any who would find in them the origin of our lead and zinc deposits.

B. Undulations of the Strata.

In his preliminary reports, Dr. Percival called attention, with some emphasis, to certain "centers of elevation" which apparently he deemed to have some significance.[1] Precisely what views he entertained cannot now be determined, but he seemingly regarded these as evidences of forcible mechanical disturbance that had some causal connection with the ore deposits. Mr. Murrish, also, in his report as commissioner for the survey of the lead region,[2] lays very great

[1] Annual Report, 1855, pp. 8-9, 22-26.
[2] Annual Report, 1871.

stress upon a great north and south "axis of physical disturbance," crossed by subordinate east and west axes. He, however, makes but the most meager attempt to present the necessary definite evidence of the existence of any such "axis of physical disturbance," and subsequent observers have been unable to find anything worthy of such designation along the lines indicated by him.

Whatever may be the prepossessions of any one in regard to these or similar views, the character of the stratification can scarcely fail to have some significance, and therefore deserves attention.

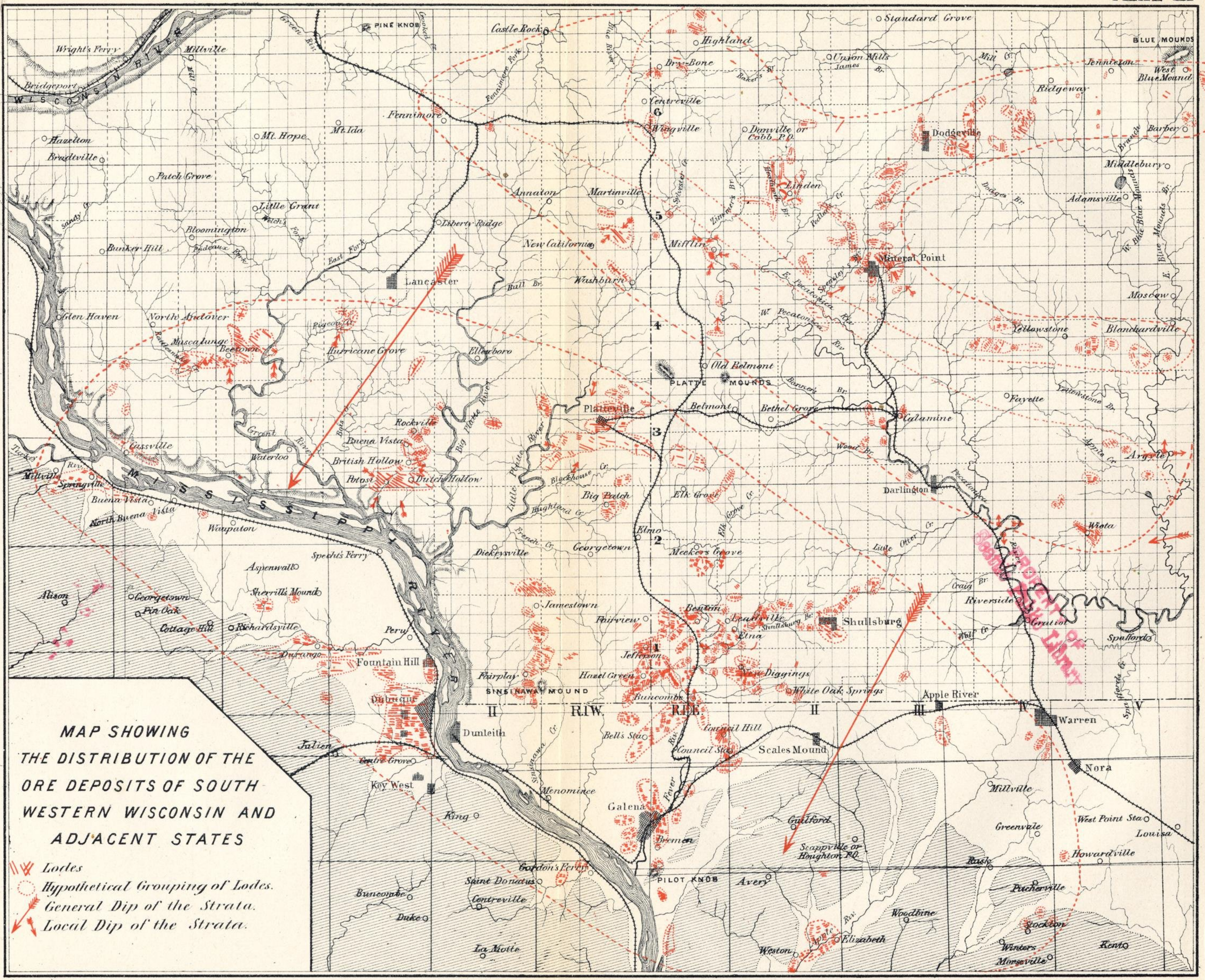
Strata may depart from a perfectly plane and horizontal attitude from two entirely distinct causes: 1st, irregularities of deposition, and 2d, mechanical disturbance. The first is altogether too much overlooked by inexperienced and unskilled observers. An arching or dipping rock is too often hastily assumed to be an instance of upheaval, and "volcanic force," that great resource of the tyro, invoked to explain it. It will be our duty to discriminate, as sharply as possible, between the unevennesses of the strata of the lead region arising from these two causes.

I. Undulations due to deposition. Between the time of the upheaval and metamorphism of the Archæan rocks and that of their burial under the Potsdam sands, there intervened a vast interval of time, during which the surface of these rocks was worn down several thousand feet, at the most moderate estimate. This worn surface, from the unequal hardness of its rocks, became very irregular and, as the sands were spread over it, they in some measure partook of its irregularities, so that the Potsdam beds were never perfectly plane or horizontal. But, by the time the one thousand feet of this formation had been accumulated, the minor undulations had, in the main, disappeared under the leveling action of the ocean. The base of the Lower Magnesian limestone was, therefore, nearly plane and horizontal, as far as can be ascertained, save such swells and depressions as are common to extensive tracts of submarine sands. But for reasons somewhat extraordinary in their nature, the accumulation of the upper portion was very irregular, resulting in an uneven, billowy surface. In eastern Wisconsin, where this irregularity is most strikingly displayed, there is abundant evidence that the phenomenon is due to deposition and not to upheaval. It appears to me probable that it was caused by a retiring and advancing beach, after the lower beds were formed, the waves eroding their surface, breaking and heaping up the fragmental material in mounds and ridges, and, at length, by a deepening of the sea, depositing a mantle of more homogeneous layers over the whole, giving it the remarkable swelling, billowy surface it possesses. In the lead region, the undulations were more distant and massive than in the typical region cited. Upon this uneven surface, the St. Peters sandstone was laid down and, while its tendency was to level up the irregularities, it did not entirely accomplish this, but left a somewhat undulatory surface for the reception of the Trenton and Galena limestones that followed in deposition. The inevitable result was irregularites in the thickness and variations in the constitution of these formations, for the fine and light material, the clay, comminuted rock and organic debris, necessarily drifted into the depressions, while the coarse and heavier remained on the more exposed swells of the sea bottom. It is also quite apparent that the fossils in these depressions, because of their less exposure to wave action, were more perfectly preserved from mechanical destruction and, by the finer and more compact character of the rock, protected from chemical decomposition. The true "glass rock" seems to have been formed from impalpable calcareous powder that could only have collected under quiet conditions. Doubtless the character of the deposit was affected by the depth of the ocean and the character and direction of the currents, but the worn upper surface of the rock, above figured, shows that it was not uniformly beneath the action of the waves. The observation of Mr. Strong that, as this rock grades away into that prevalent to the eastward, it is last found retaining its peculiarities in a basin, is quite significant in this connection.

Conditions favoring quiet deposition seem to have prevailed quite extensively throughout the lead region during the formation of the Blue limestone, and that formation, though varying in thickness and character with the conditions of accumulation, yet spread like a thick undulating blanket over the bottom of the sea and still left a surface of low swells and sags, on which the Galena limestone accumulated. This, like the preceding, was, therefore, necessarily somewhat undulatory. It is evident, from its constitution, that it was formed under less quiet conditions, and that, at times, its surface was subjected to the forcible action of the waves, by which brecciated beds were formed, with accompanying irregularities of accumulation, analogous but far inferior in degree to those of the Lower Magnesian limestone. Hence its irregularities are due partly to the unevenness of its floor and partly to irregular accumulation. Doubtless the Galena limestone left an uneven surface for the accumulation of the shales that overlie it, but as these have been almost completely swept away by subsequent erosion, it is impossible to verify it by observation except in a few instances.

It appears, therefore, from these facts, and a thoughful consideration of the subject, that irregularities in the floor of a formation, arising from any cause, tend to propagate themselves upward through the accumulating strata, but with continually less and less force, owing to the leveling action of the waves on the sediments. The subduing effect of sandstone is doubtless much greater than limestone, because of the shifting nature of the material, and because this material must originate from the shore and be carried backwards by wave action and currents, leveling the bottom as it goes, while the material of limestone may accumulate from animal remains growing essentially *in situ*. Irregularities of bottom, however, affect the action of currents, and so make themselves felt upon sand accumulation, and thus propagate themselves through such formations where the thickness is moderate. It would appear, however, that, in the growth of sediment, the points of greatest prominence and depression might not lie exactly over the corresponding points in the beds beneath. For, suppose the irregularities to consist of a parallel series of alternating ridges and troughs, and that the prevalent action of the ocean currents is at right angles to these, and from one side predominantly. The main accumulation on the ridges will not lie on their immediate crests, but somewhat beyond in their lee, and the adjacent slope of the depressions will retain more sediment than the opposite sides which are exposed to a more forcible action of the current. So that there will be a certain drift, so to speak, of the prominences and depressions in the direction of the prevailing currents. This matter will seem less trivial in the outcome of our discussion than it may in its connection here, simply as a part of a consideration of the undulations of the strata of the region.

II. Undulations due to disturbance. But are all the undulations and sloping and arching attitudes of the strata due to causes affecting the original deposition? Manifestly not. The strata on the north side of the lead region are 500 feet higher than those on the south side and, if traced further, the difference in altitude would be found greater. Beds on the eastern side are 350 feet higher than on the west side. Now, from the nature of some of these beds, it is evident that they were formed in essentially the same depth of water and hence their present inclination is due to subsequent tilting. The extreme altitude of the region at present is over 1,700 feet above the sea. Making a very moderate allowance for denudation, it may be roundly asserted that these strata stand 2,000 feet higher than they did at the close of their deposition by the ocean. Their present sloping attitude shows that they were not lifted bodily to this hight, but arched upwards. A general study of geological history shows that


MAP SHOWING
THE DISTRIBUTION OF THE
ORE DEPOSITS OF SOUTH
WESTERN WISCONSIN AND
ADJACENT STATES
Lodes
Hypothetical Grouping of Lodes.
General Dip of the Strata.
Local Dip of the Strata.
WISCONSIN RIVER
MISSISSIPPI RIVER
PINE KNOB
Castle Rock
Standard Grove
Highland
Dry-Bone
Union Mills
BLUE MOUNDS
Jenniton
West Blue Mound
Ridgeway
Wright's Ferry
Millville
Bridgeport
Centreville
Wingville
Fennimore
Mt. Hope
Mt. Ida
Hazelton
Bradtville
Patch Grove
Dodgeville
Linden
Middlebury
Barber
Adamsville
Annaton
Martinville
Little Grant
Bloomington
Liberty Ridge
Bunker Hill
New California
Mifflin
Mineral Point
Lancaster
Washburn
Moscow
Glen Haven
North Andover
Muscalunge
Beetown
Hurricane Grove
Ellenboro
Yellowstone
Blanchardville
Old Belmont
PLATTE MOUNDS
Fayette
Cassville
Rockville
Buena Vista
British Hollow
Potosi
Dutch Hollow
Platteville
Belmont
Bethel Grove
Calamine
Waterloo
Millville
Springville
Argyle
Darlington
North Buena Vista
Waupaton
Big Patch
Elk Grove
Elmo
Georgetown
Meekers Grove
Dickeysville
Specht's Ferry
Wiota
Aspenwall
Sherrills Mound
Alison
Georgetown
Pin Oak
Cottage Hill
Richardsville
Jamestown
Fairview
Benton
Leadville
Etna
Shullsburg
Riverside
Gratiot
Spafford
Peru
Durango
Fountain Hill
Jefferson
Fairplay
Hazel Green
New Diggings
SINSINAWA MOUND
Buncombe
White Oak Springs
Apple River
Dubuque
Dunleith
Warren
Bells Sta.
Council Hill
Julien
Council Sta.
Scales Mound
Centre Grove
Nora
Key West
Menominee
Galena
Millville
King
Guilford
West Point Sta.
Louisa
Greenvale
Bremen
Scappville or Houghton P.O.
Howardville
Gordon's Ferry
Saint Donatus
PILOT KNOB
Avery
Rush
Pitcherville
Buncombe
Centreville
Duke
Woodbine
Stockton
La Motte
Weston
Elizabeth
Winters
Morseville
Kent
R.I.W.
R.I.E.
II
III
IV
V
1
2
3
4
5
6

this was not done at a single push, but by oscillating stages at successive times. It appears that the strata were first slightly lifted near the close of the Upper Silurian period, but subsided somewhat by the middle of the Devonian. Reëlevated before, or at the close of the Devonian, they sank away again during the Carboniferous, but were reëlevated to a greater hight at its close. They settled back again during the Cretaceous, but were pushed up once more at its close, and immediately preceding or at the commencement of the Glacial period, they appear to have stood higher than at present. There is direct evidence that the Mississippi river formerly ran in a channel about 100 feet lower than its present one, and the fact that the Rock river, a tributary, once flowed in a channel at least 250 feet lower than its present bed, is presumptive evidence of a former still deeper channel. The bed of Lake Michigan is more than 300 feet below the ocean level and, without attempting to settle with a passing assertion the mooted question of the origin of the Great Lake basins, and, while conceding, and, indeed, claiming for glaciers much erosive power, it is yet safe to conclude, from demonstrated glacial movements, that there preëxisted valleys sufficiently deep and capacious to control the direction of the glacial currents. Such valleys seem to imply a greater elevation of the land as a condition precedent to their excavation. Taken with other phenomena, that support this view, the whole, while not entirely demonstrative, justifies a confident belief in a former greater elevation of the land and that the region has since settled back somewhat.

The question now arises, by what agency and manner of movement has this been accomplished? These elevations and depressions were parts of great movements profoundly affecting the whole or a large part of the continent. In other regions where the movements were more pronounced, it is demonstrable that the agency of upheaval was lateral pressure, presumably due to the cooling and consequent contraction of the earth. There is convincing, though less striking, evidence of similar import in the region under consideration, as will appear in the sequel. This pressure, acting edgewise on the strata, caused them to arch upwards in certain regions and downwards in others, according to their previous attitude and strength. As the result of these flexures a broad very low arch spans Wisconsin from east to west, having an axis running north and south, joining the Lake Superior heights on the one hand and, on the other, dying away into the plains of Illinois. So broad and low is this arch that its exact summit is determinable only by accurate measurements of the altitudes of the strata. For a broad area on the summit they are practically level. Even on the sides of the arch, the dip only attains about 30 feet to the mile.

Corresponding to this low anticlinal there is a broad synclinal depression underlying Michigan on the east and a similar one under Iowa on the west.

The axis of the Wisconsin arch lies nearly in the center of the state and passes along the eastern margin of the lead region. The sides of the arch do not form a single simple curve but undulate slightly, forming subordinate parallel axes of limited extent. By comparing the east and west sections on Atlas Plates XVI, XVII, it will appear that one of these slight undulations occurs near the fourth principal meridan. This appears to broaden and become lost to the north, while it becomes scarcely traceable to the south, and has not been detected in the southern part of the district. This is the "north and south axis of elevation" upon which Mr. Murrish has laid so much stress [1]. He regarded this as "a line of physical disturbance" of great potency in metalliferous deposition and held that it was crossed by subordinate east and west "lines of physical disturbance" which gave rise to mineral belts. He regarded this as the great north and south axis of elevation of the state, though the fact that the main anticlinal axis of the state passes on the east edge of the lead region had been for some years the current possession of geologists. The strata on the eastern margin of the lead district are shown by Mr. Strong's data to be roundly 200 feet higher than along the line of this exaggerated "axis of elevation" in the southern half of the lead area. While recognizing this as a very low gentle swell of the strata, it is altogether dangerous to safe and trustworthy conclusions to magnify its extent or importance beyond what the simple facts warrant. Mr. Strong's section on Atlas Plate XVI, exhibits a more marked undulation at the head waters of the Grant river, but the profile on Plate XVII, shows no corresponding one on the north side of the Wisconsin river and the contour maps do not indicate any marked extension southward.

Notwithstanding the very evident fact of a broad low anticlinal arch extending southward from the Archæan heights of Lake Superior flanked by feeble undulations, it is a somewhat remarkable fact that the general strike of the Archæan folds and the prevalent trend of the minor anticlinals of the Paleozoic strata are east and west. The manifolded Laurentian beds almost universally strike east-westerly with a northeasterly and southwesterly tendency. The Huronian strata show the same habit in Penokee range, in the quartzites of Barron and Chippewa counties, in the Marquette, Menominee and

[1] Document accompanying Governor's Message, 1871.

Black River Falls iron ranges, in the quartzites and schists of the Wausau region, and in the detached quartz-porphyry knobs of central Wisconsin and the Baraboo quartzites, within 25 miles of the lead region. The Keweenawan rocks were folded in a like general direction. The force which accomplished the flexure of these rocks was vast in its power, crumpling and compactly folding beds thousands of feet in thickness. So pronounced an exhibition of force naturally left the clearest evidence of the direction in which it acted, which was unquestionably meridional. If, for convenience, we regard the Laurentian nucleus as a resisting center, then the folds south of it were due to a force acting horizontally upon the strata from the southward. The idea of such upheaval by a force acting directly from beneath, though popularly prevalent, is practically obsolete with geologists, except in phenomenal instances. It must appear evident to any one who will give thoughtful consideration to the subject that any supposable agency acting directly from beneath must produce a conical elevation and not a linear fold scores, or hundreds, of miles in length, and further that the mechanical effects would be the disruption of the strata and not that compacting which is observed. To prevent misapprehension, let it be observed that these foldings took place vast ages before even the lead-bearing beds were formed and have no direct connection whatever with the ore deposits. They are cited here simply to show the early — and as it will appear — the prevalent direction of the flexing forces that acted upon the region.

The Paleozoic strata suffered some very mild flexures in the same general direction. Prof. Whitney and others have called attention to an elevation of the strata stretching along the north side of the lead district and nearly parallel to the westward-flowing portion of the Wisconsin river. This terminates essentially, on the west, before reaching the Mississippi, but eastward, it may be traced nearly across the state. It is in no sense a sharp fold, but is only to be conceived as a low linear swell of the strata. It seems to me quite evident that it extended to the original surface of the complete sedimentary series and that it was probably produced when they were first lifted from the ocean, because of the conformity of the drainage system to it. When the surface was nearly plane, as at the time of its emergence, a slight flexure would control the lines of drainage, which would not be the case when channels had been once well cut into the surface. A glance at the map will show that the Wisconsin river descends the back of the central anticlinal of the state until it reaches this transverse swell of the strata when it turns abruptly to the westward and passes around its extremity. There is satisfactory evidence that the

Wisconsin river has always pursued this course, save some slight deflections produced by drift agencies at its great bend and above. On the east, the Fox and Wolf rivers and their tributaries, by equally remarkable courses, exhibit the results of the same determining influence. While the waters descending from the north are thus parted to the right and left by this ridge, thrown athwart their course, the Rock river gathers in the waters flowing from its south flank along a stretch of no less than 120 miles, or nearly its entire length. It is a somewhat remarkable fact that the waters of the eastern half of the lead region, gathering into the Pecatonica river should flow *southeastward* to Freeport, Ill., and then, turning to the northeastward, join the Rock within three miles of the Wisconsin line, whence they return southwestward to the Mississippi. Light is thrown on this anomaly by the statements of Prof. Worthen in the Illinois reports[1]: "There are four other principal axes of disturbance along the western and northern borders of the state, in addition to the one just mentioned, besides several of minor importance. The most northerly one crosses the north line of the state in Stephenson county, and intersects Rock river at Grand de Tour, and the Illinois at Split Rock, between La Salle and Utica. This uplift brings the St. Peters sandstone to the surface on Rock river, and the Lower Magnesian limestone (Lower Silurian) on the Illinois. Its general trend is from N. N. W. to S. S. E., and its extent southward beyond the Illinois has not yet been determined. It elevates the coal measures to the surface, in the vicinity of La Salle, from a depth of from three to four hundred feet, thus showing that the disturbance took place at a period subsequent to the deposition of the coal formation."

If this axis be extended into Wisconsin it will be found to coincide with the watershed between these westerly tributaries of the Rock and those that descend directly to the Mississippi. Prof. Worthen has given good reasons for thinking that the axis was not developed at La Salle till after the Carboniferous period, and this seems to be sustained by the fact that the Rock river maintains its course directly across the axis. This it could readily do if it had previously cut a channel along its present line, for the upheaval was presumably slow enough to permit it to maintain its channel by the erosion of the rising barrier. But to satisfactorily explain why the streams of the lead region were turned eastward, as well as why this flexing at the close of the Carboniferous period occurred along this precise line, rather than elsewhere, it seems prerequisite to suppose that there occurred, at the time of the first emergence of the land, about the close of the Upper

[1] Volume I. p. 5.

Silurian period, a slight arching along this axis sufficient to keep the waters on its east side until they reached the essential termination of the main Wisconsin north and south axis, when they passed across and joined the Rock river. At the close of the Carboniferous period, that portion of this which was nearest the Carboniferous basin suffered further and more considerable flexure, while the more distant portion seems to have remained mainly unaffected. It would seem probable that there was a northeasterly ridge, running parallel to the portion of the Pecatonica between Freeport and its junction with the Rock, and we are able to glean from the Illinois reports considerable collateral evidence that such was the case. This line harmonizes more closely with the prevalent direction in Wisconsin than the axis just considered, while the latter coincides fairly with those lying south of it in Illinois, all of which, according to Prof. Worthen trend from N. of W. to S. of E. All of these are apparently of post-carboniferous origin and, by their oblique position, they nearly fronted the post-carboniferous sea, which had shrunk away to the south and west, and, in this, they conform to the general law that folds face the adjacent ocean, whence the active force in their formation is applied.

It thus appears that from Lake Superior to southern Illinois the strata are traversed at intervals by flexures or undulations which have a general, but varying, east and west trend; that these range in time from the Laurentian to some post-carboniferous period; that the active force producing them came, according to the general law, from the adjacent sea, and that it acted horizontally upon the strata; that during Archæan times, it was exceedingly powerful, producing close-folding and metamorphism; that in Paleozoic and later ages, it was quiet and gentle, causing slight and exceedingly slow archings of the strata without metamorphism, or other evidence of thermal action.

Holding these more general and comprehensive views in mind, we may descend to the details of the lead region. Dr. Percival, as already indicated, noted several "centers of elevation" scattered throughout the district. While we might choose a different order, as well as name, these will be cited in that selected by him.[1]

The first noticed is on the Fever, or Galena river, east of Meeker's Grove, where the St. Peters sandstone rises about twenty feet above the surface of the river. "In the ravine descending north from Meeker's Grove to the river the Blue limestone is elevated at least thirty feet above the bottom of the ravine on its east side, while immediately on the west side of the ravine, the brown rock sinks below the bottom, the strata on both sides remaining nearly horizontal, thus

[1] Report of 1855, pp. 22 to 27.

indicating a fault at that point." As I observed a dip of 8°—possibly at a point not exposed at the time of Dr. Percival's visit—I am inclined to refer the phenomena to an abrupt flexure of the beds, rather than to a fault. From this point southward, the Blue limestone gradually sinks—in the direction of general dip—but not uniformly so, "but presents a series of undulations, rising and falling, and that sometimes quite abruptly." "The Blue limestone sometimes appears more elevated on one side of the valley than on the opposite side, but this may have been the result of undulations merely." Along the Shullsburg branch, the same undulations occur as on Fever river. The Blue limestone sinks below the level of the river where it turns abruptly eastward between Benton and New Diggings, but at Buncomb rises at least twenty feet above its level, and further south alternately sinks below and rises a few feet above the river to its last appearance a few miles above Galena.

"The next point of extraordinary elevation is that along the west Pecatonica, near Mineral Point. The highest point of elevation is apparently in the fork of the Pecatonica and Pedlar's creek, north of the Mineral Point and Platteville road. The lower magnesian there rises above the level of the river, presenting low bluffs (10 to 12 feet high) along its banks. Its exact junction with the upper sandstone is there concealed; a considerable interval, corresponding to its upper portion, intervening. From that point the strata sink to the north as well as to the south. The sandstone, towards the south, sinks to the level of the Pecatonica, not far south of Bonner's branch. The bluffs of the same rock obviously decline towards the north, but I have not traced them far in that direction. There are in this district the same appearances of sudden local elevation, as in the preceding. Thus on the east side of the Pecatonica, opposite Bonner's branch, the sandstone rises but a few feet (5–6) above the river bottoms, while not more than two miles further north it occupies two-thirds the hight of a bluff, about 60 feet high, overlaid by the blue limestone. At Mineral Point village the blue limestone rises high on the sides of the ridges, leaving only a moderate thickness of the flint bed at their summits, while the mineral openings are principally in the lower beds of the upper magnesian, and in the blue limestone. At the Dreadnought mine, three miles north of the village, the main body of the flint bed is present, with its peculiar openings, and at Dodgeville, nearly eight miles north, a considerable portion of the upper magnesian is also present. At the Heathcock mine (Linden) six miles N. W. of Mineral Point, the blue limestone rises but a few feet (8–10) above the level of Pedlar's creek adjoining. These facts indicate a dip of the strata from the highest point of elevation towards the north. A similar dip is observable to the west, towards the Platte Mounds, and to the east, towards the high prairie ridge, separating the east and west branches of the Pecatonica.

"Another point of elevation occurs on the east Pecatonica, at or near Argyle. At that point there is an extensive basin, in which rise several low ridges, either composed entirely of sandstone, or of sandstone capped with the blue limestone. Different branches of the river here meet, from the north and the east, and along them lines of elevation may be traced for several miles, in bluffs of sandstone, gradually sinking from the center, but subject to local elevations, as in the preceding districts. This center of elevation is bounded on the north by the high ridge extending west from the Blue Mounds, on the east by a range of high prairies extending southeast from the Blue Mounds towards

Monroe; and on the west by the ridge separating the east and west branches of the Pecatonica.

"Returning towards the west, another point of elevation occurs on the waters of the Platte, the centre of which is apparently on the Big Platte at Bald Bluff in Ellenborough, where the lower magnesian rises nearly a hundred feet above the level of the river. The exact line of junction with the sandstone is there concealed by the earthy slope covering the upper bed of the lower magnesian. The next lower bed of that rock rises in a low bluff from the water's edge. In tracing down the Big Platte, the lower magnesian appears to rise about thirty feet above the river level at the Red Dog Bluff, and not more than 10 to 12 feet at the ferry on the Galena and Potosi road. At the latter point the sandstone forms a low ridge in the valley of the Platte, on the west. This is below the junction of the Big and Little Platte rivers, and in this vicinity, the different strata appear at a higher elevation on the west than on the east side of the river, the upper surface of the blue limestone, on the east, appearing but little higher than that of the sandstone on the west. This point of elevation is connected with that on the Mississippi, by which the sandstone is raised above the water level from Sinipee to some distance above Potosi, and the blue limestone towards the south, to a point on the east side, near Gregoire's Ferry (opposite Dubuque), but on the west side only to Eagle Point (above Dubuque); the strata being there apparently most elevated on the east side of the river. On the north, I have not had an opportunity of tracing the limits of this center of elevation. On the east, it extends to the vicinity of Platteville, and is limited by the country adjoining the Platte mounds, and on the south it is confined by the high prairie between the Mississippi and Fever rivers, near the center of which rises the Sinsinawa mound.

"Another center of elevation apparently occurs on Grant river, southeast of Beetown, near the junction of Pigeon creek. At that point the sandstone is elevated 30–40 feet above the river, while lower down on the same river, at Waterloo, it is not exposed. The same is true on Rattlesnake creek, towards the west, and on the Beetown branch, toward the northwest; only the blue limestone appearing there at the surface. On Boyce's creek, southeast, toward Potosi, the blue limestone appears more elevated than in the vicinity of Potosi, as if within the limits of this center of elevation. These limits are apparently the ridge of Boyce's prairie on the east, the high ridge between Grant river and Cassville on the southwest, and Blake's prairie on the northwest." [1]

It is not a little strange that, though Dr. Percival seems to have believed that these "centers of elevation" were indices of agencies influential in the deposition of the ores, he should not have observed the fact that *none of these are centers of great ore-deposits.* If "centers of elevation" or "lines of physical disturbance" of any kind are potential in the production of ore-deposits, then it is fair to expect such deposits in greatest richness where such disturbances are thought to have taken place, while barrenness should pervade undisturbed districts. But the facts cited by Dr. Percival seem to lend their influence in precisely the opposite direction. The most marked instance of elevation, and apparent disturbance, in the whole region is Red Rock situated in a barren region. The nearest deposits are four miles distant, the little Wiota diggings, among the least of the districts of the lead region, while the nearest important deposits are those of

[1] Annual Report, 1855, pp. 23–26.

Shullsburg, fully ten miles away. Even where there is a close juxtaposition, Dr. Percival incidentally testifies that the mines are located in relatively depressed portions of the strata, rather than on the elevations, for he says:[1] "The excavations in the mines, in the vicinity of these extraordinary outcrops of the lower strata, are farther proof of sudden elevations of the strata, the shafts being often sunk in the upper strata to a greater depth than would be sufficient to reach the lower, if the range of the latter from their outcrop was horizontal."

It appears, therefore, that while Dr. Percival noted and emphasized the undulations and apparent disturbances of the strata, his observations do not show any close connection, or clear relation, between elevations and ore-deposits, but rather the contrary.

To justly interpret his observations, however, some subtraction from the full force of his expression, "extraordinary elevation," must be made, if the idea of upheaval is intended, as the context would seem to imply; for, as I have endeavored to show, a portion of the undulation the strata now exhibit is to be attributed to irregularities of sedimentation, and, from inspection, I am convinced that these more conspicuous archings of the beds are in part due to original deposition and, in part only, to subsequent flexure. The flexure took place at these points rather than elsewhere *because* there were slight bends here before, and these were, therefore, the points that would yield easiest to lateral pressure.

In addition to the qualification imposed by this dynamical distinction, the term "extraordinary elevation," so frequently used, seems too strong to judicially express the facts. While the surface of the Lower Magnesian limestone, owing to its irregularities, rises and falls rapidly, there is rarely a true flexure of the body of this or of the other formations, giving a dip exceeding 10° or 15°. Mr. Strong gives the following calm statement concerning the most notable instance of the kind:[2] "There are several new [i. e. additional to those examined in 1873] localities which were examined in 1874, where slight upheavals of the formation appear to have taken place. The most marked example of this, known as Red Rock, is situated in the valley of the Pecatonica in T. 2, R. 4, E. The sandstone emerges from the river near the center of section 20. It reaches its greatest elevation near the quarter-post of sections 17 and 18, where it has a thickness of over 100 feet, and disappears again below the river in the southeast quarter of section 7. The average width of the exposure is about half a mile." The phenomenon is illustrated by a figure, to which reference is here made. Beyond the simple fact of arching,

[1] Page 26, Report of 1855. [2] Vol. II, p. 678.

there is little evidence of the action of unusual force. The rock is exceptionally colored with hematitic material, but this is manifestly due to the unusual amount present, and not to dehydration by heat, as sometimes hastily inferred. The beds are not notably broken or dislocated, nor are they metamorphosed, though somewhat indurated; nor is the flexure, though striking for this quiet region, more than very moderate, when compared with metamorphic districts. Both Prof. Whitney and Mr. Strong noted cases of such undulation and slight flexure, and, in selected instances, described and figured them; but neither of these observe s regarded them as more than quiet and moderate manifestations of that tension to which the crust of a shrinking earth is necessarily subjected. Neither of these writers attached sufficient importance to them to enter minutely and exhaustively into a description of them; and this is undoubtedly the true judgment to be passed upon them, considered simply as stratigraphical phenomena. As phenomena connected with the ore deposits, however, something of special significance, in my judgment, does attach to them, but, at the same time, I am studiously anxious not to magnify them into extraordinary upheavals or instances of powerful mechanical disturbance, a character which they do not bear. It had been my purpose to enter at length upon the description of these warpings of the strata, but the tediousness of the attempt is a sufficient reason for limiting special attention to those immediately relating to the productive ore districts.

It is worthy of remark, however, before passing from the general review, that all trustworthy observers agree that these are, if not strictly "centers of elevation," at least noteworthy flexures of local and limited extent In some instances, anticlinal axes of considerable extent appear to be indicated, but all attempts to discover any regular system of folds pervading the whole region, other than such general ones as have been already noted, have been burdened with arbitrary assumptions and doubtful data to such an extent as to make them quite unsatisfactory, however plausible, and probably no one has made the attempt more assiduously than the writer. These local flexures seem to have arisen from unevennesses in the original deposition, by virtue of which, certain portions of the beds, being already curved, yielded more readily to lateral pressure, and thus determined the points of flexure, and, since these irregularities of deposition would not presumably take any very rigid linear arrangement, being subject, as they were, to the multiform agencies that affect marine deposition, no symmetrical system of yielding could be anticipated.

It is further to be emphasized that, not only are none of the "centers of elevation" of Dr. Percival, but none of the convexities cited by Whitney or Strong, nor any observed by the writer, the site of productive mines. It is, therefore, a necessary conclusion, that, if these protuberances have any agency in influencing the ore-deposits, they determine their location in some other place and not upon themselves.

But, if the deposits are not upon the swells of the strata, are they in the sags? Owing to the dominating influence of that mysterious potency assumed to reside in an "upheaval," little or no attention was given by the earlier observers to the depressions and their relations to the productive mining districts. It is not often possible, because of the concealment of the rock, to throw a complete cordon of observations around a mining district, or about an individual lode, and determine precisely the attitude of the beds on all sides, especially as the undulations, at best, are usually slight and irregular. But when it is considered that the general dip of the formations is southerly and southwesterly, it is evident that a northerly or northeasterly dip, at any given location, points to a synclinal in that direction. If therefore the beds on the south or southwest of any mining district dip northerly or northeasterly, it is a clear indication, though it may not be a complete proof, that the district lies in a stratigraphical depression. In some instances we are happily not confined to this inferential method. The rich little diggings of Dutch Hollow furnish a fine example. The mineral ranges all lie within the sides of a sharp little synclinal trough whose flanks have a dip of about 15°. The rock in and near the axis of the trough is of a highly brecciated character and contains considerable lead and zinc ore scattered through it in seams and isolated or clustered crystals, even where there is no distinct lode, making the nearest approach to stockwerk found in the region. On the north edge of the trough, there runs a well defined anticlinal, the beds dipping southward into the trough about 15°, but having a more moderate slope northward. All of the ore is found south of this. An adit was started nearly on the crest of this anticlinal, at a point where cut down by a stream, and driven westward nearly a quarter of a mile without developing ore, when it was deflected southward and reached productive ground within the trough. This is a marked instance of productiveness along the axis of depression and of barrenness along that of elevation. The expensiveness of the experiment which demonstrated this fact should incline all interested in such mining enterprises to cordially accept the results of experience and observation without regard to preconceived views or wishes.

Taking a larger view of the main Potosi district, we find the beds on its west margin dipping eastward. The Long and Wooley ranges pitch eastward 1 ft. in 173 ft. By comparing the Trenton beds outcropping in the bluffs of the Mississippi with the same where seen nearest below Potosi village, there is found to be a northward dip. Mr. Strong's measurement (aneroid) from a point on the face of the bluff some distance east of the mouth of Potosi creek, to the disappearance of the Trenton, below Potosi, gives a northward decline of about 25 feet, while my own, from a point on the west side of the creek gave 40 feet—results harmonious with the easterly dip of the ranges above given. Just east of the mouth of Potosi branch according to Mr. Strong, the St. Peters sandstone rises about 10 feet above the Mississippi and the Blue and Buff limestones have a thickness of 78 feet. Tracing along the face of the bluffs, the sandstone rises 76 feet in about a mile and a half, *the Trenton beds meanwhile having thinned to 50 feet.* Beyond this point, both decline to their former height in about three miles. Making some deduction for the curvature of the bluffs, it is yet apparent, by comparison with the surrounding strata, that here is a notable arch of the beds lying south of the Potosi district. Combining these facts it appears that the Potosi diggings lie in a stratigraphical basin. The thickening of the Trenton in the basin, that seems to be indicated, is an interesting and significant fact, beautifully consonant with our view that these undulations had their beginnings in submarine inequalities, for such depressions would favor the accumulation of the fine Trenton sediments and thus give that formation exceptional thickness in the basin and thinness on the prominences.

South of the British Hollow mines, there is a low but well defined arch that may be seen along the creek below the village. The maximum dip shown is about 5°. The apparent trend of its axis is N. E. and S. W., a direction essentially parallel to one set of the adjacent ranges, and, it may be observed, that set which is most exceptional in this district.

Passing to the Beetown district, analogous facts are presented. Between the village and Hutchinson's furnace, less than half a mile below, the shaly stratum in the upper part of the Trenton limestone, known as the "Pipe Clay opening" appears in the bank of the creek at the water's edge, but within less than half a mile below the furnace the whole of the Trenton group, the St. Peter's sandstone, and a low arch of the Lower Magnesian limestone rises above the stream, indicating, when full allowance is made for the descent of the stream, a very notable rise in the strata. About two miles to the east, on Grant river, is found one of the points of elevation noted by Dr.

Percival, and to the west on Rattlesnake creek a similar rise is indicated. It therefore appears that a stratigraphical ridge stretches closely along the south margin of the whole Beetown district and that the mineral ranges lie in a depression of the strata on its flank and have their trend mainly parallel to it.

By consulting Mr. Strong's map, it will be seen that southwest of Pigeon diggings, the Lower Magnesian limestone is represented as rising to the surface on Pigeon creek and sinking away again below.

By turning to the Platteville region, it will be seen that the Little Platte river cuts into the St. Peters sandstone for some distance along its course above Platteville, but that, near the north line of the township, the sandstone sinks beneath the stream, but, in the southern part, again emerges and soon exposes its whole thickness and the upper face of the Lower Magnesian limestone[1], beyond which, it again sinks away. Such a casual inspection indicates a depression of the strata crossing the river between the Platteville and Whig diggings. A more detailed examination of measurements made by Mr. Strong, Mr. Buell, aided by Mr. Nye, and myself, independently, shows dips not only from the north and south but also from the depressed beds on the Little Platte, toward Platteville, indicating a deeper depression beneath the productive area.

At the Crow Branch diggings, the depression of the beds is conspicuously displayed in the natural section formed by the stream that gives name to the mine. At the mouth of the tunnel, the base of the Trenton beds lies near the surface of the water, but immediately to the southwest, it rises rapidly to a heigth of about 20 feet and then gradually sinks away with the common slope of the strata. At the time of my visit, the adit was inaccessible, but concerning it, Prof. Whitney makes the following significant remarks:[2] "This adit starts on the sandstone, and was when examined, with difficulty accessible, and so much filled with mud and water that the relations of the rocks it passes through could not be well made out. As it rises, however, it passes into the Buff limestone and from that — owing, as it would appear, to a basin-shaped depression or rapid undulation of the strata -- into the glass rock, in which it continues most of the way."

In the vicinity of the rich concentrated Mifflin mines, there are better opportunities for observation than are common to most districts. The ranges run N. W. and S. E. and are mainly productive in the Lower Galena and Upper Trenton beds, below which a part of the Buff appears, but the St. Peters sandstone is, by estimate, some distance below the surface of the adjacent Pecatonica river. But nearly opposite

[1] Not represented on the maps. [2] Geol. of Wis. 1862, p. 361.

the outcrop of the ranges, the St. Peters sandstone emerges three or four feet in a low undulation and again sinks below the river surface, and there is no further opportunity of observation until a creek joining the Pecatonica on the west is crossed, about a half a mile below, and directly south of the mines. Here the St. Peters sandstone rises 20 feet higher than at the point above cited and by estimate 30 to 40 feet higher than its position beneath the mines. It thus appears that between the sandstone outcrop east of the mines and that south on a line running a little west of south — the general direction of dip — there is a considerable downward curvature of the formations and this depression lies in the line of projection of the mineral ranges. An instructive east and west section may be constructed along the Pecatonica river north of the village of Mifflin which will show the prevalent tendency of the strata to undulation, as well as exhibit the special depression in which the Mifflin deposits are located. Starting at a little promontory of rock lying between the river and the creek that joins it on its left bank, less than a quarter of a mile northeast of the village, there appears a dip of 9° westward (W. 5° to 10° N.) This appears to involve but a very small area, for, a short distance to the N. W., the beds are seen to rise gradually. At the bridge north of the village, and nearly west of the first point of observation, the strata dip 3°, as measured along a vertical face trending W. 18° N. which may not represent the maximum or true dip. From this point the beds may be traced, in a direction about W. 20° N., along the side of the river, the slack-water of which affords a convenient datum plane. The beds first curve downwards until the Buff limestone, which showed half its thickness, is submerged, then run quite horizontally for a short distance, beyond which they very slightly rise and then descend at an angle of about 5° until the thin beds of the Blue limestone are submerged, when they rise at the same angle, forming a marked synclinal. On this last upward slope, at a point about 40 rods west of the axis of the synclinal, an adit has been driven into the hill on about the same beds that are productive south of the village. The attempt was evidently unsuccessful although a little zinc blende, in disseminated crystals, appears among the material excavated. From the adit westward, concealment of the rock prevents wholly reliable observations, but there appears to be, at first, a slight rise of the beds, beyond which they maintain a nearly level attitude. It is our view that this synclinal is to be correlated with that above described and that the Mifflin deposits lie in this depression, which we conceive to be a broad flat boat-shaped basin.

The Mineral Point district presents an obstacle to convenient discussion in its want of sharp limits. From the rich lodes in the suburbs of the city, ranges scatter away northward to the Van Meter ranges, if not to Dodgeville, and northwestward to Linden and beyond, not to speak of those dispersed further southward. Dr. Percival, however, aptly sweeps the whole field by some general observations made in 1855,[1] and I choose to quote him rather than give the observations of my associates or myself; for, entertaining different theoretical views, he cannot be thought to have been biased by those that have arisen at this late date. After locating the highest point of elevation near the junction of Pedlar's Creek and the West Pecatonica,[2] and referring to the tendency to sudden local elevation, he says: "At Mineral Point village the blue limestone rises high on the sides of the ridges, leaving only a moderate thickness of the flint-bed at their summits, while the mineral openings are principally in the lower bed of the upper magnesian, and in the blue limestone. At the Dreadnought mine, three miles north of the village, the main body of the flint-bed is present with its peculiar openings, and at Dodgeville, nearly eight miles north, a considerable portion of the upper bed of the upper magnesian is also present. At the Heathcock mine (Linden), six miles northwest of Mineral Point, the blue limestone rises but a few feet (8–10) above the level of Pedlar's creek, adjoining. These facts indicate a dip of the strata from the highest point of elevation towards the north."

To the southeast the district is essentially limited by Rock creek, where the strata are found dipping to the northwest. Three miles southwestward from Mineral Point, an arch brings up the Lower Magnesian limestone to a height of thirty feet above Spensley's branch. That this is not simply a protuberance of the upper surface of the Lower Magnesian limestone is shown by the unusual altitude of the overlying formations. A comparison of altitudes between the formations on Spensley's branch, west of Mineral Point, and on Mineral Point branch, in the northern suburbs of the city, indicates a dip eastward nearly equal to the thickness of the Trenton limestone. A meridional section through the district immediately adjacent to the city shows a northward pitch with a gradual rise beyond. I have incomplete data, justifying a belief in the existence of several local depressions associated with special groups of ranges in the region. It appears, therefore, that, beside the sweeping generalization of Dr.

[1] Report of 1855, p. 24.

[2] It is not quite certain which branch Dr. Percival called the West Pecatonica. There are some reasons for thinking that the point here referred to is near the junction of Pedlar's Creek and Spensley's branch.

Percival, which is somewhat too broad for definite application, there are local undulations more closely fitting the productive areas.

Along the south side of the scattered Yellowstone diggings the strata rise above their average altitude.

To the west of the Wiota district lies the Red Rock elevation, to the south and southeast, the rise of the strata along the Pecatonica, and to the east, the anticlinal between the Yellowstone river and Jordan creek, but these are all somewhat too remote (3–5 miles) to be entirely unequivocal, beyond indicating the general fact that the mines lie in a relatively depressed area.

South of the Meeker's Grove mines, the beds dip strongly northward, being on the margin of one of the centers of elevation of Dr. Percival. Concerning the great complicated area formed by the diggings of Hazel Green, Benton, New Diggings and Shullsburg, connected as they are by scattered ranges — not to include the slightly separated deposits of Vinegar and Council Hills, which lead on toward the Galena district — nothing very satisfactory can be said. The Trenton limestone only appears in the valleys of the Galena river and its tributaries, in the midst of the region, and above this there are no distinct horizons, readily and surely identifiable, over a large area, so that little precise data have yet been accumulated concerning the attitude of the circumjacent strata. The same circumstance limits our knowledge concerning special groups of lodes. Southeast of Benton, the Galena river crosses a depression of the formation, within which lie a considerable number of important ranges. I conjecture that the Hazel Green deposits lie in a projection of the same trough.

According to Mr. Kimball's observation, quoted by Prof. Whitney,[1] a synclinal axis extends along the ridge between the Peaslee and Shullsburg Branches, the strata on each side of which dip toward the center at an angle of 4°. The Peaslee diggings lie within this. Concerning another location near this, Prof. Whitney[2] says: "The ore sheets are all of the kind called 'flat and pitching.' At Earnest's diggings, one of these pitching sheets, carrying the usual ores of zinc and lead, follows for some distance the stratification of the Galena limestone, of which the beds dip here at an angle of 10° to the northeast, then suddenly drops down, following an oblique line, and carrying ore all the way, a distance of from four to six feet to another stratum below, where it again follows the planes of stratification for some distance, and then goes down again, and so on."

Waiving much minor evidence, and not unmindful of the want of

[1] Geol. of Wis., 1862, p. 299. [1] Geol. of Wis. 1862, p. 300.

data regarding several districts, I arrive at the conclusion that the ore deposits usually — possibly not universally — occupy depressions in the strata. It will be observed that in this collocation of evidence I have quoted as largely as possible from others who could not possibly have been prejudiced by the views herein entertained and thus have magnified observed phenomena to suit theoretical ends. And indeed, in regard to my own observations, I have most to regret that I arrived so late at the conviction that the ore deposits usually, if not universally, occupy stratigraphical depressions; otherwise it would have been possible to have secured greater fullness and precision of data. It was, with me, quite otherwise than a preconceived notion.

V. Surface Aspect of the Lodes.

Both a practical and theoretical interest attaches to the surface aspect of the lodes, both in their individuality and in their groups. To the prospecting miner it is of supreme importance to recognize at the surface trustworthy indications of a lode. To the student of the philosophy of deposition the characters which the crevices present at the surface are, in like manner, a subject of thoughtful consideration.

The impression is prevalent that deposits occur which have no crevice connection with the surface, but such impression, we apprehend, is rarely, if ever, true. Lodes are sometimes reached by lateral drifting, whose upward connection, not having been traced, is assumed to be absent, and in some instances the cap rock immediately overlying the deposit may be entirely unbroken, but if the crevice be traced to its extremities, it will, we believe, be found to be connected, either with a crevice directly leading upward, or with lateral fissures, or openings, which at length have such connection; so that most, if not all, such apparent cases are illusive. The majority of lodes, as they appear at the surface, are not lodes at all, but simply crevices, and thus differ in a marked degree from fissure veins and similar deposits in which the seams are filled with ore and gangue to the very surface, save so far as it may have been removed by erosion and decomposition.

The lodes of the lead region are represented at the surface usually by simple crevices which gape more or less widely and are usually filled with soil and residual clay derived from the surface. This is thought to have been the almost universal aspect which they presented originally, but by the wearing away of the rock they have been, in not unfrequent cases, cut down to the ore deposit, so that the crevice, where first struck, bears between its walls more or less of ore, usually corroded and scattered through the clay filling. In other instances, decomposition has proceeded further and the ore has been left behind mingled with the residual clay, forming a "patch" deposit. Where the original ore formation was a flat deposit and has been thus reached by surface decomposition, an extensive and very rich "patch" may be left within the clay; the most remarkable instance of which within the region is probably the Big Patch, south of Platteville, from which two or three million pounds of ore have been taken.

If, therefore, the surface, simply, of the productive districts were mapped, the ranges would usually appear only as tracings of rock crevices, differing in no very remarkable way from those common to limestone districts generally, save perhaps in something more of regularity and magnitude.

The vertical sheet deposits, which consist of a seam of ore, closely filling a narrow crevice, constitute an exception to this general statement, in that they frequently fill the crevice to the surface of the rock, the most numerous and notable examples of which class occur in the Hazel Green district.

It is more serviceable, however, to map the lode itself, reproduced upon the surface, or, more accurately speaking, that portion of it that has been mined. In the maps accompanying this report, prepared by Mr. Wilson, the lodes of the lead region have been thus represented with as much of precision, both as to position and direction as has been found practicable in the time and means at the command of the survey. The reader is, therefore, respectfully referred to these maps for both the general aspects and the detailed facts presented by the superficial arrangement of the ore deposits. An attempt has been made to distinguish between those lodes that simply occupy crevices and crevice openings, and those which belong to the peculiar system of flats and pitches, or of simple flats, hereafter to be described. But this distinction is not altogether practicable, since crevices lead to the flats and pitches, and these by the closure of the pitching crevices, are not sharply distinguishable from the flats proper. The whole really belong to one complex system and the distinctions are only valuable as showing which element, at the present stage of development, seems most important.

Referring to these maps, it will be seen that the ranges are mostly rectilinear, though frequently bent or angled, and their length seldom reaches and very rarely exceeds one mile. The longest range in the district thus far developed is probably the easternmost of the group lying on the west side of the Heathcock branch, in the Linden district, which has a length of three miles, throughout which it has been traced with little interruption.

That the crevices and possibly the lodes are considerably more extensive than has as yet been proved by actual exploitation, is very likely true in many instances; but that the open and productive portion is limited to a comparatively short range, seems to be the verdict of experience.

While the great majority of the lodes, as remarked, pursue a straight or slightly angulated course, it is worthy of note that the flat deposits, notably those near Dodgeville, have the peculiar habit of curving in hooked or horse-shoe forms, and, what is equally or more singular, this corresponds in a noticeable degree to the surface contour of the locality, lying habitually near the brow of a ridge or bluff, and curving in general conformity to its face.

Even a casual inspection of the crevice maps will develop the fact that the vast majority of lodes assume an east and west direction, while a subordinate number take a northerly and southerly course. It will be observed that the two systems are very frequently combined in the same diggings, and indeed in the same group. Where both occur together, the easts and wests are almost invariably the more open and stronger ranges, while the norths and souths are usually close crevices bearing sheet deposits. The easts and wests are, with few exceptions, the master ranges, to which the norths and souths may be regarded as tributaries, and are often styled by the miners, "feeders." In all cases, whether mapped or not, there is a transverse system of fissures, filled or unfilled, crossing the lode. These have only been plotted where they carry a workable amount of ore. In some instances, however, the norths and souths are more open, and bear strong deposits, while the easts and wests crossing them are subordinate. There is usually a distinction between the ore occupying the two sets, that which characterizes the easts and wests being usually "chunk mineral," or large massive aggregations, which show upon fracture broad crystalline plates, whereas the ore from the norths and souths, besides being externally in the form of sheets, shows on the interior more interrupted crystalline planes, which gives upon fracture a texture and luster by which expert miners and smelters are able to detect it, even in the ore heap.

In addition to the two systems, conforming to the cardinal directions, there is a third that locally assumes considerable importance, commonly known as "quarterings." In some districts, signally at Muscalunge, the main east and west system, instead of being crossed at nearly right angles by norths and souths, is traversed very obliquely by quarterings. These often have the open character of the easts and wests, and sometimes, as in the Atkinson range, become the master lodes. The term quarterings is sometimes applied to distinct ranges which have a northeast-southwest or northwest-southeast direction. But it would be better usage to confine it to oblique crevices crossing those of one or the other of the cardinal systems.

Besides these, some districts are characterized by very irregular crevices, of which class the Shullsburg mines are a noteworthy example.

The total number of lodes in the whole region, as enumerated by Mr. Wilson, is 3,769. Probably a considerable number in Illinois and Iowa, and possibly some in Wisconsin, have escaped noting, so that the entire number is nearly 4,000. It is difficult to draw hard and fast lines between the several classes, so as to determine precisely how many belong to each, but, throwing out a considerable number of doubtful classification, and estimating somewhat roundly, about 60 per cent. is found to belong to the east and west system, 20 per cent. to the north and south, and 15 per cent. to the quarterings, the remainder consisting of patches, irregular crevices, and those of uncertain classification.

By inspection of the map, it will be seen that the individual ranges tend to group themselves in clusters, and that these are gathered in larger groups, sometimes designated lots, sometimes diggings, and these again into larger assemblages, constituting subdistricts and districts.

Much study and ingenuity, not to say imagination, have been expended in the endeavor to discover some law of systematic arrangement of the crevices into groups and larger collocations, but without any conspicuous success, as it would appear from the different results arrived at. If there were any simple determinate law, it would seem that, if discovered, it should command general assent and acceptance. This much is certain, that individual ranges are not uniformly distributed over the productive area to which they belong, but are gathered in groups. But these groups present the utmost variety in the manner and attitude of their formation. Perhaps the most noteworthy fact is that to which Dr. Percival long since called attention, that these ranges are sometimes arranged so as to give a rhombic outline to the group, and that these groups are arrayed somewhat like troops *en échelon*. But this is only true of a few districts, the best example being the Vinegar Hill diggings. The gathering of the subordinate groups into districts, with barren intervals between, is a conspicuous fact concerning which, there is little opportunity for differences of view. But when it comes to arraying these in larger groups and showing the profounder relations of the districts, wide differences have been the result.

Dr. Percival made nine great groups as follows:[1]

"The different series, which I have been able to trace, are the following, beginning at the northwest: 1. That commencing at the Muddy Diggings, north of Cassville, then passing N. N. E. to the North Diggings, and then east to the Beetown Diggings, where it expands particularly towards the north, and towards the east shows a bearing to the southeast. This is probably connected with the Pigeon Diggings and other diggings farther east, north of the line of my present exploration. On the southwest, it may be connected with the diggings in Iowa, opposite Cassville. 2. That extending from near the mouth of Grant river through the different groups of the Potosi Diggings to the Red-Dog Diggings in a northeasterly (N. N. E.) direction; then east by the Brush-hill and Whig Diggings, where it expands towards the north; and then in an E. S. E. direction through the southeast Platteville and Elk Grove Diggings, to the Strawberry Diggings, where it is interrupted by a wide extent of prairie farther east, in which no ranges have yet been traced. This is probably connected in range with the diggings west of the Mississippi, in a direction south from Potosi (the Macoqueta and Dubuque Diggings), which would farther complete it on that side. 3. That commencing near the south line of the state in the Fairplay Diggings, and extending northerly (first N. N. E., then N. N. W.) through the Lower Menominee to the Upper Menominee (Jamestown) Diggings; then bearing E. N. E. through the latter, then shifting northeasterly to the Patch Diggings, then passing E. S. E. to the Buzzard's Roost Diggings, and then bearing southeast to the Shullsburg branch, north of New Diggings. This is probably connected with the Lower Galena Diggings, in the forks of Fever river and the Mississippi, S. S. E. of the Fairplay Diggings. 4. That including the Hazel Green Diggings, which may be traced from those diggings into Illinois, first S. S. W. then S. S. E. to the Upper Galena Diggings (north of Galena). On its western border, in the Hazel Green Diggings, it bears N. N. E. to the Hoss Diggings, and then curves around to the E. S. E., through the Benton Diggings to Fever river at Benton. 5. That including the Vinegar Hill Diggings, bearing N. N. W. to Vinegar Hill, then northeasterly to Buncomb and Shaw's Hollow, and then easterly through the New Diggings. 6. East of the southeast point of series 3, the E. S. E. direction of series 4 (at Benton) is resumed at Earnest and Spenceley's Diggings on the Shullsburg branch, and continued through the Shullsburg Diggings. These are intersected by the extensive range of north and souths, leading from the East Blackleg (connected with a series of east and wests on the east fork of Fever river), through the north and souths at Townsend's, and the Irish Diggings to the east and wests at Stump Grove, N. N. E. of Shullsburg. 7. A series of small groups may be traced easterly, in a line east from the Strawberry Diggings, through Skidmore's and Halstead's Diggings by Darlington, to Whiteside's Diggings, whence it bears southeasterly to the Wiota Diggings. 8. Another series, commencing at King's and the Forked Deer Diggings, west of the West Pecatonica, extends first E. N. Easterly by the Duke's Prairie diggings to the Yellow Stone Diggings, then through these in a general easterly course to the East Pecatonica, and to Bigg's and the Badger Diggings, and then southeasterly by Shook's Prairie (the Aspen Grove Mine) to Skinner's Diggings and others north and east of Monroe. 9. The diggings at Mineral Point apparently form part of another series, commencing on the southwest at the forks of the West Pecatonica and the Mineral Point branch, and thence bearing N. N. Easterly, but the course of which I have not yet had an opportunity of tracing satisfactorily to the northeast and east. This series perhaps extends by Dodgeville, Ridgeway and the Blue Mounds to Exeter; first bearing N. N. E. to Dodgeville, then east to the Blue Mounds, and then southeast to its termination at the valley of Sugar river.

[1] Annual Report, 1855, pp. 77, 78, 79.

"These series are in some instances connected by intermediate groups. Thus the southwest Platteville Diggings may be considered as intermediate between series 3 at the Patch Diggings and series 2 at the main body of the Platteville Diggings. Other instances will be stated in the details following. In no part of the mineral district examined, have I observed so great a connection of different series as at Benton and New Diggings where several seem to concentrate."

The reader, if he chooses to trace these out upon the general crevice map (Atlas Plate XXXI), will doubtless find it difficult to discover anything very natural in some of the features of this grouping.

Mr. Murrish attempted[1] to marshal the districts into great east and west belts of exceptional richness separated by barren zones, the whole traversing and subordinate to a magnified north and south line of elevation nearly coincident with the fourth principal meridian.

"To do this" he says, "let us go to the southwest corner of the state, where these mining districts commence, and drive down a stake at Fairplay, and another 4 or 5 miles to the north, at Jamestown. And now let us draw two lines from these stakes east, or a little to the north of east, to range seven, in Green county. Now let us carefully look along within those lines and see what we can find. We have (within those lines) the mines of Fairplay, Jamestown, Hazel Green, Benton, New Diggings and Shullsburg. Extending east from Shullsburg no very important deposit of ore is found until we reach the east side of the west Pecatonica, where we find Wyota, on the extreme north line, and the region about Monroe the eastern extension of these mining districts."

For the second belt he says: "Looking north, we observe in the distance other mining districts apparently arranged along a similar line. On reaching town 3, and following its south line west to where it intersects the Mississippi, we notice very similar phenomena to that described in the belt just referred to.

"Let us put down a stake here, also, and measure four or five miles north, and put down another, and from these two stakes draw two lines as before, east, or a little to the north of east, and see what we include. We have the mines of Potosi, British Hollow, Rockville, Pin Hook, Red Dog, Whig and Platteville, in Grant county. In extending into La Fayette county, this mineral range encounters the elevated lands of the Platte Mounds, and but little is seen of it until we reach Calamine, Fayette and Argyle, where it may be seen as a mineral belt extending into Green county, where, like the other, it is lost in range seven. What was said of the other belt may be said to a great extent, of this; only not quite as productive, perhaps, as a whole.

"With the additional light of this fact, it is not difficult now to see another belt near the south line of town 5. A belt, though well defined through three ranges of townships in Iowa county, and one in Grant (including the mines of Mineral Point, Diamond Grove, Lost Grove and Mifflin, in Iowa county, and New California and Crow Branch, in Grant county), is nevertheless disturbed at the west end, as it comes in contact with the geological break along the valley of Grant river, where it seems to be borne down a little out of its course to Beetown, but there it again takes its regular course. Towards the east end it encounters a very heavy ridge, or elevation of land coming down from the northwest of Dodgeville, and extending in a southeast direction through the county. This belt, when coming in contact with this ridge, or elevation of land, seems to follow its course, and groups of mineral ranges are found along its flanks for ten or fifteen miles. * * *

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[1] Report on the Lead Regions, 1871, pp. 9–11.

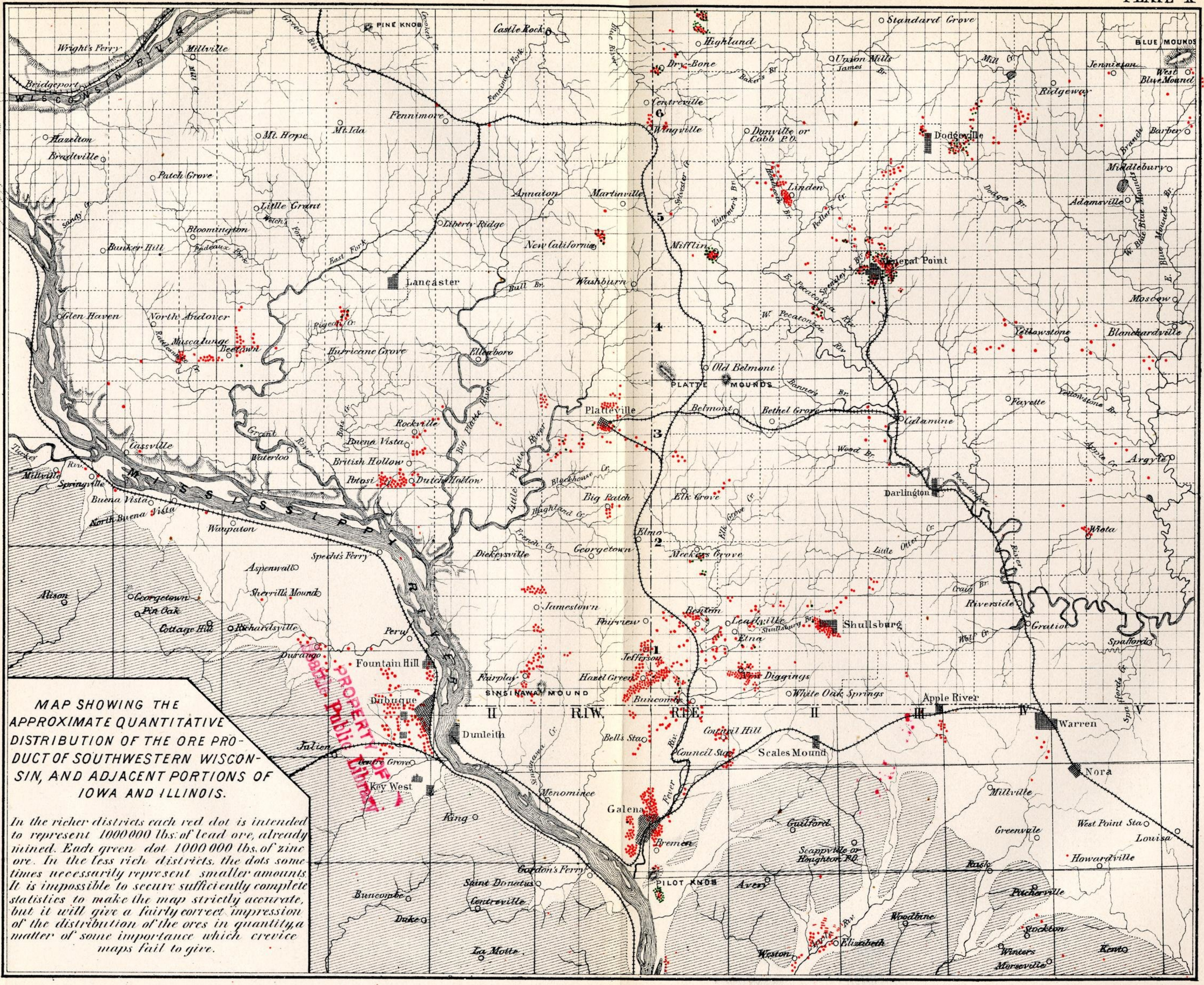
"North from the third belt we commence to ascend a gentle elevation, which culminates in about the middle of town 6. Along the south flank, or near the center, is another well defined belt, extending through a large portion of Grant county, the whole of Iowa, and for several miles into Dane; and the mines of Fennimore, Wingville, Spring Valley, Dodgeville, Ridgeway, Porter's Grove and Blue Mounds form a chain of mineral ranges, extending through nine ranges of townships; and their course is as distinctly marked as the lines of the town (6) in which they are found. The north side of this belt is said to be the extreme north side of the lead district, beyond which no ore has been found, and beyond which, it has been said, none will be found. We will pause here for a moment and gather up what facts we have discovered."

If the reader will pause here long enough to mark out these belts upon Atlas Plate XXXI, on which the lodes are laid down with approximate accuracy, he will be able to gather for himself how much of fact there may be represented in this staking off of the lead district into great parallel belts. He will perhaps observe that the third and fourth belts are in close contact, and that the remainder either do not include all of the productive mines or are separated by very narrow intervals. How the districts of Dubuque, Vinegar and Council Hills, and Galena could be brought into this system, as they must in any comprehensive study of the subject, is not quite clear. A single glance at the map will show that such a grouping is quite arbitrary.

If I were to venture upon the forlorn hope of discovering a profound system underlying the distribution and arrangement of the lead districts, where doubtless no such profound system exists, I should seek a basis in those causes of undulation which gave origin to the depressions in which the deposits are found to lie. Doubtless those causes were complex in their nature and gave as the result a complex system, which, though the definite result of forces acting under uniform and inflexible laws, are nevertheless complicated and unsymmetrical in their combined results. Some of the salient features of this complexity may be discernible and our only attempt will be to suggest some of them.

If a ruler two inches in width and of sufficient length be applied to the general map of the lead region (Atlas Plate XXXI), it will be found that it can be made to cross the heart of the lead region in only one position without concealing important lodes. The ruler represents a belt only four miles in width, and it is therefore evident that well defined belts separated by broad linear zones of barren territory are not a characteristic of the region. The position referred to is the line of the extension of the anticlinal described by Prof. Worthen in the Illinois Report.[1] Crossing the Illinois river and extending north-

[1] Geology of Illinois, Vol. 1, p. 5.



MAP SHOWING THE APPROXIMATE QUANTITATIVE DISTRIBUTION OF THE ORE PRODUCT OF SOUTHWESTERN WISCONSIN, AND ADJACENT PORTIONS OF IOWA AND ILLINOIS.
In the richer districts each red dot is intended to represent 1000000 lbs. of lead ore, already mined. Each green dot 1000000 lbs. of zinc ore. In the less rich districts, the dots sometimes necessarily represent smaller amounts. It is impossible to secure sufficiently complete statistics to make the map strictly accurate, but it will give a fairly correct impression of the distribution of the ores in quantity, a matter of some importance which crevice maps fail to give.
WISCONSIN RIVER
MISSISSIPPI RIVER
Wright's Ferry
Bridgeport
Millville
PINE KNOB
Castle Rock
Standard Grove
BLUE MOUNDS
West Blue Mound
Highland
Dry Bone
Union Mills
Ridgeway
Jenniexton
Fennimore
Centreville
Wingville
Danville or Cobb P.O.
Dodgeville
Barber
Hazelton
Bradtville
Mt. Hope
Mt. Ida
Patch Grove
Little Grant
Bloomington
Annaton
Martinville
Linden
Middlebury
Adamsville
Bunker Hill
Liberty Ridge
New California
Mifflin
Mineral Point
Lancaster
Washburn
Moscow
Glen Haven
North Andover
Muscalunge
Beetown
Hurricane Grove
Ellenboro
Yellowstone
Blanchardville
Old Belmont
PLATTE MOUNDS
Platteville
Belmont
Bethel Grove
Calamine
Fayette
Cassville
Rockville
Waterloo
Buena Vista
British Hollow
Potosi
Dutch Hollow
Argyle
Millville
Springville
North Buena Vista
Wapaton
Big Patch
Elk Grove
Darlington
Wiota
Elmo
Dickeysville
Georgetown
Meekers Grove
Specht's Ferry
Aspenwall
Sherrill's Mound
Alison
Georgetown
Pin Oak
Cottage Hill
Richardsville
Durango
Peru
Jamestown
Fairview
Benton
Leadville
Shullsburg
Riverside
Gratiot
Spafford
Fountain Hill
Jefferson
Elna
Fairplay
SINSINAWA MOUND
Hazel Green
New Diggings
Dubuque
Buncombe
White Oak Springs
Apple River
Warren
Dunleith
Council Hill
Bell's Sta.
Council Sta.
Scales Mound
Julien
Centre Grove
Key West
Nora
Menominee
Galena
Millville
King
Guilford
West Point Sta.
Louisa
Bremen
Scappville or Houghton P.O.
Greenvale
Howardville
Gordon's Ferry
PILOT KNOB
Avery
Saint Donatus
Buncombe
Centreville
Pucherville
Duke
Woodbine
Stockton
La Motte
Weston
Elizabeth
Winters
Morseville
Kent

westward from La Salle, through Grand Detour and Oregon on Rock river, and striking into Wisconsin from Stephenson county, it runs parallel to the west Pecatonica, through the Platte Mounds and onward to the elevated strata at the head waters of the Grant. The ruler applied along this line would conceal only some unimportant and long abandoned diggings on the Ames branch. This axis, it will be observed, is the approximate watershed between the tributaries of the Rock, and those of the Mississippi, and was doubtless connected with the original determination of the general drainage systems of the region and therefore must have been an influential circumstance as early as the date of the origin of the rivers.

It is further interesting to observe that the Mississippi, descending in a nearly southerly course from La Crosse to the limits of the lead region, turns to a marked southeasterly course, essentially parallel to this line and continues in that direction, until it reaches the southern limit of the lead district, when it recurves to the southwest and maintains that course, until it reaches the meridian which it was following when it was deflected southeastward. This deviation of the "Father of Waters" could be accounted for by a depression of the strata which would thus lead it away from its general course.

It is still further to be observed that the general directions of the crevices approach parallelism to these lines. The master ranges of the great Beetown, Potosi, Platteville, Menominee and Shullsburg districts all trend to the south of east, though more easterly than these lines. Many of the subordinate ranges have a similar trend. On the opposite side Crow Branch, Mifflin, a portion of Linden, of Mineral Point, Duke's Prairie, Darlington and Wiota ranges, with others more remote, or less important, bear in the same direction.

If I were to attempt to marshal the crevices into belts, they would be very broad and rude, but would consist of one great zone lying west of this barren strip mentioned, and including all the districts on that side, i. e., on the immediate Mississippi slope; of a corresponing second belt, lying on the east side, the axis of which would extend from Highland through Linden and Mineral Point onward to Duke's Prairie and the Argyle deposits, embracing the adjacent districts on either hand; and of a third joining this from the northeastward stretching from the Moundville deposits through the Ridgeway, Porter's Grove, Dodgeville and Van Meter groups, to its union with the preceding, being essentially parallel to Military Ridge, a stratigraphical, as well as topographical axis, stretching across the state south of the Fox-Wisconsin river valley.

But these general circumstances attending the distribution of the deposits seem to me quite too general to be of much practical consequence in the localization of the lodes, whatever of interest they may have in a comprehensive survey of the subject. The conditions that controlled the localization of deposits were more special, definite and limited in extension, and are to be sought for in the special local circumstances of each district, not to say of each subordinate group of ranges within the district. We, therefore, pass from these general conditions to study some of the special features of the several districts. In this immediate connection, however, we shall do little more than glance summarily over the surface grouping and prevalent directions of the ranges. For special features and details reference is made to the maps.

In the Beetown district, three notable sub-groups are to be discovered, (1) that northeast of the village in which the ranges are scattered with a good deal of regularity, and have a very uniform direction and considerable length, a number of them exceeding a mile, the average direction being about N. 81° W.; (2) *the Nip and Tuck diggings*, southwest of the village, which are more closely and irregularily grouped, and more varying in direction, the average trend of the easts and wests being about N. 83° W.; and (3) *the Muscalunge diggings*, separated from the Nip and Tuck by a comparatively, but not wholly barren, interval of less than one mile. These consist of a closely clustered series of east and west ranges with an average direction of about N. 87° W., crossed by a remarkable series of quarterings of varying direction, but averaging about N. 60° E. By examining Atlas Plate XL., it will be observed that, even in this well compacted group, at least two distinct subdivisions are clearly indicated. To the southeast lies a remarkable complex group of about fifty east and west and quartering crevices, forming a single series, the Atkinson range. In the vicinity of this are gathered several more regular east and west crevices. Between these and the more numerous ranges to the northward, there is a belt of ground that has thus far proved barren. From the south Hutchcroft & Co. range to the Spenser, the productive stratum appears to incline northward, while from all the region above, the water gathers southward, the master ranges lying near the union of the two. By inspection of the map, it will be seen that drifts have been driven, for the greater part, along quarterings, and easts and wests have been mined on either side greater or less distances, but in the northern group these quarterings do not develop the complexity nor richness that they possess in the southern or Atkinson group, while the easts and wests develop more relative importance. It would seem, therefore, that while the circumstances of origin were such as in the one case, to give unusual development to the quarterings, they, in the other, favored the easts and wests, though the general systems of fissuring are alike in both instances. It is propable, though it has not been demonstrated, that the Atkinson group occupies a very shallow stratigraphical valley, separated from that on the north by a low swell of the beds.

The topographical relations of the lodes of this district may be studied by comparison of the contour lines, but this cannot be done with entire success, since the crevices, for practical convenience, are mapped with lines of uniform width throughout the extent to which they have been worked, and do not indicate the variations in the richness of the deposit along the crevice, and, of course, the essential thing is the deposit and not the receptacle. Were sufficiently exact data obtainable to construct a map which, by the varying width of the lines representing the crevices, should indicate the relative richness of the ore deposit, it would furnish an excellent basis in connection with the contour lines, for the study of the relations between surface contour and the lodes, but it has been found quite impracticable. Mr. Wilson who has had occasion to make exact underground and surface surveys of these diggings to determine questions in litigation, at various times during the last twelve years, and has been quite familiar with the productive development of the region, has arrived at the following confident generalizations:

First, that where the crevice passes directly under the ridge, at right angles, it usually encounters close or barred ground, and is lean under the steep face of the ridge, but develops its greatest openness and richness under the more receding brow, while, as it approaches the summit, it usually pinches up and becomes unproductive; second, where the crevice passes obliquely under the face of a ridge, it is usually meagerly productive, and third, where it pursues a course nearly parallel to the surface contour, but neither near the summit nor under the steep face of the ridge, its situation is favorable to productiveness.

These rules, as applied to the Atkinson range, where the complex crevices pursue varying courses and present repeatedly the several attitudes named, consecutively, in the same general belt, are claimed to be quite severely and successfully tested.

By examining the numerous short ranges along the bluff facing Muscalunge diggings, it will be observed that the majority lie nearly at right angles to the bluff, but do not come out to its face; nor reach far back toward the summit, indicating, as the practical result of experience, that they are neither found productive on the extreme face of the ridge nor under its summit height.

These generalizations, in common with all that attempt to connect the character of the metallic deposits with surface contour, will be received by geologists generally with a large measure of skepticism. While, in common with all rational observers, we sympathize with the feeling of impatience with views, in general, connecting metallic deposits with the "lay of the land," yet these deductions, applied, as they are, only to this special class of accumulations, are not without a rational basis, as will appear in the sequel.

The Potosi district consists (1) of one large group of long, strong ranges gathered about the village, (2) of a small compact group at Dutch Hollow, (3) of another a little north of British Hollow, (4) of a few ranges south of Rockville, from which lodes scatter on to the districts known as Pin Hook and Red Dog diggings. These last are but a scattered line of crevices showing a tendency to group by twos and threes, but not constituting a well defined district. Their average direction is N. 74° W. and their average length about a quarter of a mile.

The Rockville cluster shows more irregularity of direction. Some incline south of east, some south of west. the average being N. 80° W.

The British Hollow group consists of a more compacted assemblage of ranges trending south of east, crossed by others ranging east of north and connected with a single one trending west of north. With the exception of this last, they constitute a well compacted group.

The Dutch Hollow group has the same general direction as the main Potosi diggings, but is closely concentrated within a sharp synclinal trough of the strata, the rock being very much fractured, and the ore widely distributed through it in sheets, floors and irregular impregnations, so that the distinctness of the ranges is obscured.

In the main Potosi group the lodes are scattered with more than usual uniformity over the district, and have more than usual length, nearly half of them exceeding half a mile in length. Their average direction is about N. 67° W. They pursue their individual courses usually with much regularity, but several deviate from their general course. They stand, in general, at right angles to the main ridges, and, as will be seen, cross minor valleys without interruption or deflection. Potosi Branch cuts off, in its course, all except those near its head, but whether the ranges on one side are resumed on the other is answered by only negative evidence, except that the Brock and Hull is situated as though it were a continuation of the Wood and Dean. The general dip of the opening of the West Potosi district is to the east, that of the Long and Wooley range being determined as 1 ft. vertical descent to 173 ft. horizontal. That of the East Potosi ranges is not positively determined. In the inclined Long and Wooley ranges the deposit is said to have been richest under the summit of the range, being an example of another rule of deposition in relation to surface contour, according to Mr. Wilson's generalization, namely, that where the crevice openings, i. e. the strata, dip beneath the hill rich deposits under the summit often occur.

The Fairplay diggings are notable as constituting one of the most regular and systematic groups in the entire region. The lodes run very nearly parallel, their average direction being N. 88° W. These ranges, as will be observed at a glance, are arranged in a north and south belt, so that if a line be thrown around the lodes, it will describe an elongated north and south oval. While somewhat uniformly distributed, the ranges have nevertheless a notable tendency to groups. One cluster of ten short lodes lies at the southern extremity and another of six at a quarter of a mile north, and another of seven a little farther to the northwest, while another of nine longer ones lies north of these. Near the village of Fairplay there is a group of eight ranges, having a course north of east, with three associated ranges having the prevalent direction.

The remaining lodes, on the north, fall into three general groups, the more northerly one known as Hunsacker diggings. The Shawneetown diggings constitute a detached group about a mile distant to the east, with an average course of N. 88 ° W.

The Lower Menominee diggings are less than a mile distant from the northernmost Fairplay district, and constitute a circumscribed, compactly arranged group, leaving out of consideration three or four outlying ranges, and have a common direction about N. 81° W.

The Upper Menominee diggings present a very interesting surface arrangement, consisting of a closely arranged group, more than usually inclined from the cardinal directions, the average trend being N. 56° W.

The Hazel Green district presents a singular complexity in the grouping and direction of the ranges. The district may be said to be concentrated about a belt of ranges running in a northeast-southwesterly direction from about the southeast corner of Sec. 19, T. 1, R. 1, E., to Sec. 35, T. 1, R. 1, W.

Along this belt the crevices are thickly distributed in irregular groups. The prevailing tendency is to form two sets, one of which has a general east and west direction, but shows a disposition to incline from north of east to south of west, instead of the more general inclination from the north of west to south of east. The cross set generally trend from the east of north to the west of south; but between the prevalent directions there are many intermediate ones, so that no general average can fairly express the facts, nor any verbal description, and the reader is referred to the crevice maps, Atlas Plates XXXIX and XXXI. There is here to be noted, at two points, a disposition to change from one system of directions to another, through intermediate forms. It is conspicuously exhibited in the combined group formed of the Adney, Bruce and Yount lots. It is seen less distinctly in the group southeast of the village of Hazel Green, adjacent to the Durley lot.

The disposition of the crevices to form close groups or gangs of lodes is here most conspicuously displayed. "Sheet lot" is a striking example. Mills' lode and the ranges with which it is connected are worthy of note as pursuing a northwesterly course, a direction at variance with the prevalent trend.

In the *Benton district* the lodes are distributed in clusters scattered over nearly the entire township (T. 1, R. 1, E.). The prevalent direction of these is a little south of east, but to this there are many exceptions. Marshall Group, Black Lock, Burrills, Sheet Lot and a few others trend east of north to west of south. Ellis and Gear lodes and associated ranges, McAffrey, Dean, Merrit, Goodfellow and associates, Appleby, Dormer, Peaslee, French, Van Hook, Heard, Adams and associated ranges, with a number of others, have a decided tendency to west of north and east of south. The great complex group of Swindler's ridge represents the trend of the master ranges, in the direction N. 77° W.

The great group of *New Diggings* have a more nearly east and west trend and are associated with cross crevices of varying inclination, but, for the most part, east of north.

The Shullsburg Diggings proper present ranges which transcend all others in their irregular zig-zag courses. (Atlas Plates XXXVII and XXXVIII.) The general trend is southeasterly, but only an inspection of the map can give an adequate conception of the irregularities of detail. Associated with these broken ranges are several of more direct course, which by a direction N. 68° W., indicate fairly the average trend of the group. Connected with these are a few transverse lodes having a bearing a few degrees east of north. Of the associated groups of the district, the Deep Clay and Townsend diggings constitute two groups lying to the west, which vary only a few degrees to the east of north.

The Irish diggings on the north consist of a series of grouped ranges with trends varying from N. 5° E., to N. 40° E.

The Stump Grove diggings, beyond, have a more northerly direction, with a few associated east and west ranges.

The Platteville district embraces a scattered assemblage of ranges less definitely clustered than some of the preceding. The most notable group is gathered about the village of Platteville and consists of rather short rich ranges of nearly uniform direction, averaging N. 84° W. North of the village about one mile is another notable cluster two of which are long ranges, having an average direction of N. 82° W., beyond which are scattered a few short ranges.

Southeast and southwest of Platteville isolated lodes, or groups of two or three crevices, are scattered for several miles. In Meeker's lot there is a more concentrated group. All of these maintain a direction approximately parallel to those of Platteville, inclining somewhat more to the northwest and southeast. West of Platteville *the Whig diggings* occupy a circumscribed area with about a score of short ranges which have the same average direction as the Platteville ranges, except the two Schmidt ranges, which run southeast, being among the very few examples of transverse lodes in this district. *The Big Patch* and *Elk Grove* ranges are closely harmonious in direction with those of the general district, except in showing a larger relative number of transverse lodes.

The Mifflin ranges constitute one of the most compact and isolated groups in the whole district, considering their richness and importance. The ranges have a general course of N. 35° W., but are slightly convergent in that direction.

Crow Branch diggings exhibit one master range, with a few subordinate associated ones, the former bearing N. 30° W., to which one of the latter corresponds, but the the rest have a more east-westerly trend.

Mineral Point district centers in three rich clusters of ranges situated respectively north, northeast and southeast of the city. Of the first named the average direction is about S. 55° E., the second are quite divergent, ranging from nearly southeast to south-southeast, while the latter is about S. 20° E. The scattered ranges north and south of Mineral Point assume nearly a due east and west direction, occasionally inclining 10° or 15° south of east.

Those which scatter away to the northwest in the direction of Linden vary from east and west to a northwest-southeast direction.

The Linden Group is difficult to characterize by a simple statement of direction. The few short ranges in the vicinity of the village vary but a few degrees from east and west. The long ranges that lie to the northwest have a general north and south direction, but curve considerably in their course, a somewhat unusual fact for ranges of this class. The transverse easts and wests trend a few degrees to the north of west. The great Linden range has throughout the greatest part of its extent a southeasterly direction, but in its eastern portion it curves upon itself until it assumes a direction W. 20° S. The general form can best be appreciated by consulting Atlas Plate XXXII.

The ranges scattering north from Mineral Point toward Van Meter's Survey have, in general, a more southeasterly direction than those either north or south of them, though this is not a uniform fact. The Van Meter ranges consist of a very closely grouped set of parallel ranges having a nearly due east and west direction with a few outlying ranges associated with them, and a single due north and south lode crossing them.

The ranges in the immediate vicinity of *Dodgeville* have a northwesterly trend, in general, but the Lambly group diverges gradually to a nearly due northerly direction. The transverse ranges vary in direction from a few degrees north of west to as many south of west. The remarkable cluster of flat deposits lying east of Dodgeville are notable for their want of definite direction rather than for conformity to any rectilinear system. As will be observed by consulting the map, they are prone to curved forms. If a line be thrown about the group, it will form an oval, having its elongated diameter lying nearly northeast and southwest. The crevices associated with the group vary but a few degrees from the east and west direction, except the Messersmith ranges, which are nearly north and south, curving eastward at the northern extremity.

Porter's Grove ranges average a direction about northwest and southeast with considerable variation.

Those of *Moundville* are quite uniform in direction, being about N. 25° W.

The Yellowstone district consists of groups of three or four short ranges, each quite widely dispersed, whose direction is most frequently northwesterly, but, in the case of a few groups, northerly. The ranges near Argyle present similar characteristics.

The Wiota diggings consist of a concentrated group with a prevalent direction about N. 57° W., crossed by numerous secondary ranges running about N. 20° W. A single associated group runs N. 20° E.

The Highland ranges have a northeasterly trend. Those of *Wingville* are nearly due east and west.

Passing beyond the limits of the state, *the Dubuque lodes* are remarkable for their extreme parallelism and their close approximation to an east and west direction, transverse lodes being very rare. In *the Galena district* there is much more variation, but the master ranges do not depart very largely from the east and west direction. The transverse system shows a prevalent tendency to a northeast-southwest direction, but has numerous and notable variations.

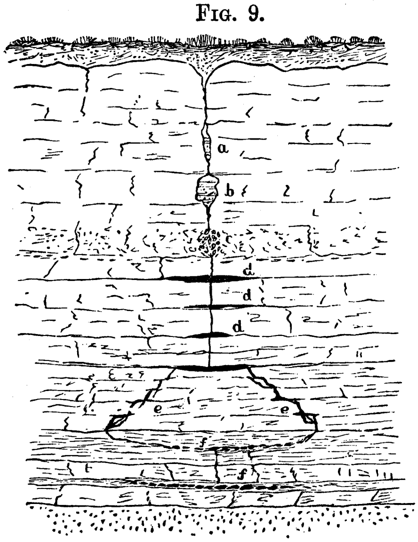
The Elizabeth group, the most southerly of the district, consists almost entirely of ranges running due east and west, with a few, nearly due north and south lodes.

It will be seen, by a summation of this brief review of the ranges, and, more vividly, by direct study of the maps, that the east and west ranges, as before indicated, vastly predominate over all others, that, in so far as they vary from the cardinal direction, the tendency is markedly toward a northwest and southeast direction, rather than toward a northeast and southwest direction. In other words, there is a conspicuous tendency to conform to the oblique axes of flexure that characterize this region and that lying southward as far as the extremity of Illinois, as heretofore described. As these flexures were impressed upon the strata subsequently to the completion of the metalliferous series of the lead region, and are the latest of such flexures which the formations are known to have suffered, the correspondence at least suggests community of origin.

VI. The Special Situation of the Ore Deposits within the Strata.

The known lead and zinc ores of the Upper Mississippi region lie mainly in the Galena and Trenton, and subordinately, in the Lower Magnesian limestones. The deposits in the first two formations must be considered jointly, not only on account of the want of any sharp line of demarkation between them, but because ore sheets traverse both and inseparably bind them together. On the other hand, there is an entire want of evidence that any ore sheet passes from the Trenton down to the Lower Magnesian limestone, and, whatever may be the evidence in favor of the belief, it is certainly not prudent at the outset of an investigation to assume that there is a genetic continuity between the deposits of the two formations.

Fig. 9.



Soil and Residuary Clay.

Upper Galena.

Middle Galena.

Lower Galena.

Blue Limestone.

Buff Limestone.

St. Peters Sandstone.

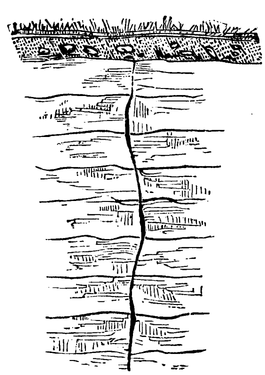
Ideal Section, showing Characteristic Forms of "Openings" and Ore Deposits in the Different Horizons. a, Vertical Crevice Opening. b, Cave Opening. c, Tumbling Opening. d, Flat Opening. e, Flats and Pitches. f, Flats.

While there is no disjunction of the lodes in passing down from the Galena to the Trenton beds, there is a change both in the form of the ore receptacle and of the ore deposits. In the Upper Galena the ores are found almost exclusively in vertical fissures, or in local enlargements of these, known as "openings." In the Lower Galena and the transition beds, there is a prevalent tendency to "flats and pitches," while in the Trenton layers "flats" are the dominant form.

THE ORE RECEPTACLES. It goes without saying that the fissures and openings were first formed and afterwards received the ores, and, perhaps, we might well follow nature's order by considering the character and origin of these ore receptacles and then the manner in which their metalliferous treasure is stored in them, but some departure from this will be found convenient.

It is a familiar observation that rocks are habitually traversed by seams of varying length and width, and that these, broadly speaking, are wont to consist of two sets which cross each other at wide angles, blocking out the rock for the convenience of quarrymen. This is peculiarly the custom of limestone, and there is in our region a prevalent tendency to keep square with the world by conforming to the cardinal directions — giving rise to "easts and wests" and "norths and souths," while "quarterings," "ten o'clocks," "four o'clocks," etc., show, at the same time, that the rule is not rigid. These simple fractures of the rock gape a little and leave space for filling.

FIG. 10.

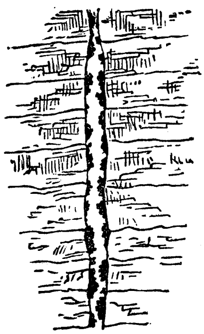


VERTICAL FISSURES FILLED WITH ORE CONSTITUTING "VERTICAL SHEET" DEPOSITS.

1. *Vertical Seams.* Many of the lead-bearing crevices are of this simple sort. These constitute the vertical sheet openings and range from the merest seam up to fissures a foot or more across, filled either solidly, or partially, with ore. The north and south crevices are mainly of this kind and seldom open very widely or assume other than this simple form as represented in figure 10.

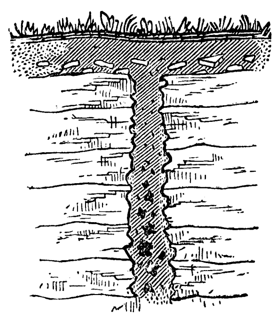
2. *Open Crevice Deposits.* The east and west fissures, however, and often the quarterings, are prone to open more widely and so sometimes furnish a rift of some magnitude, along the vertical sides of which the ore is deposited in layers, or, perhaps, more often, in scattered clusters of crystals as shown in figure 11.

FIG. 11.



OPEN CREVICE LINED WITH GALENA.

FIG. 12.



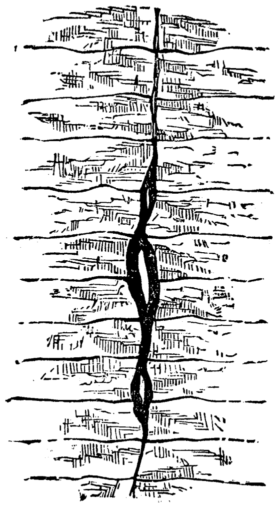
THE SAME CREVICE AFTER HAVING UNDERGONE SOME DECAY BY WHICH THE ORE WAS LOOSENED FROM THE WALLS AND MIXED WITH CLAY BROUGHT FROM ABOVE OR PRODUCED BY THE DECAY OF THE WALLS.

Secondary Openings. Whenever a fissure is not entirely closed up by its mineral contents and is afterward brought within the reach of atmospheric influences, by the gradual wearing down of the surface, and the draining away and lowering of the subterranean water, so that the air penetrates deeply, both it and its contents are subject to disintegration. This is especially so if iron sulphide be present in abundance. This decay not only enlarges and modifies the fissure, but loosens and throws down the ores, mingling them with the clay and sand resulting from the disintegration of the rock. Thus "openings" quite different from their original form are produced, and are found, nearly or quite, filled with calcareous sand, clay, ocher, loose ore, flints and other products of decomposition. The simple, open, vertical fissure above described, would, by very moderate decay, take such a form as represented by figure 12.

3. *Gash Veins.* Very frequently a fissure opens for a space along its course, and again closes, forming a gash-like gap, on the walls of which the ore accumulates, giving rise to one of the forms of gash veins as shown in fig 13.

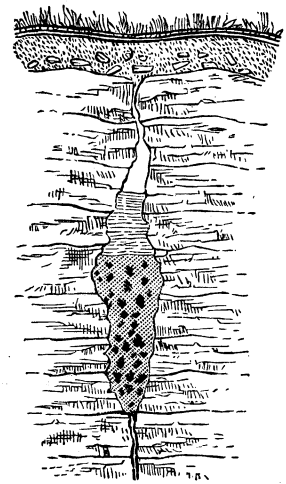
When at length, by erosion, the surface is brought near to the deposit, and decay takes place through the free admission of oxygen, the opening will be enlarged and filled with clay and calcareous sand derived from the disintegration of the rock or washed in from the surface. Throughout this, the fallen fragments of ore will be scattered, and the whole may appear as represented in figure 14.

FIG 13.



GASH VEIN.

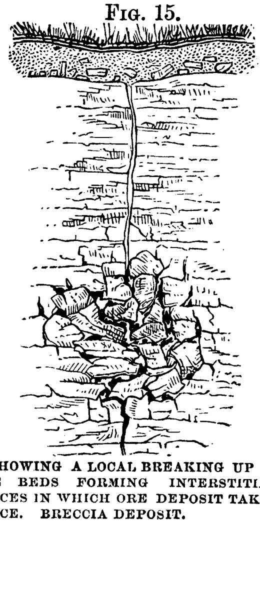
FIG. 14.



GASH VIEN AFTER DISINTERGRATION.

4. *Breccia Deposits.* Sometimes one or more layers of rock seem to have been much fractured, where crossed by the fissure, and the fragments loosened, leaving irregular spaces between them in which ore was afterwards deposited.

FIG. 15.

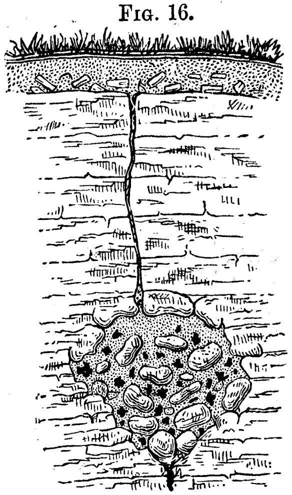


SHOWING A LOCAL BREAKING UP OF THE BEDS FORMING INTERSTITIAL SPACES IN WHICH ORE DEPOSIT TAKES PLACE. BRECCIA DEPOSIT.

5. *Tumbling Openings.* When this fragmentary mass comes to be disintergrated, the outer portion of the irregular blocks will be decomposed into sand, leaving more rounded bowlder-like masses, the "tumblers" of the miners, and the resulting sand, clay and ore will be distributed between these, and the whole will become what is known as a "tumbling opening." In other instances, the fracturing was much more intimate and, instead of large blocks, there resulted small angular fragments, between which the mineral was deposited. Not unfrequently these fragments appear to be the same that entered into the constitution of the

brecciated layer to which they belong and to have simply been forced apart again by breakage of the cementing material. In not a few instances, I found myself unable to determine to my complete satisfaction, whether the fragmental condition was due to primitive deposition as a breccia, or to forcible action subsequently. This uncertainty arises from the fact that, in many cases, the decayed condition of the rock prevents all close observation, and in others, in which disintegration has not taken place, a crystalline granulation of the rock has supervened, of a nature about equally suggestive of modification of an original breccia and the regeneration of a disrupted one. The amount of interstitial space favors the latter view and is, apparently, only reconcilable with the former by assuming a removal of material by solution, since so open a breccia could scarcely be formed under the known conditions of deposition, and, in any event, would not be limited to the vicinity of the fissure.

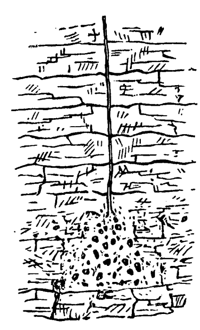
FIG. 16.



TUMBLING OPENING.

6. *Honey-Combed Openings.* A closely analogous, if not really identical, phenomenon, observed only in disintegrated rock, consists of a stratum completely honey-combed, near the fissure, by irregular perforations and cavities. Though varying much in size, if the perforations be conceived as one or two inches in diameter and the more cellular cavities as two or three, a fairly correct impression will be gained. A portion of these are entirely vacant while, perhaps, a larger portion are filled with the sandy residue of decayed rock. Within these cavities, partly in the vacant and partly in the sand-filled ones, the galena is deposited in irregular lumps. The ore is itself much corroded and worn, and even occasionally perforated, making it difficult to determine how much of the wearing out of the little passage ways was anterior to the deposit of the galena. It is clear, at least, that a considerable part was subsequent. Mining towards the

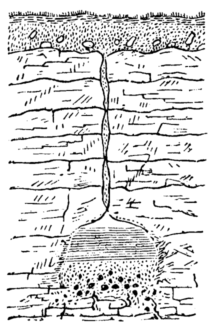
Fig. 17.



HONEY-COMBED OPENING.

sides, the perforations are found to give place to sand-filled cavities and soft spots in the rock which graduate into more solid beds. My view of both these last classes is that the particular stratum involved, originally a breccia for the most part, has been crushed adjacent to the fissure, and on the removal of the disrupting pressure and relaxation of the strata, spaces were left between the constituent fragments, in which the ores were deposited; and that some of the connected cavities became little water-ways and thus were worn. When, at length, by the wearing down of the surface, air and oxygenated waters were allowed free access, oxidation of the sulphides took place, followed by interaction between the metallic sulphates, so formed, and the earthy carbonates of the rock, resulting in the disintegration and partial removal of the latter. And this view, with slight modifications, is applicable to the whole class now under consideration.

Fig. 18.



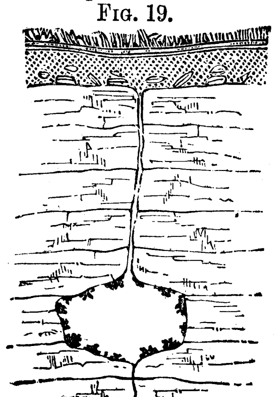
CLAY OPENING DERIVED BY DISINTEGRATION FROM A HONEY-COMBED OPENING.

When decayed, all these become "clay-openings," and carry the ore embedded in clay filling and, usually, most abundant toward the bottom.

7. *Cave Openings.* In comparatively rare instances, a cavernous enlargement of the fissure took place before the deposition of the ore, due, probably, in all instances to the solvent and erosive action of water. The only two examples, which I have seen, were unmistakable water-ways, on the walls of which the ores had been deposited. These are of course to be distinguished from cavernous enlargements made *after* the deposition of the ore, which are quite common.

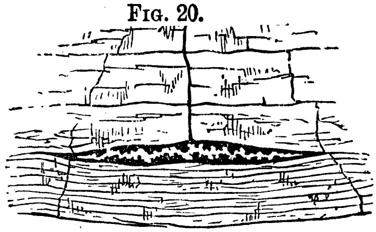
8. *Flat Openings.* Still another form of receptacle was produced by a horizontal parting of the rock layers, leaving a wide and flat but low opening between them. The ores in forming within this gathered upon the upper and lower surfaces, sometimes only coating them more or less thickly, but sometimes growing till they met and filled the entire space, or at least only left, here and there, vacant spaces, the "vuggs" of the miner.

FIG. 19.



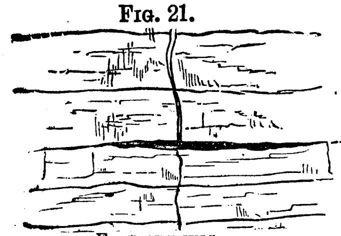
CAVE OPENING.

FIG. 20.



FLAT OPENING.

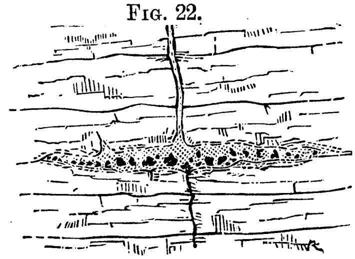
FIG. 21.



FLAT OPENING.

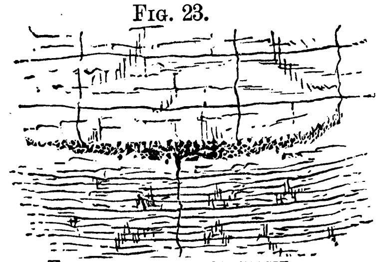
9. *Impregnations.* Another form of flat deposit consists of a stratum of rock, widely impregnated with ore, on either side of the crevice. This, especially when pyritiferous, as is often the case, is

FIG. 22.



FLAT OPENING DISINTEGRATED.

FIG. 23.



FLAT IMPREGNATION DEPOSIT.

prone to disintegration, giving rise to a flat clay or sand opening, carrying disseminated ore. This form is sometimes combined with the preceding, producing a complex type.

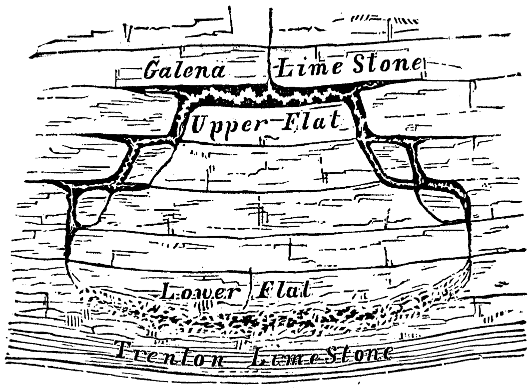
10. *Horizontal Sheets.* In still other instances, thin seams of ore form along the bedding joints of the rock producing attenuated horizontal sheets, analogous to those filling the narrow vertical fissures.

11. *Stockwerk.* A complex type occasionally occurs in which small irregular seams and rock impregnations are combined forming a species of "stockwerk." This is of merely limited and local extent and is not to be compared to those typical cases in which extensive masses of rock are pervaded by a complete network of small veins.

This class merges into the brecciated type above described, and is only a passing phase of deposit, so to speak.

12. *Flats and Pitches.* But by far the most peculiar and interesting type consists of the combination, aptly styled "flats and pitches." This type has heretofore received little more than passing notice, or brief description, and seems not to have been recognized as the dominant form of the lower horizons, or to have been thought to possess any especial significance. It cannot fail to be very instructive, however, if studiously considered. To gain a correct view of the essential characteristics, conceive a vertical crevice, after assuming the usual phases in the upper Galena to pass down as a close seam

FIG. 24.



IDEAL SECTION OF "FLATS AND PITCHES," SOMEWHAT DISTORTED AND SIMPLIFIED FOR THE SAKE OF CLEARNESS.

— except when occasionally interrupted by a "chimney" or local opening—through a solid stratum, which constitutes the "cap rock." Immediately beneath this is a horizontal opening caused by the separation of the beds. This may have a width of seventy-five feet or more, and a vertical depth varying from a few inches to one, two, or three feet, very rarely exceeding the latter. The ores in this part customarily adhere to both upper and under surfaces, and often nearly or quite fill the whole space, forming a rich deposit. This constitutes the "upper flat." Conceive this to terminate on both margins in a fissure passing down obliquely across the underlying bed for three or four feet, more or less, until it intercepts the next lower bedding plane, when it follows this horizontally for a few feet, usually nearly equal to the previous descent, and then again breaks down across the beds, only to again flat, and so continues to pitch and flat until it reaches the soft, thin beds and shaly layers of the Trenton limestone, with which, so far as my observation goes, the zig-zag system terminates. Instead of a single oblique fracture on each side, there are often two or more, one of them, however, being usually largest, and carrying most of the ore. At the angles along the stair-like declivity, a minor sheet of ore frequently projects a little distance along the bedding plane, as shown in figure 24. Besides the upper flat there is sometimes a second one only a few feet below it. In such cases the vertical fissure usually passes down to it, but is not traceable beyond. Sometimes vertical fissures come down from above at the sides as well as center of the upper flat, but they are close crevices, save that there are local gaps and enlargements—"chimneys" or otherwise. When the diverging zig-zag crevices reach the thin-bedded Trenton limestone, interleaved, as it is, with partings, and intercalated beds of carboniferous and clayey shales—the "calico rock" of some localities—and the pipe-clay opening, they often become connected with each other by a wide flat, stretching from foot to foot, sometimes in and sometimes a little above the pipe-clay opening. This flat, unlike that above, is seldom formed along a uniform parting of the beds, but traverses them more irregularly, sometimes splitting up much and occupying small fractures, or not uncommonly taking the form of an impregnation of the soft rock, as in the case of the "speckle jack" and "strawberry-blende" of Mifflin and analogous deposits elsewhere, presently to be described.

Such deposits as occur at lower horizons usually take the form of irregular horizontal sheets or impregnations of the rock. Vertical crevice deposits, like those that characterize the upper portion of the Galena limestone are rare.

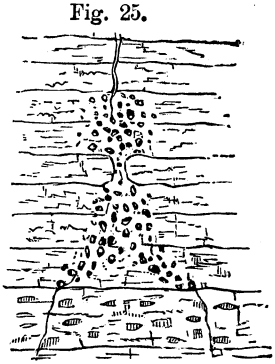
Special Descriptions. The foregoing constitute types of the more common phases of fracture and opening which the strata have presented for the reception of the metalliferous deposits. The general manner in which the ores have been implanted in these and the aspects assumed by the whole as the result of decay have also been incidentally indicated. Prepared by these generalized views, we may, the more conveniently, consider individual deposits and special features.

It was my original purpose to reproduce here all the important definite descriptions and figures that have been published by preceding observers, but to do this would greatly extend a discussion already in danger of being too prolonged, and I am quite reluctantly compelled to abandon the attempt to present a detailed description of the entire mass of facts that have been trustworthily observed. The descriptions of Percival, Whitney and Strong are, therefore, commended to such as may desire a greater mass of details than can here be given.

Breccia and Honeycombed Openings. Among crevice-opening mines, those of Muscalunge have been more actively worked, during the progress of our investigations, than others and fairly represent one phase of this general type.

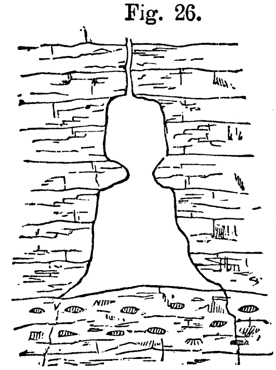
The *Atkinson range* may best be taken as a standard example, not only because it is one of the great ranges of the region, but because, being entered horizontally from the hillside, and being dry and ventilated, it is, and doubtless long will remain readily accessible to examination. Crevices descend from the surface developing in the upper horizons the "twelve foot opening"—named from its height or the thickness of its cap — and, in the lower, the "sixty-five foot opening," lying that distance below the former, with a "false opening" between. Ore is sometimes found in the descending crevice, but it is of little consequence save as a leader. The "twelve foot opening" was not accessible to satisfactory examination at the time of my visit. On approaching the "sixty-five foot opening" the crevices usually close to a mere seam and pass through a solid bed which forms the cap rock. This is, however, broken at intervals by "chimneys" which rise to considerable heights and sometimes bear considerable ore. Below the cap rock, the beds, for a depth of about four feet, are much honeycombed and softened by decay, after the fashion above described as "honey-combed openings." This structure affects the rock for a varying width, the average of it in the Atkinson range being about three feet. The next bed below this is firmer and less modified, so as nearly to close across the opening, forming what is known as the "middle rock." Below this the rock for five or six

Fig. 25.



SECTION OF DEPOSIT IN ATKINSON RANGE.

Fig. 26.



THE SAME AS IT APPEARS WHEN MINED OUT.

feet is decomposed and honey-combed more freely than above. At the base of this lies a bed studded with flint nodules which terminates the mined portion, but not at all points the softened rock. As it approaches this flint bed, the opening often divides into two branches which diverge somewhat, leaving a ridge ("horse" or "hog's back") rising in the center between them. The whole structure may be apprehended from the accompanying figure. On the sides there is no sharply defined wall rock although the softened limestone graduates somewhat abruptly into the firmer form and the miners sometimes term this the wall rock. The bottom of the excavated opening is said to be soft along a considerable portion of its length, indicating a descent of the fissure and decomposed rock, but the lower levels have not been proved here. In two or three mines in this vicinity, considerable streams discharge precipitously downward with gurgling noise, indicating an open passage way below. The inference, from this and other data, that there is another plane of openings below, is fully justified. It is said to have been actually reached and found to carry ore, but the rock was reported much broken up, leaving masses weighing several tons with little support, rendering mining dangerous and leading to its abandonment. This difficulty cannot be presumed to be a general one, but as the plane of this opening lies mainly below the water level, the question of sufficiently economical drainage is the main practical one.

The ore here is nearly pure galenite. Iron pyrites is quite rare, but seams of rust and the ochery nature of the decomposed rock indicate that it was originally quite abundant and that its decomposition was one of the agencies that produced the disintegration of the associated rock. Zinc ore is even more rare. The Galena is sometimes above the "middle rock," sometimes below, and sometimes on both sides. Occasionally the crevice bars up, i. e. solid rock replaces the decayed so that there is only a slight communication near the top of the opening random. In such cases it is asserted that the ore makes heavy just above the bar, i. e. at the point where drainage through the opening would be dammed back.

The ore is formed in the cavities of the honeycombed rock or in the loose sandy material derived from its decay and is of the coarsely crystalline, "chunk mineral" variety. It is itself, however, much worn, on the surface, a fact which speaks of much corrosive change since its deposition.

It is of course impossible to restore from positive knowledge the precise conditions at the time of deposit, but it appears highly probable that, in the operations by which the crevice was formed, these beds — already of irregular conglomeratic texture — were crushed near the fissure, and, instead of subsequently opening into a definite crevice, formed a fragmental mass, in the interstices of which lead and iron sulphides were deposited. On the access, afterwards, of atmospheric agencies, decomposition and corrosion ensued, giving rise to the modifications of both rock and mineral that are now observed.

The bars are simply portions less affected by these changes because originally sounder and less impregnated with mineral matter prone to decomposition.

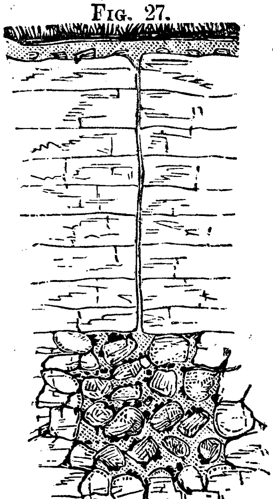
He who seeks an exhaustive explanation of these special deposits, will not fail to be impressed with the uniformity and persistence with which they take place at given horizons. The profile on Mr. Wilson's map of Muscalunge diggings—Atlas Plate XL—shows this vividly. The same plane embraces the "sixty-five foot openings" for the whole Beetown district. It is, therefore, evident, that the occasion of this must lie in the nature of the stratum itself, and, waiving a full discussion till we reach the consideration of the origin of the crevices and the attendant phenomena, it may be here suggested that the irregular conglomeratic texture of the rock would render it peculiarly liable to fracture whereas more homogeneous beds might either resist successfully or become simply compressed.

In further illustration of the same type, *Genth's lode*, at Hazel Green, an unimportant but instructive deposit, may be selected. A fissure descending through the Galena limestone, develops a narrow "opening" at a depth of forty-five feet. This appears to have originally consisted simply of broken rock, probably a disrupted breccia, between the fragments of which the ore was deposited. The seams and cavities were largely first coated with iron pyrites — which appears to have also impregnated the rock to some extent — and then the galena partially, or wholly, filled the remaining space. At some points, however, it appears to be directly adherent to the rock without any interposed film of iron sulphide. After the cessation of metallic growth and after the lowering of the water-level had brought the deposit within reach of atmospheric action, the iron sulphide was oxidized, a portion being removed, and the rest remaining as the iron oxide, which, in the form of a reddish ocherous layer, lines the cavities and stains the sandy residuum of the decomposed rock. The galena has been less affected, though its angles have been rounded and its surface much eaten. The decomposition of the rock is, doubtless, partly due to the direct action of atmospheric waters, but largely to chemical reaction between the decomposition-products of iron pyrites and the limestones. Thus the result is a softened rock lined and stained with ocher, containing corroded lumps of galenite, forming an "opening," in miners' parlance.

The galena is disposed mainly, in a rude vertical belt, near the line of the crevice, and is sometimes, but not at all properly, termed a sheet. The decayed rock extends but one or two feet back from the crevice on either side, beyond which the rock becomes more firm, forming the "wall," improperly so called. At fifty-seven feet and sixty-nine feet depth, respectively, on the crevices, essentially the same phenomena are repeated, making three planes of openings.

Tumbling Openings. Closely allied to the foregoing type, in its nature and origin, is the "tumbling opening," a good example of which is found in the ***Robbins' mine*** (Davison & Co. range) at Platteville, as illustrated in the accompanying figure.

FIG. 27.

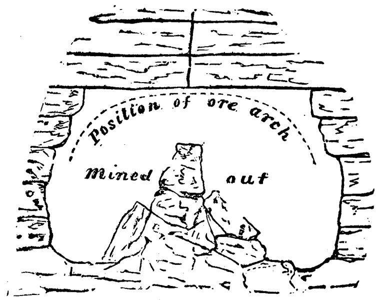


CROSS SECTION OF ROBBINS' MINE, PLATTEVILLE, TUMBLING OPENING.

From the soil there descends a fissure—two or three inches in width where I observed it—filled with dark "joint clay" vertically laminated. This clayey earth was, undoubtedly, carried down into the crevice from the surface and indicates the descent of a gentle oozing stream of water. At the depth of about fifty feet, this reaches the "opening" near one side, and terminates. This "opening," which the novice will remember is not an opening at all, or at least only a slight one formed by the sinking down of the filling, consists of rounded masses of limestone, mixed with clay and calcareous sand, taking the place of the original rock for a few feet in width and height along the line of the fissure. When excavated, such openings take the form of irregular horizontal tunnels and this artificial condition too often constitutes the conception of the incautious observer and finds its way into treatises on the subject. The rounded masses of rock are "tumblers," in the graphic phrase of the miner. They are the undecomposed nuclei of blocks of the original rock. In this mine, they have not even lost their original position, but still permit the distinct tracing of the original bedding across the opening. Their rounded form is not at all due to rolling, but simply to solution and decay. They are "tumblers" from present disposition, as the miner well knows, but not from past history. In other cases where the decomposition has proceeded farther and the whole mass has settled down from loss by solution, the bedding is more completely obliterated. These "tumblers" have a soft, sandy exterior and are imbedded in dolomitic sand, the residue of their own disintegration. Along what were originally the joints of the rock, there are seams of clay. These are more often horizontal than vertical, but may be found in almost any attitude; the horizontal ones corresponding to the bedding joints, and the others to vertical, oblique and irregular fractures. Lumps and pockets of clay also occur. The seams of clay, especially the horizontal ones, are often laminated. It is not easy to satisfactorily determine, in many cases, whether the horizontal clay seams are due to deposition in an open crack, as is the case of the vertical fissure, or whether they are the residue of original shaly layers and partings in the Galena limestone, since both forms occur. The vertical and oblique seams and the pockets evidently belong to the former class. Bands of clay and sandy material, mutually interleaved, are common. The most of the ore observed in this mine lies imbedded in close, clayey and sandy seams in the form of small crystals of galena. These exhibit a notable proneness to truncated forms. This may plausibly be attributed to the resistance of the earthy matrix in which they grew, since such forms involve a less unequal radial displacement of the surrounding matter. All doubts that they formed in yielding earth may be dispelled by observing the displaced laminæ of the inclosing clay, pushed aside by their growth, as well as their complete forms, and the entire absence of points of attachment. Some of the ore here, and probably the larger part of that formed in similar openings, shows evidence of attachment on one side and of unresisted growth on the other, such as would occur in an open cavity. The imbedded crystals form layers, or "leads," in many cases, but, in others, they are aggregated in bunches or pockets. These "leads" lie in various attitudes, but mainly horizontal.

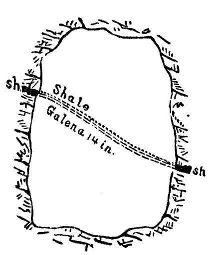
Kindred Complex Forms. There is a class of very important mines, allied somewhat closely to the preceding in the implanting of the ore in broken and brecciated rock, but somewhat analogous to flats and pitches in the general form of the deposit. These from their great richness and adaptation to mining were early worked out, and precise details can now only be obtained from testimony and the evidence afforded by the mine vaults and the dump pile. But these are essentially satisfactory. *Craig's lode*, at New Diggings, from the unusual neatness and order with which the mining has been conducted, its amplitude and large yield, as well as the intelligence of the testimony of its owner, furnishes the best available example. The mine, in its several parts, exhibits considerable complexity of deposition. Flat sheets are common. At some points the galena is scattered in lumps through the interstices of a decomposed brecciated rock, similar to that of the Muscalunge mines, already described. At other points vertical sheets occur. But that which especially claims attention here is the great swell of the opening of the main range in its central portion, where it reaches a width of thirty-five feet and a height of twenty to thirty feet. The roof is formed of a massive cap rock which maintains its position without support. Beneath this the ore lay in a grand massive arch somewhat as represented in the accompanying figure. The central portion is occupied by massive blocks of brecciated limestone, some of it essentially in place and some of it much disturbed. Near the middle line, huge, rough piers of rock are left unexcavated. Associated with these are massive blocks tilted at high angles. It is not entirely clear how much of this displacement may be due to disturbance and how much to settling from above. The first conservative tendency is to attribute all to the latter, but a more careful consideration makes it quite evident that more forcible mechanical action has been suffered. Perhaps the clearest evidence of this is found in an associated range lying parallel to this on the north. Here the drift-like excavation is on the horizon of a thin layer of clayey, carbonaceous, gray shale. This enters the drift from the north near its upper portion and curves sharply downward, leaving it from its lower portion, as shown in the accompanying figure.

Fig. 28.



Cross Section of Craig's Main Lode, New Diggings.

Fig. 29.



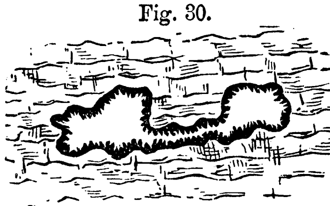
Cross section of a lateral lode of the Craig Range, New Diggings, showing flexure of the strata.

Immediately below the shale there was deposited a sheet of galena, reaching a thickness of fourteen inches. Toward the eastern extremity of the workings, the warp in the beds becomes very slight. It is evident, therefore, that here is a local flexure of the strata and that the main range is on the depressed side, in harmony with the general rule before established. The solidity of the adjacent rock, as shown by the connecting drifts, leaves no reason to suppose that this flexure is due to the settling of decayed strata, but rather to the yielding of beds already somewhat depressed under the influence of lateral pressure. And to the same cause may be attributed some at least of the displacement of the blocks in the master range.

Besides the great arch of ore, the mineral is variously scattered and insinuated among the material of the opening ground. The rock has suffered much decay, resulting in the common calcareous sand, or "opening dirt." The ore is exclusively galena, but ocherous stains imply the former presence of iron pyrites. Where bars of undecomposed rock close up the soft ground, the bar rock is seen to be a very hard gray-blue dolomitic breccia with angular geodic cavities lined with pyrite and occassional crystals of galena.

Cavernous Channels. South of Mr. Craig's house, a drift was being driven along an interesting water way, of which the accompany-

Fig. 30.



CROSS SECTION OF A CAVERNOUS WATER-CHANNEL LINED WITH PYRITE AT CRAIG'S, NEW DIGGINGS.

ing figure represents a cross section exposed at the time of my visit. It was less than three feet in width, by one in height, and of irregular and constantly changing form. The interior was lined with iron sulphide, mainly marcasite, with a little galena at some points. Among the excavated material at the surface, copper carbonate was observed as a coating, doubtless derived from copper pyrites, associated with the iron. The adjacent rock was of mineralized irregular structure. The channel was partially occupied by a small stream flowing rapidly eastward. In connection with the direction and descent of the stream, it is worthy of note that oxidation is much more marked at the west, or higher, end of the drift. It is asserted that when the wind is in the east, air, capable of promptly extinguishing a candle, issues from the small lateral openings. Similar phenomena are reported elsewhere. Probably the real cause is the reduction of barometric pressure [often accompanied by an east wind] which causes an expansion of the air and carbonic acid in the crevices and cavernous spaces of the rocks and consequently an outward flow.

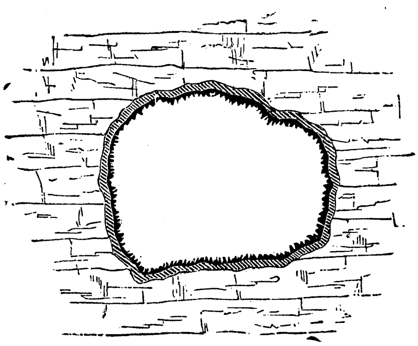
A similar cavernous channel occurs in connection with a workable deposit on the flat of Fever river, east of Benton (S. W. cor. Sec. 3 and S. E. cor. Sec. 4. T. 1, R. 1 E.). The horizon is the carbonaceous layers above the green shale, or pipe clay, the strata consisting of alternating layers of carbonaceous shale and limestone closely and somewhat irregularly interstratified. The water-way is a small irregular branching channel, through which a small stream flows. It is lined with blende, pyrite and large crystals of calcite.

Closely associated with this metallic water-pipe is a considerable deposit of blende with much pyrite and calcite and a little galena. The ores take the form of flat or inclined seams that often wedge out in both directions, while at higher or lower points corresponding sheets wedge in, i. e., this is the appearance as seen in the working face of the mine. Doubtless if all the intervening rock were dissolved out, the whole would still stand as a single interosculating group of irregular, tapering sheets of ore. The ore bands often pitch, or "roll," from one level to another, yet always confining themselves to the carbonaceous stratum. The ore is usually heaviest on the roll. The order of deposition of the ores is not alike at all points, but most commonly the iron sulphides line the walls, with blende next and often calcite or pyrite following, forming the center of the banded vein.

Galena when present is later than the blende. At one point the order was (1) pyrite, (2) blende, (3) pyrite, (4) calcite, (5) pyrite.

Geodic Caverns. Following in the line of cavernous deposits, reference may be made to a huge geode described to me by J. H. Evans, Esq., of Platteville, as occurring near Hazel Green. Its dimensions are given as from two to three feet in height, three to five feet in width and seven to eight feet in length. The uneven interior was incrusted with pyrite studded with black crystals of blende forming a beautiful combination. A similar cave deposit is described as occurring at Buncomb. Next the wall lay marcasite to which, usually, blende was attached, but, at some points, galenite seems also to have begun its growth upon the marcasite. Usually the galena reposed upon the blende and both were speckled with adhering crystals of lead carbonatė.

FIG. 31.



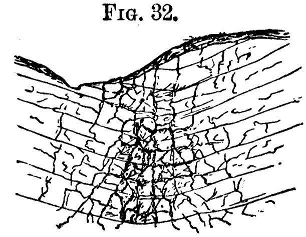
GEODIC CAVERN NEAR HAZEL GREEN, PYRITE NEXT THE ROCK TO WHICH BLENDE CRYSTALS ARE ATTACHED.

Professor Whitney describes a cavity at Shullsburg three or four feet in diameter, studded with very large crystals of galena firmly attached to its walls.

It is needful to observe, however, that true cave deposits are rare, and are probably in all cases quite limited enlargements of small water veins. The great caves, that are not uncommon, were formed subsequently to the deposition of the ore, and, in a study of the methods of deposition, must be sharply distinguished from the few cases in which the strata were eaten into caves and tunnels beforehand offering their walls for the attachment of the ores.

Stockwerk. Of those deposits which approach a "stockwerk" in character, the mines of *Preston Point*—better known under the less euphonious name of Dutch Hollow—are our best examples. Instead of a few pronounced fissures or horizontal separations between the beds giving rise to vertical or flat sheets, or localized openings, the limestone has been more generally and minutely riven and seams and floors of lead and zinc ores permeate it extensively, from near the surface as low as

FIG. 32.



SECTION ACROSS PRESTON POINT, SHOWING SYNCLINAL, AND BRECCIATED AND MINERALIZED ROCK.

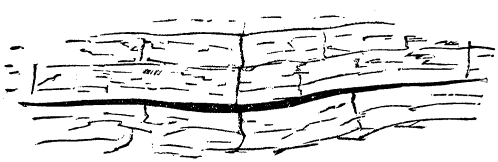
mining has penetrated. In addition to this network of sheets, the body of the dolomite is widely impregnated with scattered lumps of lead and zinc ore, the former as usual predominating in the upper levels, and the latter below. The exceptionally fractured condition of the rocks here is doubtless closely related to the unusual narrowness and sharpness of the stratigraphical depression in which they lie, which would naturally result in more concentrated and intimate crushing and fracturing of the beds, under the force of lateral pressure, than would take place in the broad shallow basins of most districts, and there would likewise be less opportunity for the gaping of the crevices on the relaxation of the pressure.

Flat Openings. Of the numerous horizontal flat deposits, those of Dodgeville are the most abundant and interesting. While varying in their special features, they consist essentially of a separation of the limestone beds to the extent of a dozen or a score of inches, more or less, in height, for a width of a hundred or two feet, and for a known length varying from a few hundred to two or three thousand feet, filled with ore. They are usually thickest in the central portion and thin out toward the edges. The thin marginal portions are, therefore, not usually mined, and the exact width of the deposit is seldom accurately known, except at occasional points where mining has been extended for the sake of testing its extent. In most instances, it is perfectly clear, from the nature of the ore filling, that the separation of the beds took place before the implanting of the ores and was not due to any intrusive or crystalline force, inherent in the deposit itself. Some, however, instead of being simple sheets between well defined layers of rock, split and reunite, forming between and about cracked and riven layers of rock, leaving it less clear that all the mechanical action preceded the deposition of the ores. In other cases, "dice mineral" and blende impregnate soft beds of rock in sheet-like belts, in which instances it is quite evident that the metalliferous crystals displaced the yielding rock, in the process of their growth.

These flat deposits are connected with crevices descending from the surface. There is usually at least one such fissure that is marked and persistent and, in the wider and stronger ranges, three crevices are not uncommon, one near the center and one near each lateral margin. In cases where oxidation has taken place, it is most advanced in the vicinity of these crevices and has evidently proceeded thence. It is very common here and elsewhere for the central portion of the sheet to be somewhat depressed, forming a very shallow trough.

The great flat of the *Sobey and Davey mine* exhibits most of these characteristics and will be taken as an illustration, though the mine, as a whole, belongs to the flat and pitching class. A surface plot of the sheet is mapped by Mr. Strong in Volume II., page 731. Near the center there is a crevice, descending from above, which is quite persistent along the course of the range. At the sides are less notable seams, not everywhere observable in the mine. The sheet sags about two and a half feet near the middle, where also it is the thickest. The ore here is nearly all blende, changed more or less, on the wings and near the central crevice, into smithsonite. Pyrite is but feebly present, except near the margins, where it is more abundant. Calcite is disposed in a similar manner. As the ore is mined westward toward the summit of a ridge it "pinches up," and on the west side, the south half of the sheet is said to have been galena, while the north half was blende. The opening is generally filled solidly with ore, but at some points there is a small space between the upper and lower half of the sheet, and occasional geodic cavities — "vuggs"— are found. In this vicinity the flat sheets show a singular tendency to curved forms, as may be seen by a glance at Atlas Plate No. XXXII., and, what is further remarkable, there is a seeming tendency to follow the brow of the main ridge or hill on which the range may be situated. If this occurred in fewer instances, it might be dismissed as a mere coincidence, but it is difficult to escape the conviction that there is some genetic connection between the topography and the ore deposits, either direct or through some common agency, to which they are both related. While I have thus far been unable to find an explanation that, in its details, is satisfactory to myself, the general principles to which this discussion will lead will relieve the phenomenon of much of its strangeness and suggest an explanation of most of the difficulties.

FIG. 33.

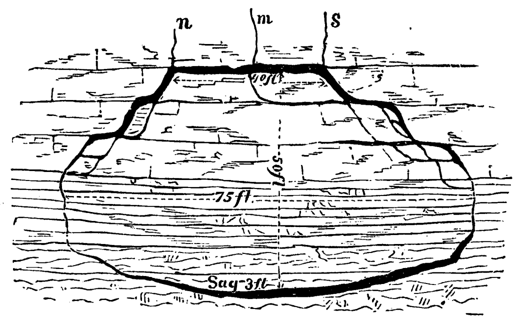


SECTION OF FLAT DEPOSIT OF THE SOBEY AND DAVEY MINE, DODGEVILLE.

The great majority of the flat openings are associated with ore-bearing vertical crevices, or with some system of flats and pitches, indeed it may be questioned whether they do not all belong to some such system, the other portions of which are seemingly absent by reason of denudation, feeble development, or lack of discovery.

Flats and Pitches. The most curious and significant form of deposit is, beyond question, that of the flats and pitches. Among the numerous examples, a few must suffice for special description. In some respects the *Roberts mine*, near Linden, though not the most important, furnishes our best initial example. The following typical section was made under the direction of Captain John Poad, and verified by personal observation so far as the accessibility of the mine would permit. These crevices descend from above, one near the

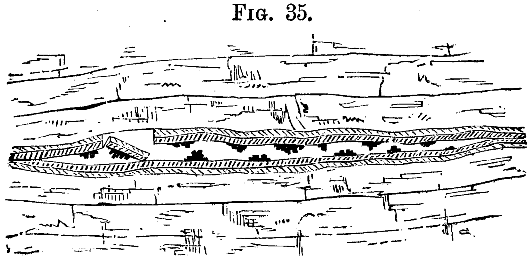
FIG. 34.



SECTION OF FLATS AND PITCHES OF ROBERTS MINE, LINDEN. Upper flat sheet, 1 ft. thick; lower, 2 ft. thick; on the pitch 2 in. to 8 in. thick; sag of lower flat, 3 ft.

center and one each on the north and south margins of the upper flat, the trend of the range being east and west. These crevices terminate in a fine flat opening about forty feet wide and one foot in depth. On either side this descends by slopes and steps through the lower beds of the Galena limestone till the stratum, known locally as the "blue-bed," is reached, at which point the divergent sheets are found to be seventy-five feet apart. On the pitches the ore is from two to eight inches thick. It usually follows one main crevice, but sometimes branches into minor seams, reuniting below, as indicated in the figure. Through the "Blue-bed" and what is here termed "Quarry rock" (not to be confounded with the Buff limestone below, also known as "Quarry rock"), a narrowed seam descends nearly vertically. On reaching the "Brown rock" the crevice reverses its pitch, and on entering the "Glass rock" forms an extensive flat, two feet in maximum thickness, having a central sag of three feet. Below this point the disposition seems to be toward impregnation of the rock rather than the formation of well defined veins. The depth from the upper to the lower flat is about fifty feet. Figure 35 illustrates the nature of an opening exhibited on one of the flats at the time of inspection.

FIG. 35.



SECTION OF CAVERNOUS FLAT DEPOSIT, ROBERTS MINE, LINDEN. Order of deposit: 1, rock; 2, pyrite and marcasite; 3, blende; 4, galena.

Next the rock, both above and below, lay iron sulphide, in the forms, pyrite and marcasite. To this was attached a layer of blende, over the inner surface of which were large detached aggregates of galenite crystals, leaving a low cavernous space unoccupied. At one point a portion of the roof-crust has become detached at one side and fallen, leaving the other side still essentially in position. At other points, not figured, considerable masses have fallen entirely. In some similar instances there is evidence of deposition since the fracture and displacement. Some of the galenite crystals are coated with the lead carbonate, cerussite. At a number of points in the mine there are seams from which ooze forth red oxide of iron and black oxide of manganese coating the rocks down which they flow, showing that active decomposition is in progress. The order of deposits given above, (1) iron, (2) zinc, and (3) lead sulphides, is that common to the mine. The carbonates and oxides are all due to subsequent changes.

There are many individual exceptions to this order, however, if attention is confined to a circumscribed point or to hand specimens, owing, it would appear, to the fact that the ores were in some measure laid down simultaneously.

One of the most remarkable mines of the whole region is that of Messrs. Ross and Henry, near the village of Linden, formerly known as the *Heathcock range*. For its salient features, reference is made to the description and plot of Mr. Strong, Volume II, page 726, and only those points immediately bearing upon this discussion need be cited here. This deposit begins as high up as the flint beds of the Galena limestone. In its earlier history, it appeared to consist simply of three parallel crevices making ore in sand and tumbling openings, after the habit of that horizon, and, as such, proved exceedingly rich. But on being traced downward the veins were found to join a common wide flat sheet. On either margin, this sheet turned down and on the north side, dipped quite uniformly to the lower flat in the Glass rock opening. But on the south side, the more common habit of alternate pitches and flats was found to prevail, complicated by subordinate sheets, which unite with it and join the common flat below. This lower flat lies in the Glass rock opening and has been worked mainly in connection with the south pitch, but has been proved to stretch across to the foot of the north pitching sheet, a distance of 180 feet. This flat, as is common, is depressed along the center. The essential features, therefore, are three descending vertical crevices, bearing ore according to their usual methods, uniting at their base with a common flat, which pitches down on both sides and, at a lower level, forms a second wide flat; in other words, the same salient features as those of the simpler Roberts mine, but stronger, richer and more varied. Figure 36 illustrates an irregular method of branching shown by one of the pitching veins. The walls are thinly lined with iron pyrites on which the main filling of blende

FIG. 36.

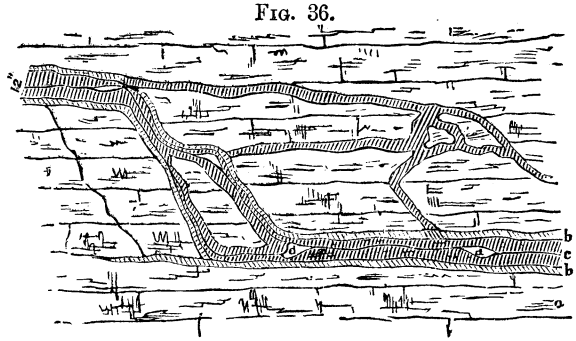
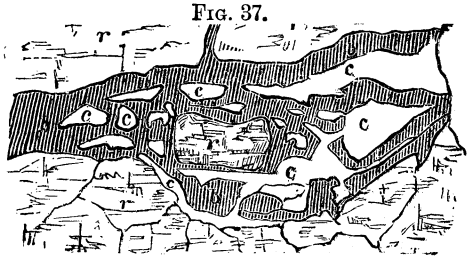


FIGURE SHOWING BRANCHING OF VEIN IN LINDEN MINE.
a, rock; b, iron pyrites; c, blende; d, calcite.

lies, in the occasional partings between which calcite occurs. Occasionally a cavernous opening occurs lined almost exclusively with calcite. In the main lower flat a crust of iron pyrites usually lies next the wall rock and is overlain by a sheet of blende, to which is attached calcite, when present. Galena, when it occurs in the lower horizons, is sometimes imbedded in the blende and sometimes mounted on its surface. It is usually older in deposition than the calcite, and, on the whole younger than the blende. Calcite is sometimes curiously intermixed with the blende, as shown in the accompanying figure, which also illustrates the fractured condition of the rocks, and the apparent envelopment of a block of it in ore.

FIG. 37.



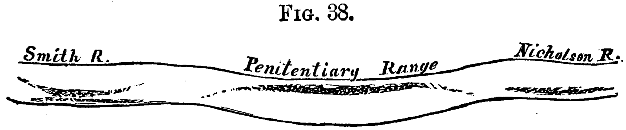
SECTION FROM LINDEN MINE SHOWING THE FRACTURED CONDITION OF THE ROCK AND THE MINGLED ASSOCIATION OF BLENDE AND CALCITE.

The mining record of this lode, which is one of the most complete and accurate in the lead region, as well as one the highest in point of yield, furnishes some very interesting and valuable data in reference to the vertical distribution of the lead and zinc ores. Previous to 1854 the mines were owned by the Messrs. Heathcock, by whom 40,000,000 pounds of lead ore were asserted, under oath, to have been raised. This was all obtained, essentially, in the upper horizons, above the water level. Zinc ores, not being then valuable, were rejected. The Linden Mining and Smelting Company, on coming into possession, mined and cleaned up the old burrows, wash places, dumps and drifts and obtained 2,850 tons of blende and 150 tons of smithsonite, together with 1,500,000 pounds of galena — or, in other words, 6,000,000 pounds of zinc ore, against 1,500,000 pounds of lead. But probably a part of this zinc ore was associated with the lead ore previously mined, though undoubtedly in less relative proportion. But as the correct distribution cannot be made, the whole may be put together, from which it will appear that 41,500,000 pounds of lead ore were taken out in the first two stages of mining, against 6,000,000 pounds of zinc ore, a ratio of nearly 7 to 1.

Since 1874, Messrs. Ross and Henry have owned and operated the mine and have raised only 1,500,000 pounds of lead ore to 36,000,000 pounds of zinc ore, or twenty-four times as much of the latter. But taking the whole together, there are 43,000,000 pounds of lead ore against 42,000,000 pounds of zinc, a very near equality of totals; or, if the ores that may fairly be said to be "in sight" be reckoned, the zinc will fully equal the lead, and if the probabilities of the future be estimated, the zinc undoubtedly would predominate largely. We have therefore here a somewhat definite mathematical expression of the fact, so widely observed, that the lead ore greatly predominates in the upper portion of the lode and zinc in the lower, and that there is a gradual transition from the predominance of the one to that of the other.

Among the mines noted for their endurance and large steady yield, those of *Mifflin* are among the foremost and furnish added instances of the dominant character of the type under consideration. There is here a closely associated group of ranges; indeed, recent mining has shown that the Black Jack and Penitentiary ranges are connected, and this involves in the union some, if not all, the collateral ranges. The relation of the Penitentiary to the collateral Nicholson range on the northeast and the Smith on the southwest, as shown in the lower or main working flat, is very interesting. The Penitentiary range lies

FIG. 38.

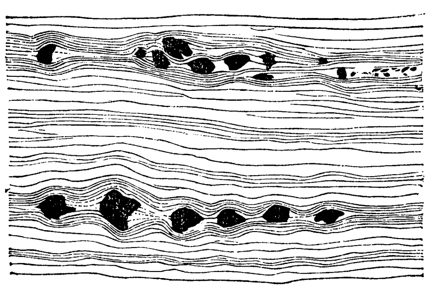


PROFILE SECTION OF SMITH, PENITENTIARY AND NICHOLSON RANGES, MIFFLIN, SHOWING SAG OF BEDS AND PECULIAR RELATION OF ORE DEPOSITS.

in a depression between the two side ranges, so that they are drained by its level. The sag of the strata and the singular disposition of the ore is illustrated in the accompanying section across the three ranges.

This relationship is made the basis of the claim that the Penitentiary is the "mother range." The stratum here represented is the Pipe clay. In the Penitentiary range, when visited, the ore was seen to lie mainly, in its usual form, as a flat sheet, near the top of the stratum, but in the Smith range, it assumed pronounced peculiarities of an exceedingly interesting and instructive kind. It is to be remarked, in preface, that the stratum involved consists, in its upper portion, of a banded and laminated, soft, clayey, calcareous rock, and in its lower, of a minutely granular and slightly porous, but not close and compact clay, and that the range is terminated on the northeast, adjacent to the Penitentiary range, by a vertical fissure. Starting from near this fissure, in the upper part of the stratum, there extends a belt of impregnated rock, aptly styled "speckle jack," across the range, curving downwards and widening in the middle so as to present a hammock-like outline in cross-section. Upon close inspection the soft, gray rock will be found to be thickly inset with scattered crystals of black blende, giving to the fractured rock a beautiful speckled appearance. Looking still closer it will be seen that the laminæ of the rock curve around the particles of blende, showing that they were displaced by the growth of the blende crystals. See Fig. 39. We have in this and the next instance just as clear cases of the forming mineral making room for itself by its own accretionary force, as in some preceding cases, it is evident that the receptacle was first formed and the ore subsequently implanted.

Fig. 39.



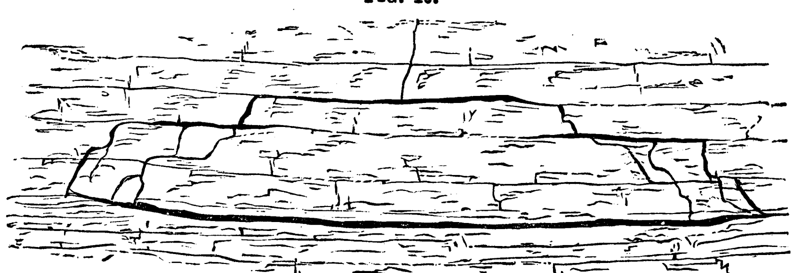
Section of a Portion of "Speckle Jack," Showing the Manner in Which Crystals of Blende are Imbedded in the Rock and the Curvature of the Laminæ About Them.

A little below this bed of disseminated ore is another of very analogous origin. The matrix, instead of being a yielding laminated rock, is a bed of clay. In this, with greater freedom of accretion, there formed larger aggregations of ore in the form of burr-like nodules, from a half inch to an inch in diameter, that are called, with the habitual expressiveness of miners' phrases, "strawberry Jack." These metalliferous berries are completely imbedded in the clay and show no points of attachment, but present small modified crystalline points and facets on all sides, demonstrating that they grew in a yielding matrix. The berries are not, however, always simply blende, but very frequently galena and blende together unite to form a nodule, the two interlocking and modifying each other, as they grew, leaving no doubt of their simultaneous formation. Pyrite is occasionally associated in a similar way. The clay bed is too soft to cohere in lumps and is hoisted as a shapeless mass, from which the ore is washed with ease. "Strawberry Jack" occasionally occurs in scattered specimens elsewhere, but it is only in this gang of ranges that it is known in such notable quantity. "Speckle Jack" is of more frequent occurrence, but it also finds its maximum development here.

The direction of drainage here is shown by the fact that these beds are most decomposed on the flanks near the limiting fissures where much iron oxide and other products of decomposition issue and accumulate on the sides and floor of the excavation.

In the Penitentiary range, the blende of this horizon takes mainly the more common massive form, filling a flat seam or fracture. Above

FIG. 40.



GENERAL SECTION OF THE PENITENTIARY RANGE, MIFFLIN, SHOWING THE RELATIVE UNIMPORTANCE OF THE PITCHES AS COMPARED WITH THE FLATS.

this lower flat there is the usual series of flats and pitches, that characterize this class of mines. The pitches are very short and unimportant, compared with the flats, and if much further reduced or less filled with ore, would not be mined at all, and to casual observation the deposit would seem to consist simply of superposed flats; and it is probable that some mines, recognized simply as horizontal deposits, really occupy a fracture system of the same order as the typical flats and pitches.

In the upper flats, as usual, much galena was found but it is almost entirely replaced by zinc ore below.

Another of the more remarkable mines of the lead region is *Mills' Lode*, near Hazel Green. The location, associated topography and superficial aspect are shown on Atlas Plate XXXIX. In respect to the latter point, it is just to remark that it is impracticable to adequately represent such a deposit by surface mapping. Indeed, it is none too easy to create a true mental conception, by the aid of sections and full descriptions.

Along the central line of the mining ground, there runs a fissure descending from the surface through the cap rock of the mine proper. This fissure has an average width of only about two inches and carries a little lead ore, with considerable iron rust. On passing through the cap rock, the fissure terminates in the main upper flat of the mine, the ore sheet of which is somewhat thickest beneath it, so that the crevice is said to act as a "feeder" to the flat sheet. The form of this summit flat is not unlike that of a domestic flat-iron, the sides gradually approaching each other and uniting in a point directed northward. This sheet is said to have reached a maximum thickness of three and one half feet of solid galena — a bonanza of its kind. It dips moderately to the north discharging its drainage in that direction. On the east, west and north, i. e. on the sides and point, this flat breaks down into pitches that decline about 45° — that on the west being somewhat the steepest.

These pitching sheets sometimes consist of a single large vein, and

FIG. 41.

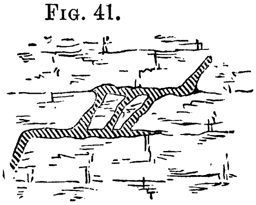


FIG. 42.

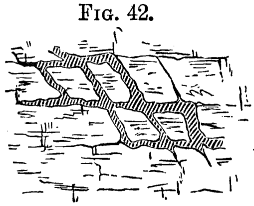
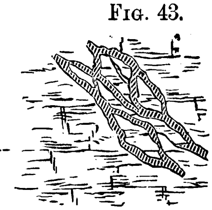


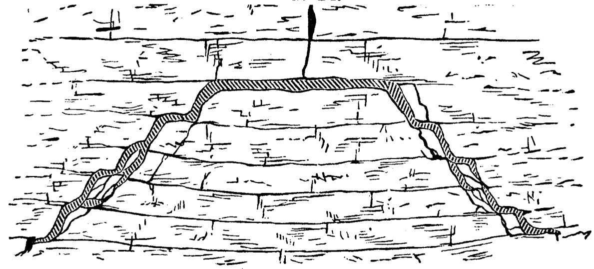
FIG. 43.



SECTIONS OF VEIN AT DIFFERENT POINTS IN MILLS' LODE, HAZEL GREEN, SHOWING VARIOUS MODES OF BRANCHING.

at others divide into several smaller ones united by oblique cross-veins or by parallel pitches and flats, forming a plexus of veins, as represented in the accompanying figure. As a general rule these minor veins confine themselves discreetly to about the width that would necessarily be mined out, so that they are usually easily wrought as a gang. In their descent the pitching sheets are inter-

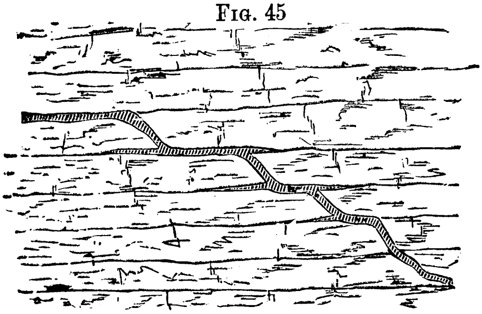
FIG. 44.



TRANSVERSE SECTION OF MILLS' LODE, HAZEL GREEN, SHOWING FLATS AND PITCHES.

rupted by frequent short flats, giving the characteristic zigzag descent already sufficiently described. The accompanying sections illustrate its double transverse pitch and its northward longitudinal pitch. The ore is accustomed to make heaviest on the "roll," i. e. on the turn from the flat to the pitch, or the pitch to the flat. At the angles, where the sheet turns from the bedding joint into the transverse fracture, a little ore is apt to lead onwards along the bedding joint. Oftimes this connects with an oblique seam farther on and joins the main sheet below, but perhaps oftener, it wedges out within a foot or two. There is frequently a reëntering projection opposite this. Sometimes they develop into considerable flats. This deposit, as thus far mined, is wholly within the Galena limestone, and the product has been mainly galenite. In accordance with the general rule, however, zinc ore gains on the lead, as the mining is carried down. The horizons in which the main zinc deposits elsewhere occur have not yet been reached, and the further progress of mining here will be a matter of much interest, if it shall determine whether the pitching sheets join a great flat stretching under the whole series, and predominantly zinc-bearing, as is the case in the mines above described and others of this type.

FIG. 45



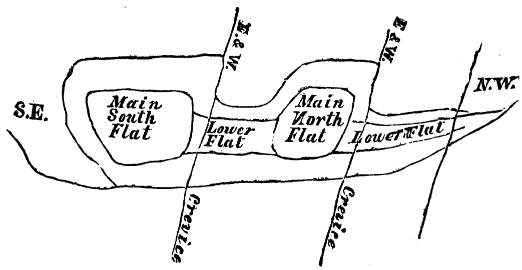
LONGITUDINAL SECTION OF MILLS' LODE, SHOWING THE PITCHING AND FLATTING TO THE NORTHWARD.

Iron sulphide, or its decomposition product, the oxide, lines the wall of the mine generally and at some points forms a notable deposit. Next this, for the greater part, lies zinc sulphide or carbonate, and the lead ore rests upon this and constitutes the main filling of the fissure in the upper part of the mine. But this general order is subject to local modification.

It will not be amiss in this connection, to describe some of the salient features of the *Marsden lode*, south of Galena,[1] since it is at present the most important mine of the lead region outside of Wisconsin; especially as definite data can be given in respect to certain features, which, though present in Wisconsin mines, are not commanded by precise information.

[1] On the general crevice map, Atlas Plate XXXI, this lode is marked "Illinois Zinc Company" to avoid possible confusion with two other lodes, southwest of Galena, mapped by Prof. Whitney as "Marsden," in Illinois Geological Report.

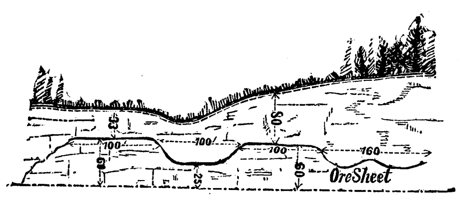
FIG. 46.



GROUND PLAN OF MARSDEN MINE, GALENA.

Figure 46 is a rude sketch of the ground plan of the mine, reduced from the measurements of an underground survey, kindly furnished

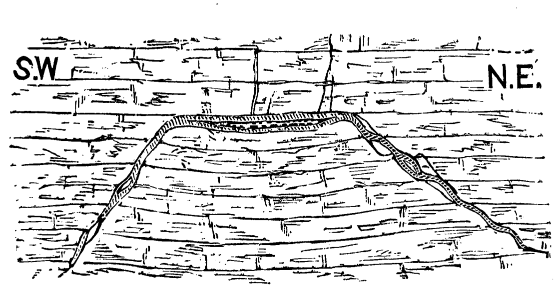
FIG. 47.



LONGITUDINAL SECTION OF MARSDEN MINE, SHOWING THE UNDULATIONS OF THE SHEET.

by the officers of the Illinois Zinc Company. By comparing this with the longitudinal profile (figure 47) and the cross section (figure 48,

FIG. 48.

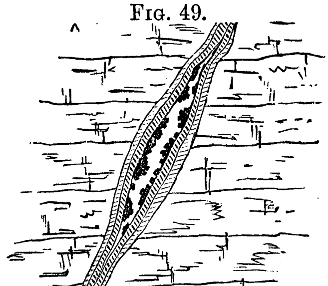


TRANSVERSE SECTION OF MARSDEN LODE, SHOWING FLATS AND PITCHES.

larger scale), some aid toward a conception of this peculiar deposit may be derived. From the surface, there descend two or more vertical crevices, which trend north 45° west. These carry some lead ore in the usual forms of a crevice deposit. At one point a considerable chimney was observed. At depths varying from thirty to eighty feet below the surface, according to position on its slope, these crevices encounter the two main upper flats. From all sides of these, the sheet pitches down. On the sides parallel to the vertical crevices, the pitches descend below the limits of present mining and correspond to the similar declivities of the mines heretofore described. But along the axis of the lode, between the two main flats, the pitches descend about thirty-five feet and form a lower connecting flat, lying between the two main ones, as seen in the longitudinal profile. At the northwestern extremity the sheet drops down into an undulating flat, while at the opposite extremity it pitches down to the bottom of the present mining. What may yet develop to the northwest remains to be seen.

At the points where the main flats break down — which are identical with the insets in the outline of the ground plan — the lode is traversed by east and west fissures to which the depression and contraction of the sheet has been assigned. It should not be understood, however, that there is any displacement of the strata. The main upper flats have a width of about seventy-five feet and a length of about one hundred feet. The pitches are mined to a vertical depth of sixty feet and are separated at their bases from seventy-five to two hundred feet, according as they belong to the wider or narrower parts of the mine. The character of the pitches is essentially similar to those described above, save that the walls are sometimes more separated, leaving a cavernous space between the ore sheets on either side, as illustrated by figure 49. Similar caves on the flats occur, attaining, in one case, eighteen feet in width, seventy-five feet in length, and from eighteen to twenty-four inches in height. Next the walls there is usually a thin coating of iron sulphide (pyrite or marcasite) on which is laid a sheet of blende to which the cubes of galenite are attached, the whole, usually, overspread beautifully with pyrite, to which is sometimes attached calcite crystals, sometimes again overlaid with pyrite, the whole subject to interesting variations of form and succession.

Fig. 49.



Section of cavernous opening on the pitch of Marsden mine. Order of deposit, (1) pyrite, (2) blende, (3) galena.

It is from such geodic caves, particularly those occurring on the flats, that the beautiful specimens, for which this mine is renowned, are derived.

Both stalactites and stalagmites of the ores are found in them, not only those of a single mineral, as pyrite or calcite, but composite accretions. One form consists of an irregular reticulated core of galena, surrounded by from one to three inches of blende, in radiant crystallization, coated on the exterior with pyrite, sparsely studded with small modified crystals of galena. In other cases the core contains calcite as well as galena.

These stalactites sometimes attain a diameter of six inches, and a length as great as the height of the cavern will permit, in fact, they sometimes form columns stretching entirely across the opening. Stalagmites, *bearing galenite on their summits*, are said to have occurred here.

On the west pitch, for a horizontal distance of about seventy-five feet, iron pyrites in thick botryoidal aggregations has almost entirely replaced the more valuable ores.

The beds of the country rock are nearly horizontal. When there is any dip, it is usually toward the center line of the range. At one point on the upper flat the beds dip slightly to the east. Near the upper flats the rock is quite brecciated and the ores are distributed through the cracks and small cavities. Some features of the fragmentary structure seem due to original deposition, while others are clearly referable to fracture subsequent to solidification. This may be held as proven by the fact that nodules of chert are fractured and the crevices filled with sulphides. The evidences of crushing and fission are most marked near where the pitches join the upper flats and near the vertical crevices. A shaly layer occurs about twelve feet beneath the upper flat, which is quite extensively impregnated with minute metallic crystallizations.

As evidence of recent changes, stalactites of calcite and limonite, an inch or more in length, were seen, which have formed since the space in which they occur was mined out. The waters of the mine are highly mineralized and make abundant red oxide deposits.

One-sided Pitches. In the foregoing mines the sheets pitch down on both margins, forming what has been called a "saddle" deposit. But occasionally only one pitch is discovered. The other may exist, as a fissure, but being close and unfilled with ore is not exploited.

Parallel Pitches. Crow Branch mine, according to the figure of Professor Whitney[1] and the testimony of others, presents an interesting variation of the system of pitches, in that both descend parallel to each other, instead of diverging in the customary manner, i. e., the

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[1] Geol. of Wis., 1862, p. 362.

sheet on one side instead of sloping downwards and outwards from the flat, pitches *under* it and so keeps parallel to that on the opposite side. This mine was not accessible to satisfactory examination at the time of my visit.

The data for the following diagram are kindly furnished by W. T. Henry, Esq.:

FIG. 50.

DIAGRAM OF CROW BRANCH MINE. a, Galena and blende opening. b, Blende opening. c, Blende and barite opening.

Patch deposits consist of ore distributed through the earth above the solid rock. Originally they undoubtedly were formed within the rock in the usual manner, but by its decomposition they have been left at the surface imbedded in the residual clay. They are mainly significant in indicating the large amount of denudation which has taken place since they — not necessarily all the ores of the region — were formed.

General Observations. It is a somewhat significant fact that nowhere in the lead region, during the time of my investigations, has mining on vertical sheets been in progress. In earlier days they were worked with profit, especially where clustered, as they sometimes were, so that two or three could be mined together. But, partly owing to their thinness and want of horizontal continuity, and partly because they have been worked down to the water level, beyond which it is not profitable to follow them, very little mining has been done on this class of deposits for years. The fact that they cannot be wrought profitably below water is less suggestive than the fact that they have not been followed up horizontally above water, beyond a limited extent, which indicates a want of persistence and strength in the vein as such.

As this is the only form of deposit in this region that approaches deep-seated fissure veins in its form, this fact should be duly weighed.

It is further to be observed in this connection that the vertical sheets, for the greater part, occupy the north and south crevices, the feebler of the two sets. However, a considerable number, notably those of Hazel Green, belong to the east and west, or to the oblique class.

It is an equally significant fact that the largest mines now wrought belong, with some important exceptions, to the type of flats and pitches, and, if the testimony of the history of mining be taken without qualification, this would seem to have proven the master type. Something of the force of this evidence is lost, however, when it is considered that these are mainly zinc-producing mines, and for that reason were little wrought in the earlier years, when zinc ores were unmarketable. But notwithstanding this statement, it still remains an incontestable fact that this class ranks among the dominant types. The only form that can, perhaps, dispute its supremacy is the crevice opening, of which the Muscalunge mines are, at present, the leading examples. If the entire amount of ore raised, since mining was commenced, could be accurately referred to the several classes of deposits — a quite impossible thing — I judge it would appear that much more lead ore has been mined from crevice openings than from any other form of deposit, and that more zinc ore has been derived from flats and pitches, and that combining the two ores, the largest aggregate has been raised from crevice openings. But in abatement of this judgment, it is to be remarked that some of the richest so-called crevice openings are really intermediate forms between the true crevice opening and the flat and pitching type of deposit, and further, that there are reasons for thinking that some of the crevices connect below with flats and pitches, as some of the latter may be supposed to have originally connected with crevice opening deposits above, which have been lost by surface denudation. So that the two classes often really form one connected complex system, as illustrated by Fig. 9, and do not admit of intercomparison.

That which is most important to be observed here is, that the master types are not of the sheet pattern, with its something of likeness to true fissure veins, but are forms notably differing from them and possessed of peculiarities manifestly dependent on the special conditions under which they were formed.

But it is not sufficient, on the other hand, to dismiss the whole group as gash veins, since, albeit many are truly of this type, some, as the flat and pitching forms, are neither defined nor explained by the term even by remote implication.

VII. How were the Crevices and Other Cavities formed?

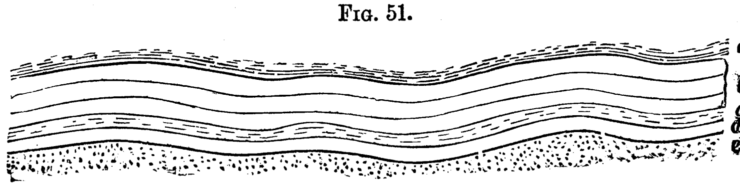
It has been heretofore shown that a considerable number of the ore districts occupy slight depressions in the strata, and the general tenor of such evidence as can be gathered with reference to the remainder indicates a like fact in regard to them. It has also been pointed out that none of the "centers of elevation" or noticeable swells of the strata are occupied by mines. It is, therefore, a fair inference that the ore deposits as a rule occupy stratigraphical depressions. This may not be an absolutely universal rule. There may, furthermore, be apparent exceptions which are not really so, since subordinate undulations sometimes form the bed of a general depression, and mines might be supposed sometimes to occupy a minor swell in a more general sag. This is rendered probable in a few instances, though the evidence is of a feeble and uncertain character.

But proceeding upon the well sustained general conclusion that the ore districts lie in stratigraphical basins, and that these, as heretofore indicated, existed as such at the time the rock sediment was deposited, it remains to be considered what effects the rock beds of such basins would suffer from the forces which are known to have been brought to bear upon the strata.

It is a well ascertained fact of geological history that the strata of the region have not only been once elevated from their original submarine position, but that they have undergone repeated oscillations, of moderate magnitude, in the course of the ages. While, in the earlier geological eras, the average position of the strata was lower than at present, there is evidence, reaching well nigh to demonstration, that in the later ages the strata were elevated to somewhat greater altitudes than they occupy at present, and that, therefore, their present position is, in a certain sense, one of relaxation from former greater elevation. Let it be clearly understood, that these are very general and, comparatively speaking, moderate movements of the earth's crust, that they are not violent or extraordinary manifestations of mechanical action. Nevertheless, they were movements which caused a moderate amount of flexure, compression and fracturing of the strata. Now we are at no loss to determine the character, or direction of action, of these elevatory forces. Attention has already been called to the fact that, extending north and south through the center of the state, there is a broad low stratigraphical arch, and that, extending east and west, there are more numerous and abrupt undulations of the strata. Those of the latter which belong to the Archæan rocks constitute folds of the most pronounced character, and are indicative of mechanical action of the most unequivocal nature. That these folds were produced by pressure, acting upon the strata horizontally from the southward, antagonized by corresponding action from the northward, will hardly be questioned by geologists fully conversant with the facts. The east and west folds that were formed in later geological ages conform in general direction to these earlier ones and there is no room for rational doubt, as has already been shown, that they were likewise produced by lateral force, acting according to the general law of elevation, from the Interior Sea lying to the southward, resisted by the ancient nucleus on the north. So true and beautiful is the application of this general law, that in the earlier geological ages, the folds have a northeasterly-southwesterly direction, in the main, facing the deeper part of the Interior Sea, lying to the southeast and the parallel lines of folding of the Appalachian region which were in those ages receiving the forcible impress of horizontal thrusts from the Atlantic; while in the later ages, after the eastern portion of the Interior Sea had become essentially filled with rock and settled into stable repose, the foldings of the upper Mississippi region shifted to a northwesterly-southeasterly course, so as to face more nearly the western portion of the Interior Sea and the Cordilleran ranges, which were then the great theaters of dynamical action. That which especially concerns us here, however, is the fact that the strata of the lead region were acted upon by a horizontal force having a general southerly direction. It is evident, that, if the strata were absolutely plane, they would oppose a great resistance to this force and would simply be compressed by it, until, at some weakest point, they gave way. But the strata, being undulatory from the nature of their original deposition, would more readily yield to such horizontal force. Where they were naturally arched upward they would, under the action of the lateral thrust, arch still more highly, and would be most fractured upon the swell of the arch. Where they were bent downward, as in the case of the ore-bearing basins, the horizontal force would cause them to bend more deeply, and these would likewise be most fractured along the bed of the depression. In each case the fractures would gape mainly on the outer curve of the strata, i. e. on the upper side of the arch, and the under side of the sag.

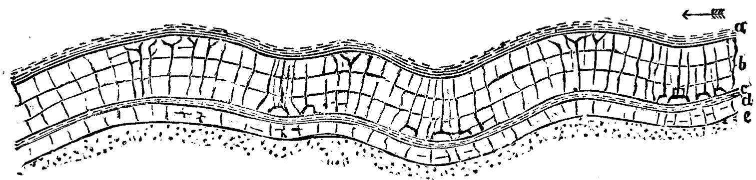
When a movement took place in the opposite direction the strata would settle back toward their original position. The result would be, the closure of the fractures upon the outward curve of the arches, and the opening of the fissures in the depressions.

FIG. 51.



DIAGRAMMATIC SECTION OF THE GALENA AND ADJACENT BEDS, ILLUSTRATING ORIGINAL UNDULATIONS RESULTING FROM DEPOSITION. a, base of soft yielding Hudson River shales; b, Galena limestone, rigid; c, Blue limestone somewhat shaly and yielding; d, Buff limestone, somewhat rigid; e, St. Peters' sandstone, incoherent.

FIG. 52.

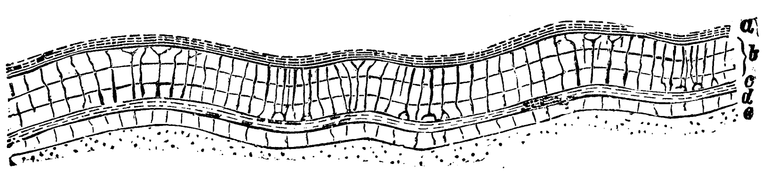


DIAGRAMATIC SECTION OF THE ABOVE FORMATIONS SOMEWHAT FLEXED UNDER THE INFLUENCE OF LATERAL PRESSURE; THE SOFT AND INCOHERENT BEDS YIELDING WHILE THE RIGID STRATUM IS MUCH FRACTURED; THE FISSURES DIVERGING ON THE CONVEX SIDE.

Let us examine more critically the necessary character of the fracturing of the strata of the depressions. Let figure 51 represent the original position of the strata, while figure 52 represents the position which they assume under the action of the horizontal thrust.

It is quite evident that the effects produced by this bending will be dependent upon the character of the rock. If it be like the Hudson River shales, that overlie the Galena and Trenton limestones, of a soft, pliable nature, it will be merely compressed and molded to the new form required. Little or no evidence of fracture will be apparent except in the more rigid portions of the formation. Quite in contrast with this, the granular rigid character of the Galena dolomite would cause it to fracture extensively. But all parts of the Galena limestone would not be affected equally, nor indeed alike, because of their differences in texture. The more homogeneous, even-textured, portions would doubtless simply suffer compression and regular transverse fracture. Those portions that were originally of an irregular

FIG. 53.



DIAGRAMATIC SECTION OF THE ABOVE FORMATIONS AFTER THE LATERAL PRESSURE HADSOME WHAT RELAXED AND THE BEDS SUBSIDED, ILLUSTRATING IMPERFECTLY THE OPENING OF THE FISSURES.

texture, honey-combed with pulverulent or cavernous spaces, or composed of imperfectly cemented fragments, would be more or less crushed, or be irregularly riven at the points of greatest strain. The highly siliceous layers, with their rigidity, would offer great resistance, and by the yielding of adjacent less firm rocks, be caused to suffer a large portion of strain, and thus be liable to crushing or to displacement by arching upward or downward, causing a separation from the adjacent beds of the nature of flat openings. And the same phenomena might occur in the case of any bed that, for any reason, was more resistant than its neighbors.

Below the Galena limestone the shales of the upper Blue limestone, especially those of the "pipe clay opening," being, like the Hudson River shales above, a yielding stratum, would adjust itself to the strain and suffer comparatively little fracture. This stratum, therefore, bounds on the under side as the Hudson River shales do on the upper, the limits of the rigid stratum of rock liable to pronounced fracture. Now it is a well known principle that, in the bending of a body, the cracks tend to diverge towards the convex side, because that portion is most stretched. So we find toward the bottom of the Galena limestone the crevices diverging in the peculiar form known as "flats and pitches."

It is quite evident that the zigzag direction assumed is simply an example of fracture along the line of least resistance. The tendency to break obliquely across the strata was in part satisfied by the easy separation of the beds, leaving the rest to be accomplished by breakage more directly across the beds which would require the expenditure of less force than simple oblique fracture. The frequency with which these flats and pitches occur does not leave us at liberty to pass them as merely anomalous, exceptional phenomena. They must be due to some prevalent circumstance connected with the formation of the metalliferous crevices in general. That they were formed as here indicated by the necessary fracturing of the bent strata on the outer side, is, I think, placed essentially beyond question by a consideration of the significant circumstances, (1) that they lie in stratigraphical depressions, (2) that both their upper and lower flats habitually sag, (3) that they lie almost wholly in the basal beds of the stratum bent, and (4) at the base of a line of general fracture, which, in its higher parts, develops the openings common to the upper horizons.

The rigid stratum being limited below by the "upper pipe clay," fracturing below that would proceed in the main independently of that above, and would tend to assume the simply vertical order, which is the prevalent fact. The Buff limestone is not sufficiently thick nor rigid, interstratified as it is by shaly layers, to permit of the development of any pronounced system of fissuring, and hence the comparative absence of large crevices or openings, or rich deposits.

The St. Peters sandstone below, being little more than a half solidified bed of sand, would yield somewhat readily to a compressing force, and hence large, or open, or regular fissures could not be expected in it. It might become somewhat fractured, or indurated, at the points of greatest pressure, and, as a matter of fact, at Mineral Point, where it occupies a depression, and at "Red Rock," where it is bent into a conspicuous arch, it is noticeably harder and firmer than is its wont in ordinary situations. It is usually an exceptionally friable rock, scarcely suffering handling without crumbling to sand. But at these localities, and some others similarly situated, it is sufficiently hard to be a very serviceable and durable building stone. This may fairly be attributed to the stress the strata have suffered at those points.

The Lower Magnesian limestone below is even more rigid and unequal in texture and thickness, and apparently more pronounced in undulation, than the Galena limestone above. It was presumably, therefore, at least as extensively fissured as the Galena limestone. Its more siliceous nature has doubtless rendered subsequent chemical action less marked, so that, in its present state, it may be less cavernous than the higher formation, but concerning its real nature beneath the metalliferous basins, we, of course, know very little, but to the north of the lead region, where it is more fully exposed, it gives indications of having undergone similar action with similar results.

Concerning the Potsdam sandstone, that which has been said of the St. Peters may be repeated. Lines of indurated, fractured rock are reported as occurring along certain metalliferous belts. As these lie almost wholly without the lead region they have not fallen beneath my personal observation, save in a single noteworthy instance. The iron mine at Ironton, Sauk Co., the most notable iron deposit in the southwestern portion of the state, lies in a belt of Potsdam sandstone which has been so far hardened that it has lost, for the most part, its regular cleavage along the lines of lamination, and assumed an irregular fracture. The outlying blocks of this belt, instead of assuming the rectangular forms common to the formation at large, usually present pyramidal shapes which have resisted the erosions of time with great success, while the adjacent rock has been much eaten and worn. This indurated belt is furthermore characterized by a line of fine springs, indicating that it furnishes an open passage-way for drainage waters. The ore of the mine is an infiltration, occupying the interspaces between large angular blocks of this indurated sandstone. The whole presents strong evidence of being a line of compression and fracture beneath a metalliferous belt which has subsequently concentrated its ore within the fractured zone. On Hagerman's Hill, near La Valle, similar ore is associated with indurated and brecciated rock, which is also impregnated with some copper ore.

Numerous circumstances of detail confirm these general views as to the method of formation of the crevices. It is evident that, since the horizontal pressure, which caused the alternate elevations and depressions, acted from a general southerly direction, the flexures produced by it would be at right angles, or east-westerly, and that therefore the main crevices and openings would trend in that direction, and this would be true, in considerable measure, without regard to the form of the basin. But it is also clear that local variations in the character of the strata, yielding at one point and resisting at another, and, in some measure, the attitude presented to the force tended to give variations from an exact east and west course. The north and south crevices, on the other hand, were not in general opened, because there was no great force brought to bear upon the strata either from the east or west. The beds were therefore merely fractured in those directions and did not, in the main, open more than was perhaps due to the shrinkage of the rocks. In exceptional cases, force may have been exerted in such a way as to cause more considerable north and south openings, but the prevalence of open east and west crevices and of closed north and south ones is, in fact, not only accordant but confirmatory of the explanation here offered. Another general circumstance deserves notice. It is a conspicuous fact, in many mining districts, that the openings occupy the same horizon throughout the entire area, a fine illustration of which is to be found in the "sixty-five foot opening," and less noticeably in the "twelve foot opening" of the Muscalunge and Beetown districts, as may be seen by consulting the map of the Muscalunge mines, Atlas Plate XL. That the ore should be deposited throughout a district at a given horizon might perhaps be otherwise explained, but that the strata should furnish a suitable *receptacle* for the ore at a given horizon and not above or below, is clearly indicative of some general physical cause. The precise cause in each individual instance may not be at once evident, but, in general, it may be found in the character of the beds involved and their relation to each other, viewed in the light of the conditions already considered.

VIII. Relations of the Ores to Each Other.

In the preceding descriptions references have been made to the relations of the ores to each other, and facts have been incidentally stated, which have prepared the way for this topic. It remains to specially consider the subject.

A. Relative Vertical Distribution. It is a law to which no noteworthy exceptions have yet been authentically reported, that lead predominates in the upper beds, but relatively decreases in the lower, while the zinc ores are very scant in the upper horizons, but relatively increase and often predominate below. It is not only true that mines confined to the upper beds of the Galena limestone bear mainly lead ore, while those lying wholly in the Blue limestone are chiefly zinc-bearing, but, more especially, that a given lode which ranges through both horizons carries lead in its upper part, which is gradually replaced by zinc in its descent. This is accomplished almost invariably by overlapping sheets, or intermingled deposits, so that there is no sudden or sharp transition.

The dividing plane at which the dominance of lead yields to that of zinc may be loosely stated to be the upper face of the Trenton limestone, but such a statement is rather a convenient generality than a reliable basis for either practical or theoretical deductions, for a considerable number of mines yield almost exclusively zinc in the lower measures of the Galena limestone, while in others, the predominance of lead is continued into the Trenton limestone. While, therefore, the dividing plane between the Galena and Trenton limestones lies near the transition of predominance between the ores, it does not mark it in any sharp, definite way, as though the transition was immediately dependent on the change of the adjacent rock, and we ought not hastily to conclude that the nature of the embracing stratum determines the character of the deposit.

The question of the relative amounts of these ores in the same lode is one of much practical, as well as theoretical interest, for if it could be determined that there is any approximation to a definite ratio between them, then, knowing the amount of lead that has been taken from the upper portion of lodes, not mined in depth, some estimate of the probable profitableness of pursuing mining below the water level might be made. It is hardly to be expected, however, that any trustworthy guide of this kind can be determined. It is quite certain that present data are altogether inadequate. Yet, however improbable any very uniform ratio may be, the question is one of importance. The best record bearing on the subject is that of the important Linden mine, that has given a yield of about 85,000,000 pounds, almost equally divided between lead and zinc ores. It is to be regretted that many such records cannot be adduced as data. But in their absence, some general statistics are not without suggestiveness, since in almost no mine is zinc found without lead, although the converse is less true. The total production of lead ore is estimated at about 1,416,000,000 pounds and that of zinc at about 400,000,000 pounds. Less than one-third of the ranges have been mined down to the zinc horizon.

When allowance is made for this and for the undoubted fact, that more of zinc than lead remains unmined, in those that have yielded both (confining attention, of course, to the Galena and Trenton limestones), it would appear that the ranges that have been developed in both horizons have proved nearly equally rich in the two ores.

Zinc ore first came into market in 1860. Waiving imperfections in the statistics, it appears that since that time the lead ore raised in the whole region amounts to about 320,000,000 pounds against 400,000,000 pounds of zinc ore. For the last ten years, the production of zinc ore has more than doubled that of lead *for the whole region* and, in more recent years, has more than trebled it. Confining attention to the region tributary to Mineral Point, and collating the statistics as well as may be since 1860, when zinc came to have value, it appears that about 70,000,000 pounds of lead ore have found shipment at that point against 280,000,000 pounds of zinc ore, a ratio of 1 to 4. It is impossible to obtain anything like an equally approximate estimate of the lead ore produced previous to 1860, but it seems quite clear that it would not be sufficient to render the total yield of lead equal to that of zinc.

Without overlooking the qualifications to which such general and imperfect computations are subject, the broad conclusion that from the mines which have been worked in both lead and zinc horizons, as much of zinc ore as of lead has been raised, is probably not wide from the truth. Among the qualifications to be observed is the fact that in many zinc-bearing mines a considerable portion of the plumbiferous beds has been removed by denudation. This is in some measure offset by the fact that in many of these the lower zinc deposits largely remain yet unmined, while the lead, being in large part above water, has been, more largely, mined. A doubt may also arise whether, granting the primal source of the ores to be equally abundant, the conditions of concentration have been as favorable beneath the fuller thickness of Galena limestone, that prevails in those regions that have thus far been only lead-yielding, as in the more superficial situations, whence zinc has thus far been mainly derived. This doubt, of course, depends upon the agencies that are held to have caused the deposition, and may be waived till that central topic is discussed.

Some service will have been rendered by the introduction of the question of the relative amounts of lead and zinc in lodes bearing both, if it shall in any measure lead miners to accumulate the proper data for its solution, which they, alone, are well prepared to do.

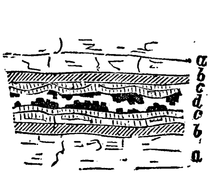
The vertical distribution of the iron is very similar to that of the zinc, except that it is more widely present. The highest lead deposits are rarely free from pyrite, or its ocherous decomposition product, but it is much more abundant in the lower Galena and the Trenton beds, and at some points zinc yields to it in depth, as lead does to zinc. There are not sufficient data, however, for the assertion of this as a law. *Copper* also selects the lower horizons and, so far as its limited development permits of judgment, tends to the same range as zinc. Its comparative frequency in the Lower Magnesian limestone, north of the lead region proper, where iron also abounds, but zinc has not yet been found, may be regarded as lending support to the view that its distribution accords more closely with iron than zinc, though it may be quite unsafe to draw conclusions from another region and a different formation, however similar, especially as lead ore occurs, at some points in this formation, quite free from associates and in form very similar to that of the upper Galena limestone.

Calcite is peculiarly frequent in the brown rock, but otherwise mainly abounds in the lower beds.

Barite occurs only in the lower beds, so far as my observations extend, and seems usually to have replaced calcite.

B. Relative Order of Deposition. In the upper beds of the Galena limestone there is often, to casual observation, but a single ore, galenite, and apparently no opportunity to raise the question of relative order, but closer examination will usually show a coat of iron oxide — the decomposition product of iron pyrites — between the Galena and the rock, and by examining the undecomposed bars of the lode, the pyrite and galenite may sometimes be seen in their unmodified relations, pyrite first and galenite upon it. A later deposit of pyrite sometimes coats the lead ore, making the order (1) pyrite, (2) galenite, (3) pyrite. Probably marcasite sometimes replaces the pyrite in such situations, as it certainly does in lower beds. Sometimes the galenite is directly adherent to the wall rock and the pyrite is attached to adjacent surfaces, in which case there are no means of judging which was antecedent, if, indeed, they were not of simultaneous formation, as is not improbable. Doubtless there may be true cases in which only lead ore was deposited, but I have seen none.

Fig. 54.



Section showing the usual order of deposit. a, rock; b, pyrite; c, blende; d, galena.

Descending to lower horizons, blende appears as a third mineral, and, in the large sheet deposits, usually takes the middle place, so that the order stands (1) pyrite (or marcasite), (2) blende, (3) galena. Dr. Percival states that he found this order invariable. While extended observation shows that it is not absolutely universal, it yet correctly expresses the prevalent law for massive sheets. At some points, the iron sulphide may be absent and the blende attached directly to the rock, or the blende may be locally absent, bringing the galena onto the pyrite as before, or the order may otherwise be seemingly changed by the absence of one or two of the ores. But the main complexity arises from reduplication. It is not uncommon to find a second deposit of pyrite overlying the blende and galena, beginning, as it were, a second series, which is sometimes feebly carried out by small crystals of blende or galena implanted on it. Occasionally layers of pyrite occur in the midst of the sheet of blende, and pyrite, blende and galena are often much mingled, their crystalline forms modified by interlocking, clearly indicating a contemporaneous growth. Some interesting examples of these complications will presently be cited.

Calcite enters most commonly as a fourth mineral, and usually takes the fourth place. It has, however, a careless habit of appearing in almost any situation, sometimes next the rock, sometimes in the midst, or between, the ores. It is quite prone to alternate with pyrite in the secondary series. Ore is sometimes wholly imbedded in the spar.

Chalcopyrite is not sufficiently distributed with other ores to make its relations altogether certain. At Mineral Point, where it is now being mined, profitably it is claimed, it occurs mainly in small cracks and cavities permeating a brecciated dolomite, in which it lies next the rock with iron pyrites planted on it. From some specimens recently mined in Spensley's lode, Mineral Point, and kindly sent me by Mr. Henry, it appears that the copper ore is either much mingled with or more recent than the blende and galena.

The discussion thus far has had reference to the original sulphides. Where these have undergone chemical transformation in place, their residuary products indicate the primal order, and no further consideration is necessary, save the obvious remark that the ores resulting from the change may have become such, much subsequently to the completion of the given series, and that the order in which they stand is no index to the order in which they arose from the change.

But the decomposition and recomposition of the original minerals gave rise to new deposits. These, as a whole, are much later than the primal series — as both their origin and position testify. Smithsonite and hydrozincite are the most common and important of these. They coat indiscriminately all the earlier minerals, and, in some cases, displace them by pseudomorphous processes. Cerussite occurs in crystals planted on galena.

Barite appears to be a late deposit, replacing calcite, but I cannot prove that this is invariably the case. In not uncommon instances, it incloses galena, and if not, in such cases, a secondary formation must have been essentially contemporaneous with the inclosed mineral.

In support and elucidation of these ordinal laws of deposition, many facts have already been given in connection with the description of the special forms of deposit, and others will incidentally find a place in the course of the discussion. Some special examples, illustrative rather of complexity and contemporaneity, than of the prevalent, simple, orderly succession, merit attention. They are mainly specimen fragments from the linings of the cavernous openings in the lower horizons, and show the result of prolonged deposition under favorable conditions.

The originals are largely in the fine collection of W. T. Henry, Esq., of Mineral Point. The first four numbers are from the Marsden lode.

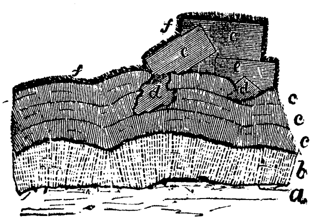
1. Our first example shows an argillaceous shale, as its base rock. To this is attached, without the usual seam of pyrite, a layer of blende, composed of alternating lighter and darker shades of radiant structure, tending toward mammillary forms. Through this are scattered some pyrite and galenite. Traced laterally, pyrite forms layers interleaved with the blende which becomes less abundant, suggesting that in an adjacent portion, the pyrite may become the predominant ore, an instance of which I have seen in the Linden mine. The upper surface of the blende is formed of crystalline points, and over most of these, lies calcite, taking at its base the form of the blende crystals, and terminating above in crystalline forms of its own. At some points, however, pyrite rests directly upon the blende, conforming to it below, but assuming a crystalline surface of its own above. Pyrite, likewise, extends over the calcite, conforming to it below, but forming its own proper surface above. At some points, however, the pyrite does not cover the calcite, which has grown up through and spread out above and upon the pyrite, moulding itself to it beneath, showing that it was formed later than, at least, some of the pyrite, while it is directly connected with the main layer of calcite which is older than the main layer of pyrite. The succession of formation seems then to be as follows: At first the principal deposit was blende with a little contemporaneous lead and iron sulphides. Calcite followed as the main formation, though at some points, pyrite may have been forming at the same time, since it rests directly on the blende. This is uncertain, but, at least, before calcite ceased to be formed, pyrite grew abundantly, so much so as to nearly shut off the growth of the calcite. The latter, however, continued to form at certain points, and at length overspread the adjacent pyrite. Whether the latter ceased forming, or was simply overrun by the faster forming spar is not clear.

At some points the blende and shale are cracked and calcite fills the seams, showing mechanical action, of a quiet sort, during the growth of the mineral group.

On the opposite side of the shale of the specimen and apparently occupying a fissure between it and its fellow rock are scattered crystals of galena, pyrite, blende and calcite, among which may be found, (1) blende on galena, (2) pyrite on galena, (3) pyrite on blende, (4) calcite on pyrite, while the calcite layer of the opposite side laps round and covers some of these. It is evident, therefore, that while there was a succession in the *predominant* deposit, there was not a complete suspension of one formation while another was taking place, in other words, there was more or less synchronism of deposition.

2. In this instance, the first deposit was marcasite in radiant mammiform crystalline aggregates, upon which lie concentric lighter and darker layers of blende somewhat intermingled with crystals of galena and pyrite. The galenite crystals, beginning low down in the blende, run in irregular strings outward to the surface of the layers of blende, and there connect with large well-formed cubes that spread out upon and overhang the surface of blende. The upper surface of the latter is composed of crystalline points and where the lead crystals enlarge upon it, they conform to it beneath, in the main, showing that the lead was formed last *at those points*, while it is evident that the included galena was formed, at least, as early as the blende, and, from its half regular, half irregular interlocking forms, there is little room to doubt, that the two ores were formed simultaneously, the blende predominating, at first, but mainly ceasing earlier than the galena, which then formed in shapely cubes on the surface. Subsequently the whole was coated with pyrite, which is now oxidized on the surface.

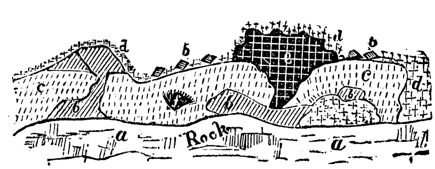
FIG. 55.



SECTION OF SPECIMEN FROM MARSDEN MINE, SHOWING ORDER OF DEPOSITION.—a, Rock. b, Marcasite. ccc, Concentric layers of blende, dd, Inserted Galena. eee, Crystals of Galena, conforming to blende below. ff, Enveloping Crust of Pyrite.

3. The wall rock in this instance is a granular dolomite bespangled with pyrite. To this is attached pyrite, calcite and blende, interspersed in an irregular way somewhat as represented in figure 56. A little distance from the rock the blende predom-

Fig. 56.



SECTION OF SPECIMEN SHOWING ORDER OF DEPOSITION. a, rock; b, calcite; c, blende; d, pyrite; e, galena; f, marcasite.

inates, but is still mixed with calcite and pyrite, to which galena is added. The latter gradually increases and soon becomes the leading ore, forming beautiful clusters of cubes. The surface of these cubes is incrusted with a thin layer of minutely crystalline pyrite. At most points this rests directly upon the galena, or blende, but at a few points it is based upon pink calcite formed at an earlier date and possibly continuous with the earlier calcite above mentioned. On the surface of the pyrite are scattered crystals of transparent calcite of later date than the pyrite. At one point a thin layer of pyrite lies between the pink and the transparent calcite, showing its intermediate deposition. The superficial pyrite is lightly coated with zinc carbonate over a portion of its surface. Before the formation of the superficial pyrite, and after the cessation of the deposit of the blende the latter was fractured, and its fragments somewhat displaced, and subsequently pyrite coated the fractured edges and filled the cracks. The order of formation may be shown in the diagram, figure 57.

FIG. 57.

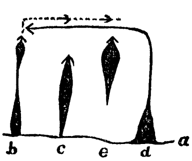
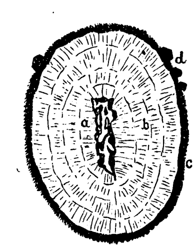


DIAGRAM ILLUSTRATING THE GROWTH OF THE MINERALS OF SPECIMEN 3. a, rock; b, calcite; c, blende; d, pyrite; e, galena.

Another specimen of identical structure, shows small, hemispherical aggregations of marcasite under the coat of pyrite, and; still another shows such miniature domes of marcasite, wholly inclosed in the layer of blende.

4. One of the most remarkable and instructive forms of these deposits is found in the composite ore-stalactites, for which the Marsden mine is celebrated. The specimen we select for study is six inches in diameter and fifteen inches long, though its original length was greater. The outline in cross section is oval. Instead of the usual cylindrical opening, extending along the axis, its core consists of a very irregular space, surrounded and interrupted curiously, by reticulated galenite. The interior surface of the latter, in part, presents a bright specular surface, and for the rest, has a dull leaden, but still fresh, appearance. Around this core has gathered about two inches of blende in concentric layers of radiant, fibrous structure. The whole is crusted with pyrite, on the outside of which are clustered some small crystals of galena, partially imbedded in it, and these are again bespangled with minute pyrite crystals. The surface of these little galenite crystals is dull leaden in luster, but

FIG. 58.



CROSS SECTION OF AN ORE STALACTITE FROM MARSDEN MINE, ONE-SIXTH NATURAL SIZE. a, galena; b, blende; c, pyrite. White in center is open space.

otherwise clean and fresh. Some of these penetrate the superficial pyrite crust and attach to the blende beneath.

In other specimens there is calcite as well as galena in the core, and the lead ore is sometimes more sprangled out into the blende. In one there is a ferruginous layer next the interior galena, probably the remnant of pyrites. In some cases the small exterior galenite crystals conform at their base to the pyrite coat, showing their later formation, while their minutely studded surface of pyrite shows a still later deposit of that mineral.

5. At Linden mine the usual order, (1) pyrite, (2) blende, (3) galena, is predominant, but there is often much mingling of the ores, and calcite is frequently much distributed through them. An interesting occurrence of the latter consists of large cream colored crystals of "dog tooth" spar, having a rough, much corroded surface, over which are scattered white tabular crystals of calcite, having clean, smooth, perfect surfaces, showing a deposition of later calcite on earlier with a period of corrosion between.

Another interesting specimen consists of white "nail-head" spar, on the decomposed surface of white dog-tooth spar, which, in turn incloses a crystal of pink calcite, also of the dog-tooth form.

6. A specimen from Marsden mine shows both fracture and corrosion, within the period of formation. The basal portion is blende, which was fractured after its formation and on the broken side there formed a creamy colored crystal of calcite.

This has an eroded surface and, upon it, are white crystals of smooth fresh surface. There is also present lamelliform pyrite, which appears to have been simultaneous, in part, with the later calcite in formation and in part older, but wholly subsequent to the earlier calc spar.

7. The deposits of Mineral Point have generally undergone much modification, but the original nature and order are usually determinable without uncertainty. The general succession is in accord with the prevalent law, with considerable modification arising from simultaneous growth. As an illustrative instance, the specimen we select shows a base of mixed pyrite and blende against the rock. These grew up together to some extent, the blende however, soon leading. At a later stage, some galena and marcasite were deposited, and over all these calcite and pyrite. These seem to have completed the original growth or first period of formative history. The second period consisted of decomposition and redeposit. The chemical change was essentially that of desulphurization. The pyrite became iron oxide, the blende, the carbonates of zinc, smithsonite and hydrozincite. The oxide

was left mainly in the former place of the pyrite, except that portion which was carried away by solution. The zinc carbonate, on the other hand, left a residue of "dry-bone" in the room of the blende and, in addition, coated the whole adjacent surface, including galena, pyrite, marcasite and calcite. The latter largely gave way to replacement, affording pseudomorphs of smithsonite after calcite. The galena suffered superficial change into lead carbonate, but has not usually been deeply affected. These changes lead us on to the subject of the following section.

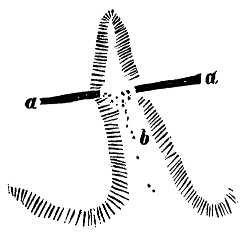
To the general laws of succession we now need to add the fact of local variation, and, more especially, that of simultaneous deposition. The fact of growth, side by side, is clearly demonstrated in the case of interlocking mutually-modified crystallizations, and is rendered highly probable in many other cases by relative position. The *conditions of growth* must, therefore, have been such as to permit of the formation of galena, blende, pyrite, marcasite and calcite, and, presumably, chalcopyrite, simultaneously.

IX. The Changes Which the Ores have Undergone since Their Deposition.

It is broadly evident that the deposition of the ores was a secondary process, secondary to the formation of the strata which now bear them, and secondary in the history of the ores themselves, since they must have been derived from an earlier metalliferous formation. To bring them into their present position and deposit them, some change of place and, probably, some change of chemical relations were involved. Precisely how the ores were brought from some other source and placed where we now find them, and by what changes of physical state and of chemical combination it was effected, are among the most vital questions of our discussion. Our truest method will manifestly be, to consider the changes that the ores are *now* undergoing and those which they have recently suffered, and from these we may the more safely reason in respect to the transportations and transformations that may have taken place in the more remote history of the formations.

I. Physical Changes. (a) *Surface Erosion since Ore Deposition.* The productive crevices, openings, and metalliferous beds quite often come out to the surface in ravines and the sides of bluffs. Immediately below where the lode thus comes to the face of the slope, there often lie, imbedded in the soil and residuary clay, detached pieces of ore. These are almost invariably worn and corroded on the surface, and are scattered along the line of wash from the outcropping lode, and, in many cases, have served the sagacious prospector as a guide to its discovery. That these loose bits of ore were derived from the lode by decay and wash does not need discussion. Its obviousness finds expression in the miners' name "float ore." In some cases a lode appears at the surface on opposite sides of a ravine, as though formerly continuous across it, and float ore may be traced from the one outcrop to the other, but, instead of stretching directly across the valley, it has been carried down a greater or less distance, as illustrated in the accompanying cut.

FIG. 59.



SKETCH SHOWING DRIFT OF "FLOAT ORE." aa, Lode; b, "Float Ore."

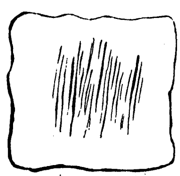
From the multitude of facts of this and similar nature, it is evident that since the original formation of the deposits, the surface has been much changed by drainage erosion, and that some of the ores have been mechanically transported, and, to some extent, wasted by wear and corrosion. But this is less to our purpose than some of the following facts:

(b.) *Physical changes within the openings.* From what has already been said in respect to the methods of occurrence of ores within the strata, it is manifest that, since deposition, they have, in many cases, been loosened by fracture, or disintegration, from their attachments and precipitated to the bottom of the cavity, or imbedded in the products of decomposition. In other cases, the ore, without having been detached, has been fractured and subsequently healed by metallic sulphides or calcite filling the seams, showing that the fission occurred before deposition had entirely ceased. It, therefore, appears that, since the ores were first formed within the cavities, which they now occupy, they have been subjected to some slight mechanical and to certain, much more important, disintegrating agencies. What these latter were claims our attention in detail.

II. *Recent Chemical Changes.* (a.) *In Galenite.* Through the kindness of W. T. Henry, Esq., I am in possession of a fine cluster of pseudomorphs of zinc carbonate after galena. An inspection of the specimen makes it evident that the cubes of galena were first coated with zinc carbonate after which they were gradually removed and the smithsonite deposited in their place. This was not done by a uniform displacement of particle by particle, as in the higher type of pseudomorphs, for the molecules of smithsonite do not have the same arrangement as the displaced galenite, indeed, they do not fill the entire cavity, but, on the interior, assume the irregular, cellular structure characteristic of "drybone." Such pseudomorphs after galena are comparatively rare, but specimens are somewhat common in which the galenite crystals are simply coated with zinc carbonate, the incipient stages of change only being visible. It would thus seem to be indicated that this is a transformation barely inaugurated.

Another change, which the galena has suffered in recent times, and is undoubtedly undergoing at present, consists of an alteration from the sulphide to the carbonate. Galena may be found, not infrequently, which is coated with a white layer of carbonate, the whole mass still retaining the original form of the galena and showing on fracture that the junction of the carbonate with the sulphide is not regular and sharply defined as though the former were laid down over the latter, as an added coating, but that it penetrates the galena irregularly along the crystalline planes of cleavage. Specimens may be found in which the carbonate penetrates the galenite through and through, leaving, however, laminæ of the latter unchanged.

FIG. 60.



SECTION OF A CUBE OF GALENA MAINLY CHANGED TO LEAD CARBONATE. Dark lines represent remnant laminæ of galena.

These specimens universally show imperfect outlines and a tendency to disintegration, demonstrating that it is a destructive process and not a method of growth. This is further shown by the fact that the carbonate has an open, porous texture and does not represent all the lead there was originally in the galenite crystal, a portion having been carried away, and by the further fact that in some instances nearly all the substance of the ore has been removed, leaving only a little pulverulent matter very aptly styled "mineral ash." It is made still more evident, if possible, that this is a process of decay, as well as transformation, by the decomposed condition of the rocks and minerals with which it is associated, and the general aspect of decay pervading the whole lode. It may be further added that the carbonate is not in its appropriate crystalline form though, in other situations, it is found perfectly crystallized after its own nature, the result of constructive action. It would be unnecessary to even cite at length these evidences of degeneration, so familiar are the phenomena, were there not still some lingering belief among miners that "mineral ash" is ore in process of formation. In the description of galena, at the outset of this discussion, mention was made of the occasional existence within its crystals, of singular cavities conforming, in a measure, to the crystalline planes and axes, and within these, sometimes small crystals of lead sulphate or carbonate. These cavities, in part at least, are due to the removal of the galena and are, of course, subsequent in origin, to its formation. There are then, leaving out of consideration mere mechanical erosion, three classes of phenomena that indicate recent and presumably present changes in the galena. (1.) Its removal and the substitution of zinc carbonate, forming pseudomorphs of smithsonite after galena. (2.) Its replacement by lead carbonate accompanied by partial removal, and (3.) Its removal and partial replacement by lead sulphate and crystalline carbonate.

What is the rationale of these changes? Under favorable circumstances oxygen has a greater affinity for the metals under discussion than sulphur and when the sulphides, galena, blende, pyrite, marcasite and chalcopyrite are subjected to the action of moist oxygen, they tend to undergo slow oxidation by which these sulphides are changed to sulphates. In the present instance, the lead sulphide galena becomes lead sulphate, which occurs in the interior cavities of the galena instanced above. This lead sulphate, while it possesses the property only in a low degree, is yet sparingly soluble and hence suffers some loss from being carried away by percolating waters. In the interior of the crystals, where there is very little access of water, we, however, find it, and, it is worthy of note, in this situation alone in our region.

But where the changing ore is exposed freely to the common drainage waters, the reaction does not stop here, for these waters contain lime and magnesian bicarbonates, and these exchange acids with the lead sulphate, giving rise to lead carbonate and lime and magnesian sulphates. The latter is very soluble and passes away and we find no further trace of it. The lime sulphate occasionally crystallizes in the form of gypsum and remains as a talisman of the reaction, but, for the most part, it also passes away with the drainage, or is subsequently reconverted by decomposing organic matter, or other agencies, into lime carbonate, which occurs abundantly in the lower metalliferous beds. The lead carbonate formed is highly insoluble but not absolutely so, from which it results that it remains, for the greater part, where it is first formed until, by the slow solution of ages, it is, at length, removed, but a portion of it will at once be carried away to crystallize as carbonate elsewhere, or be again reduced to the sulphide, or else lost with the drainage waters. It appears, therefore, demonstrably evident, not only that chemical decomposition and recomposition of lead compounds are now in progress, but that a certain small content of lead is carried onward by the percolating waters, either to be again reduced, or, at length, lost to the strata. It does not concern us here that this is exceeding small in amount. We are now but noting the facts and principles of present changes.

Is galena now being formed? It has just been implied that the lead held in solution may be again reduced, which is equivalent to implying a belief that galena may be now forming. Is there any direct evidence that such is the fact? It is certainly a very rational belief. If a lead compound, however infinitesimal in quantity, is being borne downwards by the descending drainage, it is only necessary that it should come in contact with decomposing organic matter, or sulphuretted hydrogen, to be again restored to the condition of sulphide, and, by crystallization, form galena. Now the water that descends directly through the main channels carries down considerable organic matter from the surface and from the roots of plants that penetrate the upper crevices of the rocks. A number of instances are reported on credible testimony where bones are carried down into the lead bearing crevices, and *some of these contain galena in the interior.* These must have been introduced into the crevices from above after they were opened to the surface, for nothing of the kind, of course, exists in these early Silurian rocks. It is evident, therefore, that in these cases the galena has formed at a comparatively late date, for the overlying Hudson river shales do not, from their nature, permit open crevices and, in some districts, they have been but recently removed, geologically speaking. I am informed by a wholly trustworthy gentleman that the antler of a deer, found in the alluvium of a stream, contained galena. This would seem to imply not only that the ore was quite modern, but that the water of the stream, or the alluvium, was its source, but without fuller knowledge and verification of the facts, it is best to hold this very lightly. A considerable number of cases have been reported where tools, as gads, or old shovels, which have been buried in the mines for a long period, have been exhumed bearing small adhering particles of galena or blende. One of these has come into my possession, but the adhering ore seems to have been "wash-dirt" fragments cemented to the gad by the rust of the tool, rather than a new growth upon it. This may not be true of all reported cases, but very likely is. Nails and bits of iron, with attached ore, are also reported as found in streams near mines, but these are probably to be explained in a similar manner.

In digging over old rubbish heaps from the mines much small ore is often found, and many miners accept this as evidence of its recent formation. But this is probably to be explained by the fact that the earlier miners did not usually separate the fine ore from the crevice dirt. It would be easy to determine, by inspection, whether this is new ore or old fragments, or crystals that grew in shale, but no opportunity has been afforded.

It is further reported that there sometimes occur in clay, once worked over, thin knife-blade sheets of galena occupying cracks in the clay. This would, indeed, be good evidence, if the facts had been carefully and critically verified by an observer of known skill and trustworthiness.

But leaving in doubt these cases there yet remain two other presumable sources of redeposition. The lower lead-bearing beds, preeminently the Blue limestone, are pervaded with shaly layers and interleaved partings, which contain much organic matter, as does also some of the adjacent limestone. These shales check the descending currents and cause them to soak through slowly, and of necessity come in contact with the contained organic matter. The fact that the carbonaceous shaly leaves are often thickly studded with crystals of galena and blende demonstrably formed there, is good ground for believing that the organic matter was the precipitating agent. This argument is deficient in that it does not determine whether the organic matter is still competent to precipitate the passing metallic compounds, but it is yet, at least, so far oxidizable as to burn with flame, and sometimes so abundant as to be burned in heaps for the purpose of separating the disseminated ores.

The other possible precipitant is sulphuretted hydrogen, which is evolved in a variety of natural processes, as is well known. The phenomena of our numerous artesian fountains indicate that it is very widely prevalent in the deeper strata. I have thought that the facts justified a broad classification of our natural waters into the superficial ones which are oxygenated and the deeper ones which are sulphuretted, designating the horizon of the former the zone of oxygenation and of the latter the zone of sulphuration. In strata widely impregnated with sulphides, like those of the lead region, the sources for the development of sulphuretted hydrogen are prolific, and this distinction has more than its broad general application. The lead compounds, developed as above indicated in the zone of oxygenation, descending into the zone of sulphuration, would, I am confident, be redeposited as galena, so that, in part, what is lost above is saved below. In evidence of this, we may recall the facts given in detail in regard to special cases of succession in the order of deposition, notably the specimens from Marsden mine. It there appeared that, while there is a prevalent order for the main primary deposit, there is also a secondary series in special cases of prolonged deposition, and that lead is sometimes one of the most recent of these formations, being associated with calcite and pyrite in the constitution of stalactites, even forming one of their latest deposits. When we add to this the bright fresh surfaces of the minerals, some of them especially prone to change, as marcasite, so strikingly in contrast with the aspect prevalent in the zone of oxidation, the belief that the ores are now growing and are in reality, as well as appearance, fresh, is more rational than the alternative view that they have remained unchanged, even untarnished, through the lapse of ages. It is difficult to believe that these minerals could have stood for any long period on the narrow neutral line between the destructive and constructive processes in ceaseless activity in the earth's crust, situated as they are in the drainage channels between the upper and nether zones. It is, therefore, my confident conviction, that, as the ores are being wasted by oxidation in the superficial horizons and borne down by the descending drainage, they are caught and redeposited at lower depths through the agencies that have been indicated, and possibly others beyond our ken. To be sure, the loss of substance from oxidation above and the somewhat less gain from redeposit below, are trivial matters in their effects upon our resources in any limited lapse of time, when attention is confined, as it has been here, to the ores already deposited in the lodes, but when the more vital question is raised, Are ores being deposited from the source whence the existing masses were derived? it assumes more importance, not so much from the value of the accretion, which is presumably very slow, as from the practical principles and methods, as well as theoretical deductions to be drawn from it. This question I shall also answer in the affirmative, but its discussion belongs to the second division of our disquisition.

Recent Changes in Blende. It is common enough to break open a rough mass of zinc carbonate in the form of dry bone and find the interior blende, and a close inspection of a multitude of these leaves no room for doubt whatever that the blende has been changed, and presumably is still changing into "dry bone." Associated with this there is often much of the hydrated zinc carbonate, hydrozincite, which manifestly had a similar origin. It is to be noted that the zinc carbonate not only does not habitually retain the structure and crystalline outline of the blende but assumes a new and commonly more bulky form, characterized by a very irregular, cellular structure that perhaps could not be better briefly defined than by its common name "dry bone," derived from its likeness to the vesicular interior of a bone, the similarity being often enhanced by a coating of smooth compact hydrozincite on the exterior representing the outer osseous layer. To the mineralogist, however, the likeness to calcareous tufa is more obvious. It hence appears that there has not only been transformation but also transportation over a small space. An inspection of the specimens shows that not only does the carbonate grow inward, replacing the transformed blende, but also grows outward by accretions on the surface. The hydrated carbonate enters quite largely into this latter growth, assuming concentric layers and a botryoidal surface.

It has already been noted, in connection with the changes of galena, that the zinc carbonate, in certain instances, formed coatings over galenite cubes, which were subsequently removed and replaced by the zinc compound. Here, therefore, also the ores have been both transformed and transferred.

It is further evident that the zinc formation began earlier and continued at least as late as the action upon the lead, because it first coated and then replaced it. But we have instanced reasons for believing that the dissolution of the lead ore is still in progress. It, therefore, is inferred that the alteration of the zinc is likewise continuous still. In added support of this, the zinc ore itself presents ample evidence as will presently appear.

Not only does the smithsonite coat and replace galena, but much more commonly it forms pseudomorphs after calcite in a precisely similar way. In the fine collection of Mr. Henry, as well as among the many specimens he has generously given me, every stage of the process is beautifully shown. There are specimens of calcite covered with but a thin, closely adherent film of zinc carbonate; others with a thicker crust; others in which the surface of the calcite beneath the crust is slightly eaten away and projecting points and plates on the inner surface of the coating show the commencement of inward growth, following up the dissolving calcite; others, in which the calcite is more and more reduced and the zinc more and more advanced; others, at length in which there is only a crumbling remnant of the calcite in the center, and, finally, those in which it has entirely disappeared, leaving simply a shell of zinc carbonate in the form of the original calcite with an interior of reticulate plates. In no specimen observed was the interior entirely filled with solid smithsonite, but, on the other hand, the ore is disposed in plates correspondent to the cleavage lines of the calcite. In many instances, when the calcite is only partially removed, the smithsonite plates may be seen advancing along the cleavage cracks of the calcite. The latter mineral evidently dissolved most readily along certain crystalline planes and cleavage crevices and the zinc deposition followed closely in the abandoned space. In the Mineral Point region, pseudomorphs of this kind are quite common, especially in the Hutchinson range. They take all the prevalent forms of the calcite. The precise method by which these transformations took place seems to be as follows: Antecedent to the alteration there existed the original deposit of blende, associated with crystals of calcite, the latter usually adherent to the surface of the former, being a later deposit. Usually galenite and pyrite, or marcasite, were also present, but that does not concern us just here. The blende, zinc sulphide, underwent oxidation, as in the case of galena before explained, and the result was zinc sulphate. This is a highly soluble compound and would be promptly borne away but for two circumstances. In the first place, this reaction does not take place habitually beneath water, but in moist situations above the water level, and hence is not exposed to copious drainage. In the second place, zinc sulphate and lime carbonate coming together mutually exchange partners and become zinc carbonate and lime sulphate, the former of which is only slightly soluble, while the latter is moderately so. When, by the oxidation of the blende, zinc sulphate is formed, it creeps over the moist surface of the calcite crystals and the above reaction takes place between the lime carbonate of the crystal and the zinc sulphate, by which zinc carbonate is formed and deposited as a film on the crystal, while the lime sulphate passes on with the capillary moisture. When the coating has once been formed, there is little or no farther action on its surface, and so the form of the calcite remains essentially unchanged, but the zinc sulphate, penetrating between the coating and the calcite, continues its action on the latter, at the same time adding to the growth of the former on the inner side. This capillary action would naturally take place most readily in the cleavage fissures of the calcite and thus give rise to the reticulated plates of zinc carbonate above described. It is to be noted, however, that the entire space occupied by the calcite is not filled with smithsonite, or in other words, the calcite is wasted faster than the deposition of the zinc carbonate demands. Without entire confidence as to the adequacy of the explanation, the following will satisfy, at least, part of the demands of the problem.

It has been stated that, in connection with the blende, there is usually present iron bisulphide in the form of pyrite or marcasite. Some is also intermixed with the blende as an impurity. This likewise undergoes oxidation, but, containing two atoms of sulphur to one of iron, gives rise, on ultimate oxidation, to an extra equivalent of sulphuric acid, which will remove part of the calcite without residuum. Furthermore, when the reaction between iron sulphate and the lime carbonate takes place, the carbonic acid, instead of forming an iron carbonate, is set free and passes off, leaving only the iron oxide, whose volume is less than that of the iron sulphate, from which it was derived, or of the lime carbonate it displaced. Between the calcite removed by the extra acid and this shrinkage in reaction, there would result a considerable unoccupied space. The fact that the interior of these pseudomorphs are peculiarly ferruginous and the calcite sometimes coated with iron oxide, sanctions this explanation. Probably, also, the freed carbonic acid assisted in carrying away in the passing moisture some of the calcite, as bicarbonate.

The reaction which gave origin to the formation of "drybone" from blende was essentially the same as that involved in the production of the pseudomorphs, the reduction of the sulphate being due to earthy carbonates in the capillary moisture derived from the adjacent limestone.

In regard to the question whether blende is being now formed, essentially the same arguments and answer may be offered as in the case of galena. It probably is forming in the lower horizons both from the waste of the blende above and from the original source whence that was derived.

Recent Changes in Pyrite and Marcasite. As these are both iron bisulphides and undergo like changes, they may be conveniently con-considered together. These minerals also show in the clearest light the chemical and pseudomorphous changes which they undergo. A series of specimens may be readily gathered which show all stages of the process. First, there are those which are barely tarnished on their crystalline faces, then those coated with a thin film, and then others with a deeper crust of iron oxide, whose junction with the sulphide shows that it is not a supperadded coating, while its texture demonstrates that it is not a product of accretion but of alteration. Then there follow specimens, in which the oxide penetrates deeper and deeper until the sulphide has been entirely displaced. But we are not left even to this class of evidence, however convincing. Fresh masses of these minerals, especially the marcasite, may be placed on a shelf in the open atmosphere and will shortly begin to disintegrate and a bitter, efflorescent salt will appear on the surface, which examination will show to be iron sulphate. But these are bisulphides, and, in the change to the sulphate, but one of the equivalents of sulphur is needed. The remaining equivalent may form sulphuretted hydrogen and escape as a gas, or by oxidation give rise to free sulphur or sulphuric acid, according to the conditions. The latter would, of course, at once unite with the earthy carbonates to form calcic and magnesic sulphates. But the iron sulphate formed, coming in contact with earthy carbonates, either in the rock, or in solution, gives up to them its sulphuric acid, which displaces their carbonic acid. In the case of lead and zinc we have seen that the carbonic acid thus displaced united with the metal forming a carbonate. With the iron, however, this does not usually take place, but the carbonic acid is set free, to the discomfort and danger of the miner, to whom it is known as "the damps" or "bad air." The iron takes to itself more oxygen, and usually water also, and becomes a hydrated sesquioxide, in most cases, known to the miner as ocher or rust. Occasionally, however, the iron sulphate is not removed by solution and does not undergo this reaction, but remains as a whitish, bitter salt, or organizes itself into pale greenish crystals, identical with our common copperas. This, of course, only occurs when there is very little percolating water and is not a stable or permanent product. Indeed it shows on the other hand the instability of some of the constituents of our mineral lodes under certain natural conditions and illustrates the relative rapidity of their changes.

The limonite, produced by the oxidation of these sulphides, very commonly retains the form of the original mineral, and, in some of the radiating varieties, presents very interesting, and, to the mineralogical sense, very beautiful forms.

Recent Changes in Chalcopyrite. As might now be easily conjectured, this mineral, a double sulphide of copper and iron, suffers alteration in a manner precisely similar to the foregoing. Oxidation gives rise to copper and iron sulphates and these, in turn, are reduced to copper carbonate and iron oxide by the action of the earthy carbonates. The copper carbonate may take either the form malachite or azurite. Both are not uncommon in the same specimen.

Recent Changes in Calcite. Mention has already been made of the changes which calcite crystals suffer, in certain instances, through the agency of the decomposition products of blende where it is quite clear what the agencies of alteration were. In many other instances, this spar has manifestly suffered much corrosion and, from the foregoing considerations, it is clear enough what might have been, and, in large measure, probably were the agencies. Any one of the sulphuric products of the oxidation of the sulphides was competent to destroy its integrity. But, in addition to this common corrosion, calcite not unfrequently sustains a relation to barite that appears to show that it is being replaced by that mineral. The barite occurs in patches in what would seem to have been otherwise a continuous seam or mass of calcite. The ragged interlocking edges, at their junction, forbid the idea that they were originally deposited in this juxtaposition. The crystalline planes of the calcite are interrupted by the barite in a way scarcely accordant with the view that the barite was present when they were formed, while the structure of the barite is very irregular as though assumed under conditions adverse to symmetrical crystalline devolopment. Neither have the outline they would have assumed had they formed either before or after the other, or indeed simultaneously, without corrosion or substitution. It seems, therefore, quite clear that the barite is replacing the calcite. Precisely how this is being done is not so clear as in the preceding instances of substitution. If the barium was brought into contact with calcite in the highly soluble form of barium sulphydrate (presumed to have been formed from barium sulphate by the action of decomposing organic matter), simple oxidation and recombination would form both barium and lime sulphates, the former remaining because of its extreme insolubility and the latter passing away in solution. While possible, it is not highly probable, that the barium comes into action in this form, but rather in that of the carbonate, since it occurs in this form in springs and the deposits from them, and is also found in the lead regions of Lexington, Alston Moor, Silesia, and elsewhere.

Barium carbonate is soluble in water charged with free carbonic acid and, in this form, it would be carried into the minute fissures and capillary crevices between the calcite and the metallic sulphide with which it is associated, usually blende. Here it would meet either a metallic sulphate, formed from the direct oxidation of the sulphide, or with lime sulphate, due to the secondary action of the metallic sulphate on lime carbonate. In the former case, there would be a simple exchange of acids, resulting in barium sulphate and a metallic carbonate, usually smithsonite; in the other case, there would be a similar reaction between the barium carbonate and lime sulphate, yielding barium sulphate and lime carbonate. This latter in the abundant presence of free carbonic acid will pass away in solution. In either case, the final result is the removal of the calcite and the deposition of the barite. It is not altogether improbable that all of the foregoing reactions take place under different circumstances.

Recent Changes in the Inclosing Rock. In addition to the recent transformations in the minerals of the lodes, it is worthy of note that the adjacent rock participates. The walls of the fissures have, in many cases, been extensively disintegrated, giving rise to the clay and calcareous sand that now fills the crevices. The outer portion of blocks of rock have been much eaten forming "tumbling rock," caves have been formed, and, in general, the whole upper portion of the formation has been changed from its original blue or gray color to its present buff hue and, at the same time, corroded in various degrees. This action is due partly to the dissolving of the rocks by drainage waters, carrying free carbonic acid and other solvents brought down from the surface, partly to the action of corrosive substances derived from the rocks themselves, and partly to the reagents arising from the chemical reactions of the minerals of the lodes.

The last two agencies arise mainly from oxidation. The descending surface waters carry down oxygen not only through visible fissures but by means of capillary crevices and minute pores and thus oxygenate all substances whose affinities are not already satisfied. The main results are the peroxidation of protoxides, the decomposition of organic matter, and the change of sulphides to sulphates. The attendant secondary results are the solution and removal of a portion of the rock and a change in the composition, coherence, and color of the remainder.

That portion of the strata that has been subjected to this action has been designated *the zone of oxidation.* The superficial region above the permanent water level most obviously belongs to this zone, and there the results of oxidation are most conspicuous. The most active portion of the zone lies just at the water level where chemical transformations are relatively vigorous. Below this line, the free oxygen of the water is gradually consumed and its activities correspondingly lessened and the zone shades away to the neutral line, beyond which, in our view, the oxygenated compounds are robbed of oxygen by compounds of stronger affinities and there is, in large part, a return to the former state, the metallic compounds again becoming sulphides.

X. Ore Deposits in the Lower Formations.

Our attention has thus far been confined to the ore deposits of the Trenton and Galena limestones, in which are situated all the lead and zinc mines that have been thus far profitably wrought for any considerable period of time. It is a matter of supreme practical and theoretical interest to determine whether the formations lying below these are productive or barren, a question upon which there has been much diversity of opinion. Theoretical views and financial interests alike are affected by this important problem. It is more important, however, to ascertain the probable facts than to sustain a theory or be led into false practical conclusions. It is manifestly, therefore, our first duty to gather all the trustworthy evidence within our reach concerning the actually observed occurrences of ores within these formations.

Ores in the St. Peters Sandstone.

Concerning the metalliferous character of this formation Dr. Owen, writing in 1851, in the midst of the earlier mining explorations, says:

"This sandstone formation appears to be destitute of other minerals foreign to its composition. Its structure is unfavorable for the retention of metallic ores for reasons previously enlarged upon."[1]

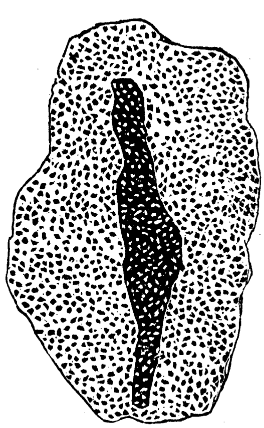
Dr. Percival, in his report of 1855, says:

"The Upper Sandstone, so far as I have been able to ascertain, has not yet been found to contain mineral either in crevices or openings; but a sheet of zinc ore and iron pyrites at Mineral Point, already referred to (p. 55), is said to have been traced 2–3 feet into that rock, in the line of a crevice bearing mineral to the base of the blue limestone. Copper ore is also said to have been found in the sandstone at the depth of several feet, in the same vicinity. It is thus not improbable that if the mineral is interrupted in the sandstone, ores of zinc and copper may be found there in its place."[2] The passage referred to is as follows: "I have not yet had an opportunity of tracing such a vein lower than the upper bed of the blue limestone; but I have been informed by J. Bracken, Esq., that such a vein, in the Victoria range (Mineral Point), was followed down to the base of the blue limestone, and that the accompanying zinc and iron ores were even traced into the upper sandstone."

Prof. Whitney, in the report of 1862, speaking of the Crow Branch mines, says, p. 363:

"Up to that time no ores had been observed in the sandstone, although the mineralized deposit was thus brought down nearly into contact with that rock. I have recently (August, 1860) learned from A. K. Johnston, Esq., that in a visit made to these diggings, in July preceding, he ascertained that 'two distinct veins of Galena had recently been discovered running through the sand-rock.' Of the size of the veins, or depth to which traced, no information was given. At all events, the fact is an interesting one, as it is the first authentic occurrence of lead ore in this rock, so far as I have been able to ascertain. It is not probable that these veins will be found penetrating to any considerable depth; but, of all the localities in the lead region, this was the one where it might be most naturally expected that, if anywhere, the ore would be found making in the sandstone."

FIG. 61.



SECTION OF SPECIMEN OF ST. PETERS SANDSTONE FROM CROW BRANCH CONTAINING GALENA. Dark portion represents galena; the light spots within it the inclosed grains of sand.

In the same vicinity in 1868, I personally extracted small quantities of galena from this formation. The deposit consisted of mere detached knife-blade sheets of an inch or two in diameter, occupying small seams in the sandstone. The quantity was merely sufficient to permit the bare assertion of its existence in the formation. Its position was within a very few feet of the upper limit of the sandstone, which, at that point, is overlain by the Buff limestone. The little, detached patches of ore had no evident connection with each other or with the limestone above, which, however, did not vertically overlie it.

Just as the above was going into type

[1] Owen's Geological Survey of Wisconsin, Iowa and Minnesota, page 71. [2] p. 66.

I received from Mr. Henry, to whom I am indebted for many similar favors, a specimen of St. Peters sandstone from Crow Branch containing galena, of which Fig. 61 is a sketch, *natural size.* The most interesting feature of the specimen is that the ore, instead of accompanying a seam, is an *infiltration* into a thin layer of the sandstone, somewhat coarser and more open than the adjoining. The grains of sand are inwrapped and bound together by the galena. In passing through the specimen, which is but three-fourths of an inch thick, the dimensions of the little vein, if it is worthy to be so called, are reduced one-half.

To these there might perhaps be added a few similar observations, less well authenticated, but they would add nothing to the character, but only somewhat to the number of instances. The St. Peters sandstone is well exposed at several localities, notably that of Mineral Point, closely beneath rich lead deposits, and is conspicuously barren and there is no sufficient reason for supposing the formation to be in any noteworthy degree metalliferous.

Ore Deposits in the Lower Magnesian Limestone.

As early as 1848, Dr. Owen collated the following evidence concerning the occurrence of lead ore in this formation.[1] After referring to the existence of trappean and metamorphic rocks in the region northward, he says:

"There can now be little doubt that the whole mining region of the Mineral Point and Dubuque districts of Wisconsin and Iowa is based upon a sienitic and granitic platform which would, in all probability, be reached by penetrating to the depth of from one thousand to two thousand feet.

"These facts, taken together, may be considered as favorable to the metalliferous character of F. 2. [Lower Magnesian limestone.] Fortunately, I am able to bring several actual discoveries in corroboration of this inference.

"Near the base of a bluff composed of F. 2, on the west side of the Mississippi, some ten or fifteen miles above the mouth of Turkey river and just above the French village, from seven to ten thousand pounds of lead ore were obtained from openings in the rock by Dr. Andros. More or less galena is found here, in all the horizontal openings, for the distance of half a mile to a mile.

"Near the mouth of the Kickapoo, on the southeast quarter of section ten, township seven north, range five west of the fourth principal meridian, pieces of lead ore, weighing from half to three-quarters of a pound, have been obtained from cherty beds of the inferior part of the lower magnesian limestone. A company has lately commenced exploring there, and has obtained some hundred pounds of galena.

"On the opposite side of the same valley Hearn and Ward obtained about four hundred pounds of galena; some masses weighed fifteen pounds. On section fifteen, township seven north, range five west of the fourth principal meridian, some lead ore has been found.

[1] Executive Document, No. 57, first session, 30th Congress, page 23.

"In the hills at the first great western bend of the Kickapoo, a little below the mouth of Plumb creek, Hearn and Miller discovered some lead ore.

"Half a mile south of the aforementioned valley, on the south half of section fifteen, township seven north, range five west of the fourth principal meridian, Burns and Miller procured about a hundred pounds of lead ore.

"East of the first locality, Hearn and Miller dug sixty feet, and followed an east and west lode, in which they obtained a small quantity of lead ore.

"All these discoveries were made in the lower magnesian limestone, F. 2.

"In the same vicinity, on the south half of sections thirty-three, thirty-four and thirty-five, township eight north, range five west of the fourth principal meridian, there are vestiges of ancient diggings wrought by the aborigines.

"Between Yellow river and the upper Iowa, Mr. A. L. Martin found several pieces of lead ore on the surface, weighing four or five ounces, and observed a place where the Indians must have excavated the hill in search of this ore.

"On the upper Iowa river in several places east and west, crevices were observed in the lower magnesian limestone, presenting symptoms of being galeniferous, especially at a bend of that river where the stream flows over solid ledges of lower magnesian limestone with bold bluffs of the same on the south side. This place is eight or ten miles below the Big Spring, and by water about sixty miles above the confluence of the upper Iowa with the Mississippi.

On the Nazi Oju, Mr. B. C. Macy, of the geological corps, saw a vein of lead ore of four inches in width, bearing nearly east and west, and ranging apparently for the distance of half to three-quarters of a mile through the lower magnesian limestone.

In his final report of 1851, he supplements the above by the following remarks; page 63.

"To the above may be added some interesting discoveries made in this formation, between Plum and Pine Creeks, tributaries of the Kickapoo. Between these streams in the southwest corner of section 26, township 8 north, range 5 east of the 4th principal meridian, on the southeast slope of a hill, copper ore, associated with hematite, was found and traced into a crevice traversing the lower cherty beds of this formation. On the opposite side of this hill no copper ore has yet been noticed; but, four miles beyond, in a north-northwest direction, on the slope of another hill of about the same elevation, similar copper ore was picked up.

"About twenty miles north of the mouth of the Kickapoo, four miles west of it, and seven miles east of the copper range heretofore mentioned, in the valley of Hale's Creek, lead ore has been obtained, apparently connected with an east and west lode.

"A heavy lode of lead ore is said also to have been discovered on the Half Breed tract near the Wazi-oju, by Joseph Bison. This vein is represented as being from ten inches to a foot wide, and filled with galena embedded in the usual matrix of red, tenacious clay.

"Two miles below Bad Axe river, Mr. Pratten, of the geological corps, found lead ore attached to calcareous spar, which evidently fell from the cliff of the Lower Magnesian limestone above the spot where the specimen was picked up.

"In the Winnebago reservation, not far from the Iowa river, and a few miles northwest of the small town of Lansing, lead ore was found, in small quantities, chiefly in *pockets* and cavities.

"The above instances abundantly prove that the Lower Magnesian limestone, as well as the Upper, is lead-bearing; whether productively so, or not, cannot be fully determined until the rock is scientifically mined. It is certain that, at many of the above localities, the rock is exceedingly cherty, and is consequently hard and difficult and expensive to work, and near the surface the ore is much scattered and disseminated through the rock, rather in horizontal openings than in vertical veins; still, if this surface ore should be connected with deeper-seated lodes, as there is some reason to believe it may be, then these would be well worthy the attention of the miner.

"Under present circumstances, however, and with the uncertainty attaching to the last hypothesis, I have not considered it my duty to recommend lead mineral reservations where this formation prevails.

"As to its copper ore, the Department will recollect that, on the 23d of November, 1848, I reported certain sections, and fractional sections, which were regarded as mineral lands, but added, that, until the chemical analyses of the various samples of ores taken from different crevices were completed, I could not decide upon their productiveness. These examinations have now been made and their results, together with other considerations, do not, in my opinion, justify their designation as *productive* mineral lands. Some of the richest portions of the copper ore have yielded, it is true, as much as twelve per cent. of copper; and, it is possible, by the outlay of a large sum of money veins might be followed and finally yield a profit to the miner; but the average percentage of all the ore and copper-earth which I have analyzed will not amount to more than four or five per cent., and a great deal of it to only one per cent. In a new country, distant from a market, ores of this description are not worth working."

Dr. Percival, in his report of 1855, makes the following additional contribution to our knowledge of the subject, page 66:

"If the mineral is interrupted in the upper sandstone it reappears in the lower magnesian. Numerous instances are stated of the occurrence of mineral in the lower magnesian in Owen's reports (1847, 1852), and several other localities have been mentioned to me by different individuals, near the Mississippi, and in the country between it and the Kickapoo, north of the Wisconsin. I shall, however, confine myself here to my own observations. I have not yet had time to explore the country occupied by the lower magnesian to any extent, and have visited no other diggings in that rock, but those in the vicinity of Blue river, known as Ohlerking's Diggings. These, however, furnish satisfactory evidence that the mineral occurs in that rock, in as proper openings, in as large masses, and arranged as regularly as in the upper magnesian. The diggings are in the sides of a ravine, 60 to 70 feet deep, leading to the Blue river, about three miles west of Franklin village. The lower magnesian occupies the sides of the ravine nearly to the summit, where it is overlaid by a low bluff of the upper sandstone. About three-fourths of the descent below the sandstone is occupied by a steep slope, formed by the softer upper bed of the lower magnesian, below which is another low bluff formed by the harder middle portion of the same rock. Three successive openings, one above the other, appear to occur here in the lower magnesian; one 8 to 10 feet below the sandstone, another just above the harder middle bed, and a third below the bottom of the ravine, in the latter bed, and at a depth of about 70 feet in the lower magnesian. The openings appeared partly narrow and vertical, partly wide and flat, with appearances of decomposition and stain in the rock, deposits of clay and ocher, and arrangements of the mineral, similar to those in the upper magnesian. Flint, such as is peculiar to the lower magnesian, is found in the openings, and is connected with the mineral in the same manner as has been noticed in the flint openings in the upper magnesian. The mineral in these openings generally appeared in more or less detached masses (chunk mineral), often very large, weighing more than 100 lbs.; a few even more than 500 lbs. It was what is called pure mineral, free from iron and zinc ores, and strongly resembled that found in the upper vertical openings in the upper magnesian. After examining this locality, I could not doubt that the lower magnesian is a good mineral-bearing rock."

The following is Prof. Whitney's review of the evidence bearing upon the subject (pp. 408–413):

"The advocates of deep mining bring forward several instances of the occurrence of lead ore in the Lower Magnesian, where this rock is exposed on the surface to the north of the Lead Region, from which they infer that it can be profitably mined in, by continuing the workings in the regular lead-bearing rock of the district down into the underlying formations. Now it might be that the Lower Magnesian could be profitably worked in when it lies next to the surface and yet that it would not pay to sink to it through a thickness of one hundred feet or more of unproductive strata, when necessarily expensive machinery would be required to keep the mines free from water, in addition to the increased expenditure for the machinery required for hoisting from a considerable depth. We will go farther, and make the assertion based on pretty extensive observation in the region, that if the present lead-bearing formation, the Galena limestone, were covered by one hundred feet of unproductive rock, as difficult to sink through as the Upper sandstone; the deposits of lead which it contains could only in very exceptional cases be worked with profit; and as these cases could not be known beforehand, the result, on the whole, would be unsatisfactory. Therefore even if it be admitted that the Lower Magnesian does contain, beneath the Lead Region, as large and valuable deposits of ore as the Galena limestone, it could not be mined with profit except where it crops out in the valleys, or is overlaid by only a thin stratum of other rocks. This statement is made, of course, with reference to the present condition of prices, wages, etc., in the Lead Region.

"But, on the other hand, we are not prepared to admit that the Lower Magnesian ever has been, or is likely to be, profitably mined in for lead, either when it comes to the surface, or when it is overlaid by other rocks. For the purpose of determining this point, we have examined all the localities where galena has been reported as having been found in any noticeable quantity, and are able to affirm that, at the present time, no profitable mining is carried on in the Lower Magnesian, and that none ever has been for any length of time; and, farther, that no well developed crevices, or such as could be followed to any distance, have ever been found in it.

"The principal localities which have been quoted and relied on as affording evidence of the productiveness of the Lower Magnesian are the Kickapoo, and Ohlerking's or Moosan's diggings, near Franklin, although neither of these has yielded as much ore, or been as worthy of notice, as those at New Galena, on the Upper Iowa river, in Iowa. The last named diggings are thus described by me in the Iowa Report:

"'Along the face of the bluff, in which a thickness of 120 to 150 feet of the Lower Magnesian limestone is exposed, a number of drifts have been extended into the rock, a little below its juncture with the sandstone, and considerable galena has been taken out. The limestone, at this point, is brecciated in its structure, appearing as if it had been partially broken up after its deposition, and then re-cemented; portions of the rock have also a concretionary structure, and its whole appearance is that of a material which has been subjected to both mechanical and chemical disturbances. The ore appears to be associated with irregular strings and bunches of calcareous spar, ramifying through the rock, but nowhere assuming a regular form, like that of a vein, or appearing to occupy a well-developed fissure. Sometimes a little decomposition of the rock has taken place, which has given rise to a sort of opening, but none were observed which were more than a few inches wide and a few feet long. It is said that between fifty and one hundred thousand pounds of ore had been obtained from these diggings; but it seems hardly possible that the operation should have been, on the whole, a profitable one; and, taking into consideration the hardness of the limestone, and the very limited extent to which it has undergone decomposition in the vicinity of the mineral deposits, we see little to encourage farther expenditure at this point.'

"Since the above was written, we have had no further news from that quarter; but consider ourselves safe in presuming that all thoughts of doing a profitable business in the vicinity have been abandoned. Probably over five dollars were expended there for every dollar's worth of ore taken out.

"The Little Kickapoo diggings were visited by Dr. Kimball in the spring of 1860, and from his notes I learn that they are occasionally worked by one person, but with no favorable results. A great number of shafts have been sunk for the purpose of proving the ground, some of them to the depth of forty or fifty feet, and, as there is no trouble from water, there is no difficulty in the way of following down the ore, if there were any to follow. There are fissures in the rock without a uniform direction, which lead down to a sort of opening, in which the ore is found disseminated in large masses of flint. The material of the opening is ferruginous, and sometimes soft, the whole appearance resembling that of the openings in the Galena limestone. The quantity of ore, however, which is found here, is too small to repay the labor required to get it out; only about 20,000 pounds have been taken out, in ten years that the locality has been worked over — or about $60 worth a year. It appears, also, from descriptions given me by intelligent miners who had worked at these diggings, that the opening-like character of the rock only extended for a short distance into the bluff, and that, on following the deposits beyond the point to which atmospheric agencies have had an opportunity of reaching, the strata became hard beyond all hope of profitable working. There can be no doubt that the locality in question is not one which can be adduced in favor of profitable mining in the Lower Magnesian.

"More recently, the occurrence of lead ore in this rock, near Franklin, has been made the subject of much comment, and given rise to unbounded hopes of profitable deep mining. These diggings, which are known as Ohlerking's or Moosan's old diggings, are situated about two miles southwest of Franklin, on a branch of Blue river, the valley is narrow and inclosed by bluffs, which rise with a steep but grassed slope to the height of 230 to 250 feet, of which the lower seventy belong to the Lower Magnesian, and the next eighty to the Upper sandstone, which is overlaid by seventy to eighty feet of Blue, with thin outliers of the Galena limestone on the summit. Dr. Percival says that three successive openings here occur; one eight to ten feet below the sandstone, another just above the harder middle bed, and the third below the bottom of the ravine, in that bed, and at the depth of about seventy feet in the Lower Magnesian. He further adds; 'The openings appeared partly narrow and vertical, partly wide and flat, with appearances of decomposition and stain in the rock, deposits of clay and ocher, and arrangement of the mineral, similar to those in the Upper Magnesian (Galena limestone). The mineral in these openings generally appeared in more or less detached masses (chunk mineral), often very large, weighing more than 100 pounds, a few even more than 500 pounds. After examining this locality, I could not doubt that the Lower Magnesian is a good mineral bearing rock.'

"On visiting this locality in 1859, I found only one person at work there, from whom a very dismal account of the prospect of mining in the Lower Magnesian was obtained. He had sunk a shaft twenty-five feet deep, from which he had raised about ten pounds of ore; but I was unable to detect any sign of crevice or opening, in the excavation; and as no other was accessible, my impressions were necessarily very unfavorable in regard to the prospects of mining in this formation, especially after listening to the vehement objurgations of this solitary miner against his own stupidity in continuing to 'prospect' in so barren a rock. According to this individual, the ore obtained here was all taken out 'in the grass roots' — i. e., close to the surface — and no crevice had ever been found leading down to anything workable, a statement which agrees with all I have myself observed in the Lower Magnesian.

"On the whole, it will be safe to say that no profitable mining has ever been carried on in this rock, and that it is entirely wanting in well developed crevices, or openings promising enough to justify expenditure in proving them. Of course, it is not impossible that some locality may hereafter be discovered which shall be worked for a time with profit; but that the Lower Magnesian can be called, on the whole, a 'good metalliferous rock,' is what we are not, in view of the above facts, disposed to admit.

Mr. J. Murrish in his report on the lead regions for 1871 makes the following observations:[1]

"I have visited several places to the north of the lead district, where the lower magnesian becomes the surface rock, and where lead ore in small quantities has been found. At Orion, in Richland county, where a small range of fissures crosses the north and south axis near the fourth principal meridian, very fine specimens of lead ore are found. At Rio, also, in Columbia county, on the eastern extension of the Baraboo range of hills, very good specimens of lead ore are found in the lower portion of the lower magnesian limestone, which for quality and form of crystallization are equal to anything we find in the lead district proper.

It is true these deposits in the lower magnesian, out of the lead district, do not compare with the very heavy deposits of ore in the upper magnesian in the lead district, and it would be unjust to draw a comparison between them, from the fact that the same evidences of the action of physical forces from beneath are not found. Yet when compared with similar places in the upper magnesian out of the lead districts, under similar conditions, the lead bearing qualities of the lower magnesian are equally apparent."

On pages 72 to 78 of the present volume Mr. Strong has reviewed, more fully than any previous observer, the facts at present ascertainable in relation to the occurrence of lead in the Lower Magnesian limestone of the region lying immediately north of what is recognized as the lead district proper, and to this the reader is referred. On pages 66–72, he has described the copper deposits of the same region, which should be studied in connection with the lead, since they belong to the same class of deposits, and occur in essentially similar situations. Since Mr. Strong examined the region, Mr. Ohlerking, of Highland, has renewed, upon a more systematic basis, mining operations at the well known locality, near Highland, with the purpose of developing the real value of that much discussed deposit. In my annual report for 1877, I gave the result of observations made during that year, as follows:

"Mining operations having been recently prosecuted in the Lower Magnesian limestone, near Highland, by Mr. Ohlerking, an examination of the locality was made by the writer in September, and subsequently the drifts were carefully surveyed by Mr. Wilson, who located them upon the surface of the ground, and made a topographical survey of the vicinity.

The mine is located on the slope of a ridge, the summit of which is formed by the Trenton and Galena limestones, the steep slope by the St. Peters sandstone, and the base by the Lower Magnesian limestone. The shaft penetrates 45 feet of the sandstone, and about an equal depth of the Lower Magnesian limestone.

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[1] p. 42.

From near the base of this shaft, a drift has been extended along an opening in a somewhat irregular course, as follows: in a direction N. 1° E., a distance of 8 ft. 8 in.; thence N. 45½° E. 17 ft.; thence N. 82½° E., 31 ft. 8 in.; thence N. 67½° E., 14 ft. 8 in., where it divides, one portion continuing on in a course N. 80° E., for 16 feet 6 in., where the working terminated at the time of our visit. The other portion extends N. 28° E., for 15 ft. 4 in., where it terminates.

A branch drift commences at 30 feet from the shaft and extends N. 50° E., for 15 feet 4 inches, when it turns to N. 13½° W., and continues 14 feet 8 inches, when it changes again to N. 16° E., for a distance of 16 feet, the limit to which it had been worked. An older drift has a direction, through about 90 feet of its course, of N. 16° E., connecting at its southern end with one extending 30 feet in a direction N. 63½° W. The entire extent of the drifts was about 280 feet. The opening was largely filled with clay and decomposing rock, and contained considerable quantities of the reddish, slightly cohesive substance, known among miners in some localities as 'joint clay.' The wall rock is not well defined, the clay and decomposing material apparently graduating into the modified strata. At the extremity of one of the drifts, there was an irregular space between the unmined clay and the arching roof of the opening, and I was informed that this was a common fact. That which is regarded as the cap rock, consists of a layer of silicious dolomite about one foot in thickness, over which lies a stratum of greenish blue clay shale of somewhat irregular thickness, averaging perhaps six inches. The openings probably had their origin in fissures around which the rock has decomposed, giving rise to the present clay filling. The lead ore was mostly taken from within the clay, being neither at the bottom nor top. I extracted a piece, however, that was firmly imbedded between two undisturbed layers of rock. The ore seen was chiefly in large cubes, considerably worn or corroded on the surface, and often coated with the carbonate of lead."

Subsequently Mr. Ohlerking sunk to the depth of 175 feet developing some further openings not well defined containing small quantities of large "chunk mineral." From the bottom of the shaft, a boring with a common drill, was extended downwards to a depth of 84 feet where the Potsdam sandstone was reached. Mr. Ohlerking is of the opinion, judging from the pulverized drillings, that oxide of manganese occurs in considerable quantity at about 35 feet from the bottom of the shaft, to a depth of about 12 or 14 feet. The first 35 feet of the boring seemed to pass through a mass of limestone and flint irregularly mingled. Below this, down to the Potsdam, the formation seems to be limestone in regular layers from one to two feet in thickness. The entire amount of ore produced up to 1880 is given at 10,000 pounds.

The foregoing constitute all the reliable data within my command relating to observed occurrences in the Lower Magnesian limestone, not only within the recognized lead district itself, but in the adjacent region on the north, which, from its more than usual metalliferous character, I embrace in the general ore region of southwestern Wisconsin.

It will be observed that these quotations include observations ranging over about a score of years, and that the observations were made by investigators who, if biased at all by theoretical considerations, were, in part, predisposed to a favorable interpretation, and in part to an adverse one, so that the evidence now presented is not open to the charge of being *ex parte* testimony. My own conclusions are reserved to the general discussion of theoretical inductions.

On pages 69–72 of this volume, Mr. Strong describes the copper deposits of this formation found in the metalliferous area immediately north of the lead region, from which it appears that this ore, though not attaining, so far as past developments have demonstrated, industrial importance, yet has a development altogether exceptional in the formation in which it is situated; for, although the Lower Magnesian limestone is fully developed and extensively exposed both to the westward and northwestward, eastward and northeastward from this region, it does not there present any noticeable traces of cupriferous ores. These localized deposits, therefore, fall in the same category with the ores that have formed the main subjects of our present discussion, and it is evident that this area is to be added to the heretofore recognized lead region, as forming one general mineral district. The force of this conclusion becomes more especially evident when we consider the fact that copper occurs at several localities in the heart of the lead region and that, at Mineral Point, in particular, it develops mines of economic importance.

Metallic Deposits in the Potsdam Sandstone.

While the Potsdam sandstone is exposed within the recognized area of the lead region, it is nowhere open to direct inspection immediately beneath any of the productive areas. What, therefore, may be its nature in such situations is purely a matter of hypothesis. In the metalliferous area lying north of this region, regarded as a part of the district, when considered in its totality, this formation develops locally unusual metalliferous character. Mr. Strong, on pages 40–56 of this report, describes no less than twenty-two localities wherein noteworthy deposits of iron occur. To these a few others, lying without the district falling under his inspection, or that have been developed since his examination, may be added. The occurrence of a small quantity of iron, a metal of almost universal distribution, would not be thought worthy of special consideration, were it not comparatively absent in the wide range of the formation on either hand. In so barren a formation, the occurrence of sufficient quantities of iron ore to attract attention on account of economic importance is a phenomenon entirely worthy of consideration. A number of these deposits have been exploited and, to a limited extent, mined, but altogether the most notable is that of Ironton, Sauk county, which has supplied a furnace with an excellent quality of ore for the last twenty years, without having determined, or given any reliable indication of its full extent. Since this deposit is the most pronounced of its class, and has been the subject of some diversity of opinion, and is, withal, an exceedingly peculiar and interesting formation, it may properly here be made the subject of description, so far as its peculiarities relate to the general subject of our discussion.

The exposed portion of the deposit lies from one to two hundred feet below the upper face of the Potsdam sandstone. It is situated within a belt of rock from ten to thirty rods in width having a northeasterly-southwesterly strike, which is indurated to such an extent as to be readily distinguishable from the adjacent friable sandstone. This induration does not reach a degree that would ordinarily be called metamorphic, though it is unquestionably a step in that direction. It has been so far compacted that its original regular cleavage into slabs has been largely replaced by an irregular fracture, rendering it difficult to shape it conveniently into dimension stone. Its natural outlying blocks assume the form of pyramidal masses quite notably distinguishable from the rectagular blocks derived from the adjacent unmodified sandstone. These pyramidal blocks further show their modified character by their successful resistance of weathering, while the unmodified masses on either hand present the worn and eaten surface common to the exposed outliers of the formation. Along the line of this belt are a few springs of really magnificent proportions. The ore, as developed within the mine, is intimately intermixed with large angular blocks of indurated sandstone. But the manner of this association is peculiar and at first inspection not readily explicable. The prevalent professional judgment seems to have been that it is an aqueous accumulation which formed on the flank and base of a precipitous sandstone hill, from the upper portion of which bowlders, loosened from time to time, fell upon the accumulating deposit and became imbedded in the forming ore. A fatal objection to this hypothesis is the almost total absence of earth, sand, soil and organic debris, that would inevitably have become mingled with the formation under such circumstances. Furthermore, critical inspection of the sandstone blocks and their precise relations to the ore, renders this hypothesis unsatisfactory. The only rational concepti on of its formation which I have been able to frame is that the ore accumulated by aqueous deposition among the fractured blocks, while they still occuaied a subterranean position within the indurated belt, which I conceive to be a line of local breakage, analogous to the fissures of the lead region. Cavernous spaces are thought to have been developed between the fractured blocks on the relaxation of the pressure which caused the original fissuring, and ferruginous solutions deposited the ore in these cavernous interspaces. During its accumulation, slight movements of the formation are supposed to have caused fractured blocks to fall from above into the accumulating deposit, so that certain of them are completely enveloped within the ore.

That the ore was a deposit from solution is entirely beyond question, since it is not only hydrous in character, though not largely limonite, but takes characteristic botryoidal forms, pipe-like accretions, with hollow interiors, mammalary embossments, with radiate interior structure, and stalagmitic and stalactitic forms, displaying in the most marked manner their aqueous origin. That the solutions were descending is conspicuously evident from the pendent forms of the accretions.

The other iron ore deposits of the region have not sufficiently fallen under my personal observation to enable me to determine whether they are attended by similar associated phenomena, except that on Hagerman Hill, a mile and a half southeast of La Valle, a similar ore of aqueous deposition occurs associated with indurated and brecciated rock. The sandstone of this latter locality is also impregnated with malachite and chalcopyrite, doubtless the original form of the whole.

Mr. Strong also notes [1] a small horizontal sheet of copper pyrites about an inch thick, somewhat mixed with iron, in the bank of the Wisconsin river, in the S. E. ¼ Sec. 35 T. 9, R. 1 E.

The Probable Character of Rock below the Potsdam Sandstone.

Unfortunately for our information, no artesian well has yet been sunk within the hitherto recognized lead district to the crystalline rock beneath the Potsdam sandstone. But within the extended metalliferous area to the north, a well was sunk at Oil City which reached and slightly penetrated granite. The artesian well at La Crosse, somewhat further to the northwest, likewise penetrated granite. The Tomah well, immediately to the north, reaches chloritic and micaceous rock. It would appear, therefore, in a very high degree probable that that region is underlain by the granitic and gneissoid rocks of the Archæan series, presumably the Laurentian. Immediately on the northeast border of the area there stand forth the Huronian quartzite ranges of Baraboo. It is not improbable that the formation of which these are an obtruded portion underlies a portion, or all, of the lead region proper.

Both these series are metamorphic sediments which were indurated, thoroughly cooled and extensively eroded before the deposition of the Potsdam sandstone, and immensely before the formation of the strata in which the main portion of the known lead and zinc ores are found.

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[1] Page 56 of this volumne.

There is no evidence whatever of any igneous eruptions within the whole region, and from the nature of the formations overlying it is highly improbable that any exist, or, if they do, the strong presumption is, that they belong to the Archæan ages, and were thoroughly cooled and solidified before the accumulation of the Potsdam sandstone.

These granitic and quartzitic rocks that probably form the floor on which the sandstones and limestones of the lead region were imposed do not, in themselves, offer any strong presumption that they are rich in lead, zinc or copper ores. While they might be the source of thermal springs and metalliferous solutions, there is nothing in the nature of the formations to render it inherently probable that they really are. And before any hypothesis involving the conjecture that they are such a source can attain the sanction of probability, independent reasons for such a belief must be rendered. It is not sufficient to appeal to the existence of such rocks as affording presumption that they are the source of the metalliferous deposits, since their known character fails to justify it.

CHAPTER II.

THEORETICAL DEDUCTIONS.

The characteristic facts relating to the associated lead, zinc, iron and copper deposits of southwestern Wisconsin, having been now described, it remains to consider what theoretical views can be held consistently with the facts, what explanations can be offered for the special phenomena presented, and what practical inferences may be drawn.

While there may not be, at the present time, any marked disposition among competent geologists to differ widely as to the origin of these ores, a somewhat greater diversity of views was entertained by earlier investigators; and, among parties financially interested in these resources, a still wider range of belief yet prevails. It is felt to be obligatory, therefore, to briefly consider such views as are rejected, and assign reasons for so doing.

I. Rejected Hypotheses.

1. *Hypothesis of sublimation.* According to this theory the ores in question were deposited by heated vapors rising from below. Its advocates appeal to the fact that galena is sometimes found in the crevices of smelting furnaces and similar situations, where, it is claimed, with undoubted correctness, that it must have been formed from the penetration of gases; and to the wider range of facts observed in connection with volcanic vapors and steam vents. That ores are formed, in certain situations, from vapors is admitted as scarcely debatable in the present state of knowledge. But the vital question is, whether those under consideration were so formed — whether the whole assemblage of facts now before us, will sanction such a view. It is essential to an affirmative answer to suppose (1.) that the whole group of mingled ores were vaporized, (2.) that this was done to some considerable extent simultaneously, (3.) that these hot vapors arose through all the strata lying between their present situation and their source in rocks heated to the temperature necessary to volatilization, (4.) that they were then condensed in the manifold forms and

phases of deposition now presented, and (5.) that the deposition was, in some measure at least, simultaneous.

The volatilization of the whole group of minerals presents great difficulties. The galena, to which attention is too apt to be confined, may be vaporized, without decomposition — at least, can be volatilized and recondensed as galena — and the same may seemingly be accomplished in the cases of pyrite and blende, but not of calcite. It is a familiar fact that, at a very moderate temperature, calcite (=limestone) decomposes to caustic quicklime and that, then, not even the oxy-hydrogen blow-pipe is able to fuse, much less volatilize, it in appreciable quantity, and to this property it owes its utility in the calcium light. To suppose that calcite is a product of sublimation is to severely tax credulity without the sanction of the slightest evidence. To the uninstructed objection that calcite is not an ore, it may manifestly be replied that it is as truly a metallic carbonate as smithsonite, and that it is only this immeasurable resistance to the decomposing effects of heat, that prevents its more frequent reduction to the metallic state, and possible use as a metal for certain purposes.

The relations of the ores in the lode are such as to require their deposition at the same time, in many cases,[1] and they must, therefore, have been supplied simultaneously and maintained in coëxistence, till deposited.

This is a very hard thing to believe, since there are such wide differences between their temperatures of vaporization and condensation.

It is easy enough to form a vague, general conception of the vaporization of metallic substances by the mysterious power of the unknown interior of the earth, but to form a precise, detailed view of just how galena, blende, pyrite, and calcite, or the elements from which they were formed, volatilized simultaneously in the face of the fact that their temperatures of volatilization are immensely separated, presents Herculean difficulties, but these are dwarfed to Lilliputian dimensions in comparison with those encountered in attempting to imagine precisely how these several substances could have been condensed so as to form, within the space of a hand specimen, a group of regular, large-faced crystals that grew up together. A temperature that would admit of the deposition of one would be quite incompatible with the formation of another. Let any theorist who fails to appreciate this make the attempt to volatilize together all the ingredients of a specimen from the Linden or Marsden mine, containing the four named minerals formed with interlocking crystals, remembering

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[1] *Ante.*

that the temperature of volatilization and condensation are the same. He will, of course, find some ingredients easily sublimed, while others will transcend his utmost powers. Nor will the force of this objection be escaped by supposing the minerals to be formed by gaseous combination, for the temperatures of combination and disassociation are likewise widely diverse.

If it is imagined that the aid of steam will remove these difficulties, we may, without attempting to prove the negative of assumed possibilities, whose nature is, for the most part, unknown, pass to other conditions of the problem that must be satisfied. These supposed vapors must have arisen through the underlying strata, and maintained themselves against all adverse conditions of the passage. Now, in the first place, neither observation nor a judicial consideration of the nature of the case, warrant the belief that the nearly four thousand crevices of the lead region, or any smaller number into which they may be supposed to unite, extend as open passages down through the one thousand to fifteen hundred feet of limestone, sandstone and soft shales, and onward into the Archæan rocks to some supposed heated source of gaseous emanation. Abundant observation shows that the crevices close up, and the yielding nature of some of the rocks makes it quite sure that this must be the case even beyond the reach of observation. Furthermore, hydrostatic evidence has a grave argument to interpose. Artesian wells demand, among their essential conditions, an impervious stratum lying above the water-bearing one. Artesian flows are derived from the Potsdam sandstone on both sides of the lead region, and even within the general metalliferous area, and this is essentially a demonstration that the strata overlying the sandstone are intact. If open fissures extended from the lead deposits down to the Archæan rocks, it would altogether change the hydrostatic conditions of the region. We are, therefore, forced to the conclusion that such fissures do not exist.

But waiving this point and granting open fissures of indefinite depth, very grave difficulties arise from the water-bearing character of the formations.

In impervious strata the hypothesis of a fissure of indefinite depth, unfilled with water, may perhaps be tenable, though I fear the problem has not received due attention by the advocates of the sublimation theory, even under such circumstances. But to suppose a fissure to traverse a thousand feet of extremely porous sandstone, saturated with water, and still be an open passage way for heated gases or steam is a supposition whose extreme improbability seems not to have been duly weighed. The Potsdam sandstone is preëminently water-bearing, as amply demonstrated by the copious artesian fountains derived from it. Some conception of the amount of water likely to be encountered may be formed from the fact that from a little circular opening five and five-eights inches in diameter, at Prairie du Chien, on the very border of the district, indeed within the more comprehensive ore area, 869,916 gallons are discharged daily, and some conception of the amount of heat necessary to change this into steam, i. e., to keep this little orifice open for the passage of vapors may be obtained by a little computation, which would show that, if all the lead ever taken from the whole region were melting hot, it would not contain heat enough to maintain an open passage for three days. But this little orifice is but a fraction of an average crevice in capacity, and there are nearly four thousand crevices in the region. The expenditure of heat, therefore, necessary to maintain open crevices is emphatically enormous. In the very nature of the case it is incredible that open fissures, such as are a necessary condition of the sublimation theory, in any of its forms, could have been maintained under these conditions.

But, if this be not convincing, there is a supreme difficulty in the demonstrable evidence that no such heat as this theory supposes has ever been brought to bear upon the rock in which the ores are deposited. The lower Galena and Trenton beds contain, as already repeatedly stated, notable quantities of carbonaceous matter, a portion of which is volatile and would be driven off by a very moderate heat. The fact that it remains is proof that the beds have never been heated, and, as the ores are intimately mingled with this volatile matter, there is no appeal or escape from the force of this fatal circumstance.

This, of course, as well as the preceding, is equally fatal to any theory of igneous injection, but, as I am not aware that this is seriously entertained by any one, and as it is thoroughly inconsistent with the nature of the deposits, it has not seemed worthy of discussion.

Theory of Thermal Waters. This hypothesis has two aspects. In the one, the ores are thought to have been brought up through fissures from metamorphic or igneous rocks below the Potsdam sandstone by hot water, and deposited where they now are. In the other, thermal springs are supposed to have issued from the bed of the ocean, at the time the sediments of the metalliferous beds were being deposited and the metallic substances, thus injected into the ocean, were soon thrown down, by cooling and chemical reaction and mingled with the rock-forming sediment, to be subsequently segregated in the crevices and other convenient receptacles. The former is the accepted phase with most who advocate thermal agencies.

But we here meet with the main objections raised against the vaporous theory; first, the absence of open continuous fissures from the Galena limestone down into the Archæan rocks. It will be apparent upon a little consideration that a simple seam will not answer. If warm waters are to rise a thousand feet through beds of sandstone, traversed by such floods of water as fill the Potsdam, they cannot ooze slowly through it, but must have free passage, as well as inherent force enough to occupy and maintain their channel. But, as previously remarked, the hydrostatic conditions forbid belief in any such open passages. But, if they existed, they would certainly be occupied by the waters traversing the Potsdam sandstone, for they are both more abundant and under stronger pressure than any known or presumable waters from below, and, so far as geological evidence goes, must always have been so since the formation of the fissures. Indeed the belief in springs rising from the metamorphic rocks below has evidently been entertained in this instance without considering the hydrostatic conditions of the problem at all. Such springs will not rise without a water supply and a fountain head, nor without a passageway down to the supposed heated and metalliferous region, nor without an adequate and unobstructed channel upwards and an exit at a point lower than the fountain head. Simple infiltration and reflection, on the principle of convection, are not adequate to the conditions of the problem, however sufficient they may be elsewhere.

To assume that such conditions are, or have been, presented in the lead region is to ignore the facts and principles of hydrology as applied to the subterranean water currents of our region, which have been a special subject of study, and our conclusions submitted to severe and repeated tests, through the demand for prognostic opinions in regard to artesian wells. Theoretical considerations and practical tests combine to show that the Archæan rocks are, in a very low degree, water-bearing and that their stratification and system of fracturing is such as to render it in the highest degree improbable that water entering from the Archæan region of northern Wisconsin should have free passage to and exit beneath the lead region in any quantity competent to cope with the immensely greater volume that traverses the Potsdam.

I estimate roundly that a trillion and a half of gallons of water fall annually upon the collecting area tributary to that portion of the Potsdam sandstone that underlies the lead region, and both collecting area and rainfall were probably greater, rather than less, in the past.

Making the most generous allowances for evaporation and surface drainage, compatible with the porous, absorbent nature of the surface, there is still left an enormous quantity of water pressing for entrance and passage-way through the sandstone, a considerable portion of which does, and a considerably larger portion of which would, pass through, if the sandstone were only extensively fractured in some lower region to give it exit, as this hypothesis assumes, necessarily, was the case in the lead region—an assumption in itself not free from difficulties.

I have been able to frame but two hypotheses by which the force of this objection to the theory of thermal waters can be escaped and they are both extremely improbable. For the first, if we could assume that, while the sandstone was extensively fractured so as to permit passage for the hot waters from the deeper regions, the surrounding sandstone was rendered impervious, then the incursion of the cold waters from the formation might be shut out. Now there is some slight evidence, drawn from the region north of the Wisconsin river, that the sandstone was somewhat indurated along the crevice belts, due, as I suppose, to the force exercised in their production, but there is no evidence that it was sufficient in degree to render the coarse lower Potsdam beds impervious, while, on the other hand, the evidence of induration is accompanied by coextensive evidence of intricate *fracturing*, so that the belt becomes a *drainage zone*, instead of an impervious barrier. This hypothesis is therefore quite untenable.

Or, if, again, we could suppose that a mass of igneous rock were thrust into the lower part of the Potsdam sandstone, beneath the lead region, it might heat the whole body of water in the surrounding strata, and thus give rise to warm springs, if the formations above were open for the ascent of the heated waters. But the artesian wells within or immediately adjacent to the metalliferous area entirely traverse, or deeply penetrate, the formation and yield no evidence of such intrusion, and all geological data are either antagonistic to it or, at best, negative. So that this suggestion is but a mere hypothesis without evidence, framed to meet a difficulty and therefore without inherent weight.

But, at the best, neither of these hypotheses more than makes it possible for thermal currents to exist under the adverse conditions imposed by the strata. They do not meet other objections to the general theory. Among these may be noted the fact that neither the form nor the contents of the lode accords well with the theory. If the thoughtful reader will call to mind the details of the deposits previously described, it will, I think, seem at least very strange (1) that the ores should be deposited in such a variety and peculiarity of forms, not common to acknowledged thermal deposits; (2) that they should be localized in openings, flats, side fissures, pockets, etc., instead of lining the main passage way of the depositing waters; (3) that the lead ore should be so strangely separated from the remainder in the upper beds; (4) that quartz, so widely prevalent in hot springs, should be absent; (5) that calcite should be no more common and should be rare in the upper beds, where it ought, seemingly, to be most freely deposited; in short, that the whole of the special phenomena of deposition should be so far at variance with thermo-aqueous lodes in general.

The existence of volatile hydro-carbonaceous matter in the lower beds, while not so fatal an objection as in the case of the sublimation theory, because the temperature of the waters is not necessarily so high, yet renders it highly improbable that these beds have been traversed by currents of water of even moderate warmth, for any considerable period of time.

The combined force of the preceding considerations is such as to render this phase of the thermo-aqueous theory wholly untenable.

Turning to that form of the theory that assumes that mineralized thermal springs issued in the bottom of the Silurian ocean, impregnating the accumulating rock-sediment with metallic precipitates, which were afterwards leached out and concentrated in the crevices, I may be pardoned for remarking that if, before the commencement of the present investigation, I was in any slight measure predisposed toward any theory, as such, it was this one, not from any evidence indicating that any such springs existed, but from the simple fact that it alone among hypotheses, then within my cognizance, seemed to offer a ready explanation of the salient features of the deposits, especially the two great facts (1) that the very nature of the deposits points to their segregation from the surrounding rocks, and (2) the localization of the deposits, pointing as clearly to the fact that certain areas were impregnated while adjoining, as well as remote, reaches of the formation, were left barren. If springs issued at several points— suppose one or more within each district — this localization would be readily explained. Yet it is but small merit in a theory to explain that for the explanation of which it was expressly framed. Before it can command any just confidence it must present evidence that the facts and processes it assumes were historical realities. When submitted to this criterion this theory is found fatally weak. There appears no trustworthy evidence at all of such springs, nor any circumstances that make their existence probable, but, on the other hand, much that renders it extremely improbable. However much we may be drawn toward the theory, because of the accommodating way in which it disposes of a serious difficulty, it must be set aside for want of inherent evidence of its truth.

II. Theory of Oceanic Deposition.

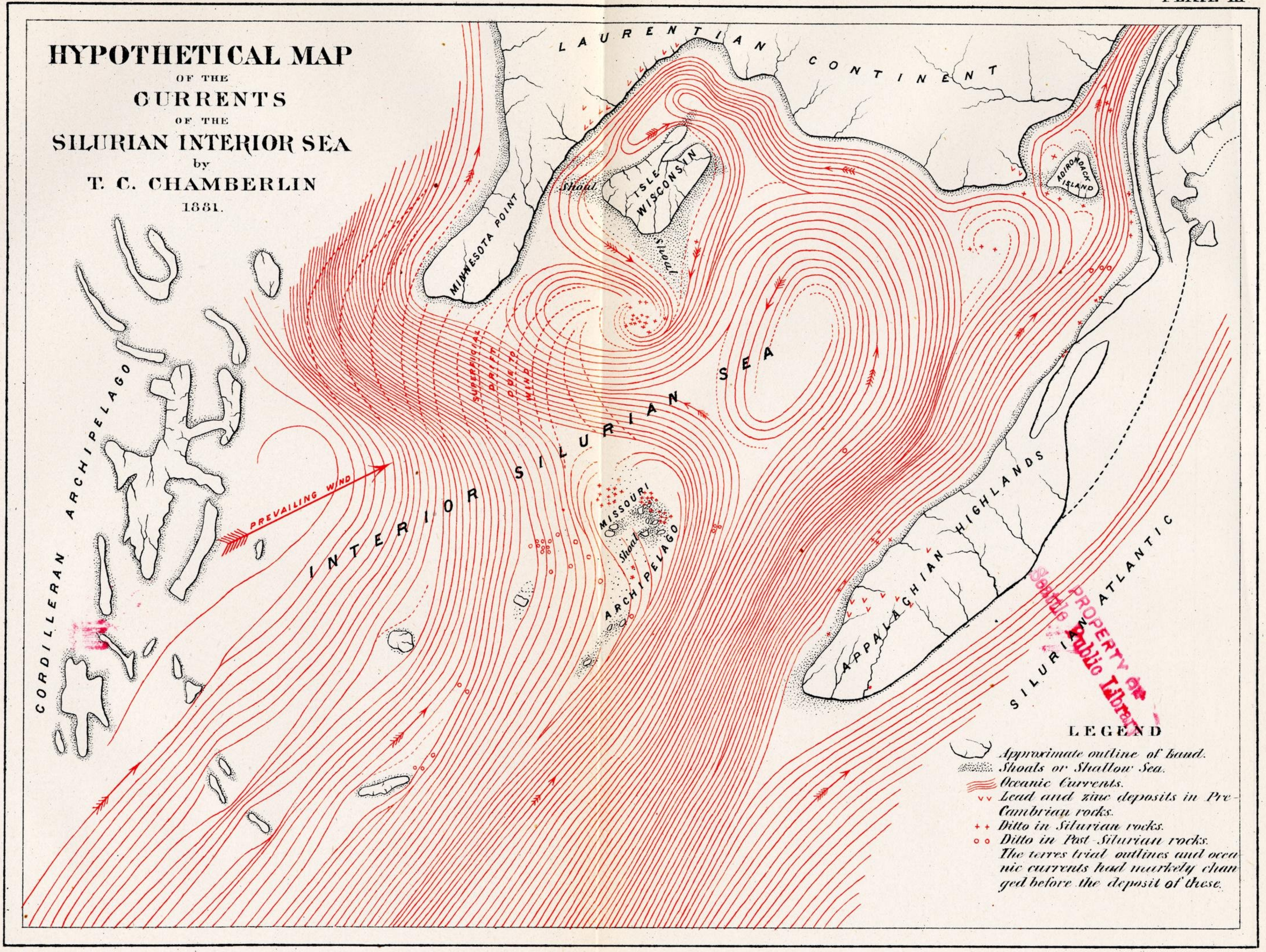
We have seen that there are grave, if not fatal, objections to the preceding theories of the derivation of the ores from beneath. It is scarcely necessary to observe that there are no sufficient reasons for presuming that the metalliferous deposits were derived from formations lying above the strata in which we now find them. The immediately overlying formation is the Hudson river shales, a stratum of soft clayey rock, perhaps 200 feet in average thickness, which, from its nature, is a very forbidding source from which metalliferous solutions could be derived, since it is highly impervious, and, aside from the presence of occasional pyrites, gives little indication of a metalliferous character. Overlying this, the Niagara limestone presents no indication of metallic richness, and, if it did, the interposod impervious shales would present a barrier to the transference of metalliferous substance to the Galena limestone below. We are, therefore, practically shut up to the conclusion that the ores now found in the crevices and openings have been derived from the Galena and Trenton limestones themselves, that is, from the rock embracing the lode. But the ulterior question arises, Whence did this rock derive its metalliferous substance? The only rational answer appears to be that it was deposited contemporaneously with the sediments that formed the rock itself, or, in other terms, that it was derived from the Silurian ocean. But, at this point, arises the objection already urged in our preface, that the ores are not uniformly distributed through the lead-bearing limestones, that it is only in certain circumscribed regions that the formations are highly metalliferous, and that, within these areas, only local sub-districts are productive, between which lie barren intervals. Our lead region, in common with those of Missouri and elsewhere, presents a group of metalliferous districts, standing in marked contrast to the barren character of the formation as found elsewhere. It has already been shown that this cannot be regarded as an illusive generalization from limited knowledge, but must be accepted as a well demonstrated reality. We have further insisted that there can be discerned no such definite and specific relation between the general lead regions and an exceptional abundance of organic matter, with corresponding absence elsewhere, as to make any such supposed distribution of organic matter a sufficient cause *in itself* of this peculiar localization of deposits.

We have, further, given reasons for doubting the adequacy of any explanation which supposes that the productive regions have furnished exceptional facilities for segregation, and that their present richness is due *simply* to exceptional concentration and not to any special inherent richness.

We have further insisted, in our preface, that the facts of lead deposition comprised within our widest knowledge do not sanction the belief that the oceanic waters were exceptionally impregnated with lead and zinc salts at the beginning of geological history, and were robbed of them in the early geological ages by organic matter, and thus escape the supreme difficulty of this hypothesis growing out of the fact that, although organic matter is extremely abundant in the medieval and later formations, lead and zinc deposits are not widely prevalent, though locally occurring in richness. We must, therefore, frankly face, at the outset, the gravest objection which has yet been urged against the theory of oceanic precipitation, namely, the localization of the deposits.

Preliminary to a definite answer to this problem of localization, there should arise the more primitive question, Whence did the oceanic waters derive their metalliferous salts? According to the accepted hypothesis regarding the earth's early history, the oceanic waters originally existed wholly as vapor in the atmosphere, held there by the heated condition of the earth. With the progress of cooling they were gradually deposited on the surface of the earth. At this stage in their history they were obviously free from metallic substances and saline matter, though highly charged with carbonic acid and such other substances as might remain in a vaporous state under the conditions then existent. Oceanic history starts, therefore, with waters essentially free from metallic substances. But coming thence down the history of the ages, lead and zinc deposits are found in the Lower Magnesian limestone, in the Trenton and Galena limestones, in the Upper Silurian limestones, in the Devonian beds, in the Subcarboniferous limestone preëminently, in the Triassic and Tertiary strata. And furthermore, the residual ocean of to-day contains the several metals, in minute quantities, of course. It appears, therefore, that since the origin of the ocean it has both gathered and deposited, and that it still retains a residue undeposited.

In the course of our discussion it has been shown that the ores are being wasted, and a portion borne away by drainage and, presumably, lost to the strata and carried into the ocean, and, therefore, that the ocean is gathering metallic substances at the present time. It has been shown by chemical analysis that the sea weed of the present ocean contains the metals in question. This, accumulating in certain localities on the bottom of the ocean, is being buried by sediment constituting the impregnated material of a slightly metalliferous rock


HYPOTHETICAL MAP
OF THE
CURRENTS
OF THE
SILURIAN INTERIOR SEA
by
T. C. CHAMBERLIN
1881.
LAURENTIAN CONTINENT
MINNESOTA POINT
Shoal
ISLE WISCONSIN
Shoal
ADIRONDACK ISLAND
SUPERFICIAL DRIFT DUE TO WIND
INTERIOR SILURIAN SEA
PREVAILING WIND
CORDILLERAN ARCHIPELAGO
MISSOURI ARCHIPELAGO
Shoal
APPALACHIAN HIGHLANDS
SILURIAN ATLANTIC
LEGEND
Approximate outline of Land.
Shoals or Shallow Sea.
Oceanic Currents.
Lead and zinc deposits in Pre-Cambrian rocks.
Ditto in Silurian rocks.
Ditto in Post-Silurian rocks.
The terrestrial outlines and oceanic currents had markedly changed before the deposit of these.

now forming. Sulphuretted compounds and possibly other agencies are doubtless assisting in present precipitation. It, therefore, appears morally certain that the ocean is both accumulating and depositing at the present time. What it is doing now it, presumably, has been doing throughout the ages. Its metallic salts were undoubtedly derived from the universal source of its saline substances, the leaching of the land. They undoubtedly have been deposited during the past, as in the present, by being taken up into the tissues of marine plants or animals, or by being thrown down by sulphuretted gases or solutions arising from organic decomposition, or by other agencies, whose efficiency has been less definitely determined. Each individual metallic particle, therefore, remains a constituent of the ocean only until it meets with a precipitating agent; and the whole history of oceanic metalliferous deposition is but an aggregation of the history of individual particles.

If any portion of the land surface yields more richly than elsewhere to the ocean, the waters of that portion will necessarily become richer in metallic salts. As such contributions are made, year after year, and century after century, they will presumably follow each other in a common course, borne by oceanic currents, and be brought within reach of depositing agencies in the same areas, being thrown down where *first* they came in contact with a competent reagent. Viewed in this light, in contradistinction from the idea of an ocean throughout which the metalliferous substances are uniformly diffused, the fact of localization is a necessary inference, instead of being a phenomenal enigma.

Our true method will, therefore, be to search (1) for the sources whence the ocean in the early Silurian ages derived its metalliferous contents, (2) along what courses the currents bore their metallic burden, and (3) where first they yielded to extractive agencies. Manifestly, therefore, Silurian geography and oceanic currents claim our attention. The accompanying lithographic map, Plate ——, may serve to convey a general impression of geographical outlines at the time of the formation of our metalliferous strata. To the northward lay the Laurentian continent, stretching its arms northeastward and northwestward to unknown limits. On our northwest border, it thrust out to the southwestward an extended peninsula, which we may conveniently designate Minnesota Point. In what is now northern Wisconsin and Michigan arose a large island, which we may style Isle Wisconsin. Southward from this there extended a shoal area to the limits of our mineral region. Between Isle Wisconsin and Minnesota Point there was a shallow strait, if my discriminations are correct. This point, however, may be thought open to question. From a careful consideration of all the data bearing upon the subject, it seems most probable that the Silurian seas swept through from the Lake Superior basin to the main Interior ocean, but the matter is not sufficiently vital to our present discussion to justify entrance upon its full consideration, which would necessarily be somewhat prolix. Between Isle Wisconsin and the main Laurentian continent on the northeast, was a broad channel connecting the Lake Superior basin with the Interior Sea to the southeast. In the distance, in that direction, lay the Archæan Appalachian Highlands stretching from the bounds of Alabama northeastward to an unknown limit. This appears, from present data, to have been disconnected from the main Laurentian continent by the Laurentian straits occupying the general position of the Champlain and lower St. Lawrence basin. In respect to the disputed geology of New England, I have followed the mapping of Prof. C. H. Hitchcock, rather because of its definiteness and availability, than from any disposition to indicate a judgment upon the questions in debate. But even if a much larger portion of New England was submerged, it would not, in my judgment, affect the general direction of the oceanic currents, though it would modify their relative volume. The Adirondacks constituted an island, or possibly, by a narrow connection with the Laurentian continent, a peninsula. On the west of the Interior Sea lay the Cordilleran Archipelago, occupying the general position of the same series of to-day, leaving a broad strait extending indefinitely northward and southward between the Laurentian and Cordilleran lands. In the Missouri region there were several islands which may be conveniently designated the Missouri Archipelago. Southwestward from these, lay other islands in the present territory of Arkansas, Indian Territory, and Texas.

Thus much rests, in its general features, upon substantial geological evidence. Our mapping of the oceanic currents of the day is necessarily hypothetical. That some direct evidence drawn from the distribution of organic remains may, in time, be made applicable to the problem is not improbable; but the collocation of such evidence is a task for the future. There is little reason to doubt, however, that the fundamental facts of oceanic circulation were essentially the same then as now, that there was a general system of warm currents flowing northward and of returning cooler currents seeking the equator that the northward flowing currents were diverted eastward, and the southward flowing currents westward by the rotation of the earth. The same general facts may safely be assumed in relation to the winds.

Applying these general principles to the Interior American Sea, we deduce that a broad, strong current entered it from the south, a part passing on northward, but probably the larger part, flowing between the Missouri Archipelago and the Appalachian Heights, swept north eastward along the flank of the Appalachian belt, and, had it been unobstructed, would have pursued a general northeasterly course, analogous to that of the gulf stream of to-day. But the Laurentian straits were altogether inadequate to give it exit. Although a portion of it is presumed to have escaped in that direction, the main body must have been reflected along the southern shores of the Laurentian continent, and have entered the wide mouth of the Lake Superior basin, whence a portion of it would be reflected, because of the want of capacity of the western strait, and return on the east side of Isle Wisconsin, while another portion is presumed to have passed onward through the basin of Lake Superior, and thence southward on the west side of Isle Wisconsin and the east of Minnesota Point. If this strait was not open, the whole would recurve upon itself in Lake Superior and flow along the eastern side of Isle Wisconsin. But presuming that it passed westward of the Isle, it would, it is conjectured, encounter a portion of the northward current that was caught and inflected by the projecting Minnesota Point, and would be forced by this current to the eastward along the flank of Isle Wisconsin and the southward-projecting shoal, and so be caused to traverse the lead district. In that region, it is also conjectured that it would be joined from the east by the current descending from Lake Superior on the east side of Wisconsin Island and would perhaps be affected by the reflected currents of the Interior Sea, so that a gyratory motion is not improbable (see plate). This would perhaps give rise to an accumulation of floating sea-weed analogous to our present Sargasso Seas.[1] This last suggestion, though very helpful to our views, is not deemed at all essential.

The Missouri–Arkansas archipelago and the intervening shoal would doubtless, in a measure, divide the broad current entering from the south, the main portion, as heretofore stated, passing to the eastward, pursuing the course already traced. The other portion passing on the west and resisted by the reflected current of the Interior Sea,

[1] This hypothesis of a Sargasso Sea is not original with me, but I am unable to state to whom it should be accredited. I derived it independently from a verbal suggestion of Prof. R. P. Whitfield to an assistant, and from a passing reference of Prof. R. Pumpelly in the article on Ore Deposits in Johnson's Cyclopedia. Both, however, came to my attention after my general conclusions had been arrived at, and the currents hypothetically sketched.

would be kept more nearly northward, passing by Minnesota Point and, hugging the northwestern arm of the Laurentian continent, flow on to the arctic regions. A portion of it, however, would be liable to be caught and inflected by Minnesota Point as before mentioned. It is not improbable, also, that the Missouri Archipelago would become the center of a rotating current, produced partly by its own influence as an obstruction and partly by the reflected currents of the Interior sea, as shown on the plate. Probably a counter current returning from the north would flank the Cordilleras, and if, as our present knowledge seems to indicate, this was rather an archipelago than a continuous belt of land, this arctic current doubtless threaded its way among the constituent islands and occupied the broad straits between its ranges, flowing with comparatively feeble current on the eastern flank.

Probably the most potential agent in determining these currents was the winds, which at that time, as now, were the return trades whose prevalent direction was from the southwest. These would drive into the open southerly mouth of the Interior sea a much larger quantity of water than could find ready exit through the narrow northeastern straits, and this would be made to impringe upon the Laurentian continent nearly at right angles, and, being resisted by the already accumulated waters on the east, must necessarily be diverted to the northwest and enter the Superior basin whence it would return in the lee of the Minnesota Point and the Wisconsin Island. The same southwesterly winds acting upon the ocean off Minnesota Point would assist in driving the superficial water northeastward within the point, and also compel the current coming out from lake Superior to hug Wisconsin Island and so assist in producing the currents we have already presumed would be produced by the general laws of thermal oceanic circulation independently of winds.

Some of the details of this mapping of the ancient currents of the Interior American sea may seem somewhat too hypothetical, but the general features have too firm a foundation in well ascertained law to be open to serious question. While, perhaps, hypotheses differing from this in some details might be framed in general conformity to the laws of oceanic circulation, which would be less evidently harmonious with our views of deposition, yet it is not apparent to me how any consistent hypothesis can be framed that shall be antagonistic to the theory here advanced.

Now it is evident that, whatever gain of saline matter the ocean makes in the Interior, it must derive in the main from the exposed land, partly through the decomposition of its general surface, and partly through penetration of surface waters into the earth's interior whence they subsequently come forth in springs more or less mineralized, in short, from the leaching of the land. Observation has shown that the ores in question are present, some or all, in the ancient rocks of the Appalachian lands, of the Adirondack Highlands, of the Laurentian Continent, of Isle Wisconsin, of the base at least of Minnesota Point, and of the Missouri Archipelago. The waters which came down from the Appalachian Highlands bearing these ores, however infinitesimal in quantity, were borne along on the right margin of the adjacent oceanic currents — as superficial waters, being fresh — until they came into contact with organic matter capable of taking them up in its tissues; or with the products of organic decomposition, as sulphuretted hydrogen and ammonium sulphide, when they were changed to insoluble sulphides and soon settled to the bottom; or with other less well known extractive agencies. Now it is a significant fact that all along the flank of the Appalachian Highlands there is a scattered chain of lead and zinc deposits stretching from Alabama to New York. It is also noticeable that at the foot of the Adirondacks there are similar deposits stretching westward, and that along the base of the Laurentian Continent in Canada some similar deposits occur. The broad Laurentian land area should contribute a comparatively large measure of mineral matter to the adjacent sea. The lands bordering the Lake Superior basin, from their exceptional metalliferous character, should yield a contribution of more than usual richness. At the time of the formation of the Lower Magnesian limestone a considerable portion of the copper-bearing series was exposed, and it is a note-worthy fact that the copper deposits of southwestern Wisconsin lie mostly within the Lower Magnesian horizon, and the lower portion of the Trenton-Galena group. But toward the close of the formation of the Galena limestone, the major part of the copper-bearing series had become submerged and the contributions from this formation were, therefore, comparatively small, but on the northwest shore of Lake Superior very considerable quantities of blende and galena are found in veins in the Archæan rocks.[1] From this general north shore area, a large contribution relatively of lead and zinc salts should arise from the disintegration of the veins, or possibly, from the issuance, at the surface, of the waters which supplied the veins with their metallic material, since it is uncertain at what period of geological history the veins of that region were filled. So that the waters in the Lake Superior basin must, we reason, have received an exceptional contribu-

[1] Geol. and Nat. Hist. Surv. of Minn. 1878, pp. 14–21.

tion of metallic substances, although, at any given time, it was, of course, extremely small.

Furthermore, the contemporaneous sedimentary formations of the Lake Superior region, so far as any indications of their nature are left to us, were not of a character to furnish a ready precipitant of the metallic salts thus carried into the ocean. Nor is it probable, from the little deposits along the Laurentian continent, that the sea adjacent to it furnished very favorable conditions for the extraction of metallic salts. And hence there was, presumably, borne along into the Lake Superior area a residue to be added to the special contributions of that noted metalliferous region. And hence, the waters passing outward from the Lake Superior area and flowing over the lead region of the upper Mississippi were exceptionally impregnated with metalliferous material.

This material was doubtless precipitated along the southwestern side of Wisconsin Isle in the Galena and Trenton limestones of that region, as it certainly was in the Lower Magnesian limestone in some degree, but the denudation which the strata have suffered has, of course, swept them all away. But on reaching the lead region these waters encountered ample agents of precipitation. The rocks of the Galena limestone carry abundant evidence of luxuriance of seaweed, while in its lower beds and the Trenton limestone carbonaceous shales, as well as fucoidal impressions, indicate an exceptional accumulation. While the Galena limestone, in its present granular condition, is comparatively barren of well preserved remains of animal life, numerous fragments indicate that it may have been abundant, notwithstanding the want of preservation. The Trenton limestone, however, is exceptionally prolific in well preserved animal remains, indicating a luxuriant fauna. If the suggestion of a gyratory current in this region is true, then the accumulation of floating organic matter, probably mostly seaweed, would be a special source from which precipitating agents might arise.

But this organic matter, living or dead, would not be, from the nature of the case, and was not, as observation, in part at least, shows, distributed uniformly over the region. Reasons have already been assigned for the belief that the bottom of the ocean was undulatory, and that in certain areas there were moderate, though notable, depressions. It has also been shown that, from the nature of the Galena limestone, it is a necessary inference that it was formed in a comparatively shallow sea. It is, therefore, apparent that the undulations of the bottom would be important elements in determining the place of growth, and, more especially, *the place of accumulation* of dead products of life. The depressions, we judge, would be more favorable to the life and growth of average marine species than the more exposed elevations of the sea bottom. But, however that may be, it is altogether certain that the movable remains of dead organisms would be mainly accumulated in the depressions, and that all floating material would find lodgment there. So that the depressions of the original ocean bottom were the areas in which were concentrated the organic matter, to whose agency the removal of metalliferous solutions from the ocean is to be attributed.

This removal may have taken place in different ways. The seaweed of the present ocean, as before remarked, is found to contain within itself all of the metals in question. Certain marine animals contain copper in their circulating fluid. So that a portion of the metallic contents of the waters was undoubtedly abstracted by the direct secretory action of life. On the death of all organisms, decay ensues, and the waters coming into contact with this decomposing matter would be robbed of their metallic contents, which would take the form of insoluble sulphides. Decay would also give rise to free sulphuretted hydrogen and ammonium sulphide, which would be absorbed into the waters and diffused through them, or rise in the form of gas, in either case precipitating whatever of the metallic salts in question they came in contact with. Now this precipitate would be in the form of exceedingly fine particles suspended in the water. These would gradually settle to the bottom and be incorporated in the accumulating sediment, but they would rarely find a resting place elsewhere than in the quiet waters of the depressions. So that we have here an additional circumstance which tends to produce concentration of metallic deposits in the depressions.

We have, therefore, in the circumstances now named what I conceive to be a true explanation of the localization of these metalliferous deposits. The general areas within which the deposits took place were due to circumstances of geographical position and geological relationship, which gave rise to special impregnations of the oceanic waters with metalliferous salts derived from the leaching of adjacent lands, and to oceanic currents which bore those specially metalliferous waters over areas competent to extract them. The special localization of productive areas within the general metalliferous region is attributable to the condition of the oceanic bed as to the distribution of organic life upon it, and especially the accumulation of dead organic matter as well as the precipitated metals within depressions.

The metallic substances thus precipitated from the oceanic waters would of necessity be intimately mixed with the sediment that formed the country rock, and would, therefore, in that condition, be wholly unavailable to mining industry, not only, but scarcely more than detectable by careful chemical analysis. For, if the amount of ore that has been mined from our richest districts, increased by the amount that can fairly be estimated to be still left unmined within the Trenton and Galena limestones, were distributed uniformly through the rock of the district, it would constitute but an extremely small percentage of the entire mass.

At my suggestion, Mr. I. M. Buell made an estimate of the amount of impregnation of the rock that would occur, if the entire quantity of ore taken from the Potosi district were uniformly distributed through the adjacent rock. This district was selected because (1) it has been one of the most productive, (2) has definite outlines, (3) a somewhat uniform distribution of crevices, and (4) is withal one of the most concentrated districts of the whole region. In determining the limits of the district, a margin outside the outermost crevices was allowed equal to half the average distance between the crevices, i. e. the outside crevice was supposed to draw only as much from the territory outside as from that between it and its neighbor crevice. As the basin occupied by the district extends some distance on every side, this is a very moderate assumption. Furthermore, it was assumed that only 100 feet in depth had been leached in the derivation of the ores, although probably twice that amount of rock originally lay above the base of the deposit. The result was *one fourteen hundredth of one per cent.*, or a little more than seven-millionths part of the rock, a quantity that may seem surprisingly small to those who, by dwelling on the relative value of the ores, magnify their relative quantity, a quantity certainly small enough to answer certain inconsiderate objections to the theory of derivation of the ores from the inclosing rock, based on the want of ocular evidence of their metalliferous character.

Before, therefore, this metallic material can become an available resource, it must be gathered into lodes, and the methods by which this was accomplished now claim our attention. These embrace two processes somewhat diverse in their nature: the one consists in the formation of the crevices and cavities which become the receptacles of the concentrated ores, the other, in the taking up of the ores from their disseminated condition in the rock, their transportation into the crevices and cavities and their redeposition there. The formation of the receptacle has already received consideration and explanation in harmony with the views here maintained.

1. Solution of the Disseminated Ores.

Two leading questions are here presented, (1) How were the ores taken up from their disseminated condition and carried into the crevices? and (2) By what means were they redeposited in the openings?

1. As soon as the metalliferous beds were in any measure exposed by the wearing away of the overlying formations, and, to some extent, even before that, they would be subjected to the action of surface waters, charged with such substances as could be gathered in their descent through the atmosphere, their contact with the surface of the earth and their percolation through the soil and superficial rock.

From the atmosphere there would be derived oxygen, nitrogen, carbonic acid, ammonia, nitrous and nitric acids, and occasional ingredients that do not need consideration here. From the organic matter upon the surface of the earth, and from that within the soil, there would be derived additional quantities of carbonic acid, ammonia, nitric acid and organic material in a variety of combinations, which are usually embraced under the comprehensive phrase "extractive matter." Of these nitrogen is habitually inert and, under any circumstances which we shall have occasion to consider, will probably be entirely inactive, of itself, and may therefore be dismissed with this mere mention. In its composite state, however, as a constituent of ammonia, nitric and nitrous acids, it is a highly active and important agent, proportionate to its amount. The ultimate form, in which it will enter into activity, will usually be nitric acid. This is not only an active chemical agent, but is, abstractly considered, peculiarly competent to accomplish the work of solution and removal because the nitrates of all the metals in question are highly soluble. That the amount of nitric acid derivable from these sources is not inconsiderable, is demonstrated by the fact that one important source of commercial nitrates is nitriferous soil, as found in Hindostan, Persia, Egypt, Hungary, Spain, Chili and elsewhere,[1] and, by the further fact, more pertinent to our present discussion, that the earth of many caves, especially of the Mississippi valley, becomes, in a comparatively short time, impregnated with nitrates, as those of Indiana, Kentucky and Tennessee, several of which have been worked for niter. The earth in many cases nitrifies itself sufficiently for extraction in eight or ten years. The niter-bearing chalk of the basin of Paris and the nitriferous caves of Ceylon are remarkable in that the surface of the rock is impregnated with nitrates, which, on removal, renew themselves twice or more a year. These are especially instructive in showing the rapidity with which

[1]Annual Report Smithsonian Institution, 1861. Article on Nitrification, by Dr. B. F. Gray.

mineral-forming agencies, so trivial as to be commonly overlooked, may, under favorable conditions, accumulate valuable deposits.

Beyond this general lesson, however, nitric acid probably renders little aid in the solution either of the metals, or our problem, except that it is the agent of some disintegration of the rock. For, while in itself highly competent, its affinities are probably always satisfied by the stronger alkaline and earthy bases, which it meets in the strata. This theoretical conclusion is supported by negative observation in that, while nitrates of potash, soda, lime, and, perhaps, magnesia, are widely distributed, nitrates of the common metals are not even recognized in standard works on mineralogy. This is not explainable by differences in solubility.

In considering the possible agency of organic matter, grave difficulties are encountered from the imperfection of present knowledge. Organic, especially vegetable, matter, when the mysterious forces of life are removed, begins to undergo slow or rapid decomposition, according to circumstances, giving rise to a group of new, volatile, or soluble compounds, and leaving a residuum of dark organic matter (leaf-mold, peat, etc.), to which the term *humus* is applied, more for the convenience of a comprehensive name than from any precise chemical signification it possesses, for the composition of humus varies with its source and the conditions of its accumulation. Indeed, it may be regarded as a transition stage of organic matter, passing with extreme slowness into permanent inorganic forms. The decomposition of humus gives rise to numerous organic acids, whose precise characteristics and natural reactions are largely yet undetermined. Among these are humic, ulmic, geic, crenic, apocrenic, nitro-humic, silico-nitro-humic acids and others, less well known. To these are to be added acids derived more directly from vegetation, as citric, malic, tartaric, tannic, gallic, oxalic, formic, acetic, propionic and others, and those arising from animal products, as uric, hippuric, etc. All these, on ultimate oxidation, give rise to carbonic acid, with or without attendant products. It is impossible, at present, to trace the transitory history of these acids individually, and determine what changes they affect and what reactions they severally undergo on penetrating the earth. Until this intricate subject has been more fully elaborated, we must be content with general views as to the prevalent effects of these agencies. In an elaborate essay read before the Amerian Association for the Advancement of Science at Saratoga,[1] Mr. A. A. Julien has discussed the geological action of the humus acids at much length

[1] Proceedings American Association for Advancement of Science, 1879.

and referred with great fullness to the scattered literature of the subject. He maintains that these organic acids are very important agencies in the disintegration and solution of rocks and of their constituent and contained minerals, as well as in reduction. He urges their great efficiency for corrosive attack and the production of solvent compounds. Of the portions of this treatise most specially applicable to the present problem, the following may be quoted:[1]

"The depressions of the surface of the ground, along the course of a vein or elevated bed of soft or erodable ore, have generally invited the gathering of surface waters, the formation of swamps, rich in humus, and the consequent concentration of solutions of its acids. The steep inclinations of the crevices, especially along the planes of contact with the strata traversed, have allowed these solutions to penetrate to enormous depths. The gossan, whose formation as a cap to the vein must be largely due to these erosive agents, does not exceed fifty or sixty feet in depth, according to the books, but apparently reaches at least 200 to 300 feet in many of the Western mines, sunken on well-drained fissure veins; and the ocherous selvage along the walls, and scattered films and bunches along the more continuous and dry fissures, certainly reach to a still greater depth, *e. g.*, 1,500 feet in the Eureka mine, in northern Nevada. The material of the gossan has certainly been the seat of a most complex series of chemical reactions, perhaps unsurpassed elsewhere in nature; and in these the acids of humus have played a very important part. This seems to be indicated by the remarkable decomposition and softening of the wall-rock and *of refractory sulphides*, the deposition of limonite and hyalite, the evidences of strong reduction, as well as intermittent oxidation, the separation of the native metals (copper, silver, gold, etc.) in forms which must have required a strong reducing agent and solvent, the abundance of carbonates and even of combinations of other humus-acids with oxide of iron, etc."

"Senft finds by experiment, that through the action of the humus solutions, silver-chloride becomes soluble, that the zeolites and simple feldspars dissolve more or less, and that even compound silicates (*e. g.*, oligoclase, mica, ordinary hornblende, and augite) are at least partly decomposed. His later experiments have shown him a great difference in the solvent power of the agencies — the ammoniacal and other alkaline combinations of the humus-acids — which he believes most efficient in the decomposition, alteration, and transport of mineral substances. This power is least in the ulmates, which can dissolve only carbonates: it is stronger in the humates, which dissolve both carbonates and phosphates: and it is strongest in the crenates, especially that of ammonia, which dissolve carbonates, phosphates, sulphates, simple silicates, and fluorides. The salts thus dissolved remain in solution only in inverse proportion to the degree of their subsequent conversion into carbonates: the latter separating, in crystalline condition, in proportion to their insolubility in carbonated waters.

"When the walls of a vein are composed of a very soluble material, like the limestone-strata which inclose the ore-deposits of Illinois, Wisconsin and Missouri, the peculiar erosion of the walls into 'chimneys,' etc., and the enormous quantity of limonite ocher which fills up the interstices of the breccia as a cement, seem to indicate the influence of stronger agents besides aerated and carbonated waters. The conversion of chalcopyrite into malachite, azurite, etc., of sphalerite into smithsonite, and of galenite into cerussite and anglesite, imply strong chemical action; and it has been suggested that 'smithsonite may even now be forming in the ground to quite a large extent.' The known solubility of the lead sulphate and carbonate in solutions of citric and other

[1] Loc. cit., 382-383, 384-385.

organic acids adds to the probability of the natural agency of the latter in such veins. The concentration of certain ores, especially limonite, often auriferous, as a solid cap (eisenhut) to a vein just below the gossan, or as a cement to a breccia made up of fragments of the walls, is a further consequence of the superficial chemical changes which have been caused or assisted by organic acids. The contact-deposits, which in Europe are often of great economic importance, also represent such a concentration, *e. g.*, the iron-ores of the Northern Banat. These consist of ferruginous clay, containing nodular masses of limonite and hematite, inserted between mica-schist and curiously eroded limestone, and in part of a limestone-breccia cemented by iron-ore and calcite."

Without claiming precise knowledge as to the form or amount of the action of the complex organic acids, the conviction that they are efficient agents of solution, within their sphere, is sanctioned by the investigations thus far made, the growing tendency of whose results is to magnify their importance.

Concerning the remaining constituents of atmospheric waters, more definite knowledge is at command. The surface drainage enters the pores and crevices of the rocks, well charged with oxygen and carbonic acid. The content of the latter enables the waters to dissolve and bear along with them, lime and magnesian carbonates, so that the waters, by virtue of these and the more soluble alkaline salts, found in small quantities in the rocks, soon become slightly mineralized.

It has already been maintained that the metallic material was distributed throughout the rock as sulphides, by original deposition. The action of oxygen on reaching these sulphides would be to change them into sulphates and there would thus arise, iron, lead, zinc and copper sulphates. All of these are quite soluble except the lead compound and that is slightly so. These sulphates must of necessity, it would seem, at once come in contact with the mineralized drainage waters and a reaction would take place between the metallic sulphates and the earthy and alkaline carbonates, giving rise to metallic carbonates and earthy and alkaline sulphates. Although the solubility of the metallic compounds is somewhat reduced by this reaction, yet they would be still sufficiently soluble to be borne away — in the minute quantities that would *at any given time* be subject to such action — by the drainage waters. These waters would find their way through the cracks, crevices and capillary pores of the rocks into the greater crevices that were the main channels by which the waters passed onward and downward through the strata. By this comparatively simple method, it would seem that ores were brought from their disseminated condition throughout the strata, into the crevices where they are found deposited. This action was probably much aided by the humus acids in attacking and rendering soluble the obdurate sulphides.

If it is objected that the action of any one of these agencies must be very slow and limited, it may in like manner be replied that the deposition was a very slow process and, in evidence, the size of the crystals, the succession of the mineral layers, the cracking and healing of the ore and other phenomena of deposit may be cited, and it may be observed, further, that the action of the penetrating oxygen and the percolating waters, *at any one point*, would have but a minute particle of ore to dissolve and remove and hence a very slight and feeble action, if it were constant and prevalent through the strata, would, in not immeasurable time, affect the removal of the diffused ore.

It should be borne in mind, that if the ores now found in the lodes were distributed throughout the adjoining rock, they would scarcely yield more than a trace to chemical analysis, and it is only necessary to find an agent that, acting on exceedingly minute particles of ore, through long ages will dissolve and remove them.

It is quite improbable that the solvent waters would, at any time, contain enough lead or zinc to be detected, except by very critical search. For suppose the rainfall to have been on the average, the same in the past as now, thirty inches per annum, and that only one-tenth of this descended through the superficial strata. Now, if prevalent estimates of geological time are to be at all trusted, it is almost certain that some millions of years have elapsed since these strata *began to be subjected* to this kind of action. In the course of one million years, at the rate assumed, a column of water nearly fifty miles in height would pass through the beds. Now, by estimate, it would be found that if all the ores from an average district were ground to a fine powder and spread over the surface of the immediate productive area, it would scarcely more than blacken the surface, and even in the most concentrated diggings, it would only form a thin layer. Now, if this metallic material were distributed through the amount of water indicated, it certainly would be an exceedingly dilute solution. From such an estimate, however crude and however much anyone might be disposed to modify it, it is apparent that only a very feeble solvent power is demanded by the problem.

It may be further remarked, in this connection, that the question of the relative solubility of compounds, within certain limits, is not as important as might appear, without consideration, as may be shown by an illustrative example. One grain of lead sulphate is soluble in 22816 grains of water, according to Fresenius, while one grain of zinc sulphate is soluble in scarcely more than two grains of water — an immense difference. Now suppose that a small particle of galena and of blende each give origin to one grain of their respective sulphates, by very slow oxidation, and suppose that, in the meantime, only a half gallon of water, or 29,159 grains has slowly passed over each, it is evident that, if the theoretical conditions have been fulfilled, both have been completely dissolved, and the extreme solubility of the zinc gives no advantage over the very feeble solubility of the other. If the production of the compounds be very slow, the solvent agents may be competent for their removal without regard to maximum possibilities.

2. *Deposition in Crevices, Openings, etc.*

If the foregoing views are correct, the ores were concentrated by drainage waters percolating through the metal-bearing beds and issuing into the receptive fissures in their way onward and downward. Let us consider attentively the precise situation.

It has been previously shown that the ores were deposited in slight depressions of the strata, and that the traversing fissures cut the beds nearly vertically in their upper portion, but towards their base take the form of flat and pitching openings, and the reason for this has also been explained. Now it is evident that the water which enters the fissure at the surface will pass directly down it and will not be detained, like that on either side, in percolating through the rock or in threading its close joints and minute fissures. It will not, therefore, be subject to the same chemical action, and when it reaches the lower portion of the crevice will be in a different condition. It is important to note what that condition is. The vertical seam sometimes becomes partially choked up with earth and clay, and this, sometimes, is highly charged with carbonaceous matter derived from the surface. Even the clay that partially fills the lower openings frequently contains organic matter. Still more significant is the fact that bones have been introduced into these fissures, in not infrequent instances, and that, in some cases, galena has been found in the cavities of the bone. It is, therefore, evident that the waters entering the fissures directly from the surface carry down organic matter in notable quantities, and that this was done *before the ore was deposited*, in some cases at least, as demonstrated by the galenite in the bones. A special source of organic matter may be worthy of consideration. Before the region was much cultivated and pastured, and the native vegetation thereby destroyed or modified, one of the prospecting signs of the miner consisted of lines of peculiar, or especially luxuriant, vegetation. These were often found to correspond with crevices, and, doubtless, the latter were the cause of the unusual growth, because they furnished a ready means by which the roots could penetrate deeply into the earth and thence derive moisture and nourishment. Certain kinds of plants, even of the herbaceous class, send roots to great depths and, although I have no specific information as to the class of vegetation that customarily assumed the linear arrangement, it probably consisted of those plants which were especially favored by the facilities for deep root penetration furnished by the fissures. However this may be, it is quite certain that roots extensively penetrated the crevices. These furnished organic matter to the descending waters, not only by their decay when dead, but also by such exudations and exfoliations as may take place while living.

Another of the prospector's "indications" consists of a slight sag in the surface, and this is undoubtedly due to the removal of a portion of the subsoil which is carried away beneath, into and through the crevices. This sometimes goes so far as to form a "sink-hole," in the bottom of which the open fissure may be seen. It is clear from an inspection of these sags and sinks, that they could have originated only in a soil somewhat readily permeable by water and which would, hence, permit organic matter to be carried in solution, if not mechanically, into the crevices. This is further sustained by the fact that the prevalent soil is a loam derived from the decomposition of the rock, a "residuary clay," owing its own origin to percolating waters.

It appears from the foregoing considerations, if, indeed, it was not inherently evident, that the water that enters the metalliferous crevices at the top, or reaches them through open side fissures, will carry more or less organic matter, and that this will be, in part, at least, in an unoxidized condition, and that it will slowly pass downwards and mingle with the common volume of water that fills the openings. At the time the ore deposition took place, the openings in which the metals were deposited were being continually supplied with water from the two sources above indicated, viz.: (1) that which entered directly from the surface-opening of the fissure and was charged with organic matter and (2) that which penetrated through the minute pores and fissures of the rock on either side of the crevice, and, becoming mineralized, found its way into the crevices. There thus came together (1) water slightly charged with metallic substances and (2) water slightly charged with organic matter. The result would be the reduction of the metallic compounds to sulphides, by the deoxidizing action of the organic matter.

It would only remain for the metallic sulphides to gather on the walls of the crevice in their appropriate crystalline forms to produce the galenite, blende, pyrite, marcasite and chalcopyrite that formed the original deposit.

But this is not, presumably, the only method of deposition. There is a considerable amount of organic matter in the rock-beds themselves. This is especially true of certain layers of the Trenton limestone, wherein there is a sufficient amount of carbonaceous matter to give rise to combustible gas when heated. These carbonaceous beds are sometimes impregnated with scattered crystals of galena, blende, and pyrite, thickly or sparsely distributed through their mass, so much so that the ore is sometimes separated by burning out the carbonaceous matter, when the residual earthy rock crumbles and permits the easy separation of the included ore. It has been previously shown that, in this kind of deposition, the type of which is known as "speckle jack," the dispersed crystals of ore were formed after the shaly rock, in which they are imbedded, was deposited, for they have forced aside the laminæ of the shale in their growth within it. There is, therefore, good reason for the conviction that the deposition in these instances was due to the reducing agency of the organic matter in the rock itself. A similar explanation may be assigned to the frequent small and scattered deposits in the interior of beds, or in situations removed from all direct connection with open fissures. In some of these instances, probably the metallic substance and the organic matter were deposited near each other originally, and whatever reactions have taken place have involved little transportation. But that this is not the case with the rich beds of "speckle jack" and allied deposits is placed beyond reasonable doubt by their limited extent, linear arrangement, local richness and definite association with crevices and crevice deposits above. In all this class of deposits, it seems much more than probable that the metallic substance was brought down from above by the descending mineralized waters, and that in slowly soaking through the carbonaceous shale, the lead, zinc, and iron were reduced by the organic contents of the rock.

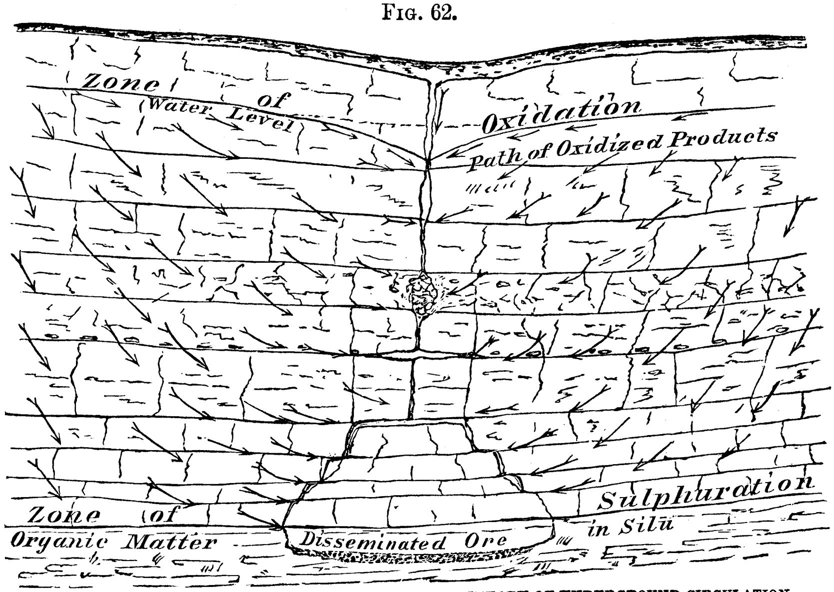
But a third agent of reduction deserves attention. With the waters that enter the crevices directly from the surface, there will be carried down oxygen, and this will attack the organic matter conveyed by the same water, or that held in the rocks, according as it is brought into relations with either favorable to action. Among the products of such oxidation there would arise sulphuretted hydrogen and ammonia, or their compound, ammonium sulphide. These will either remain in solution, or, rising through the water, escape owing to their volatility, unless they reënter into combination. But these are the very substances most familiar to the chemist as precipitants of lead, zinc, iron and copper, indeed of the metals generally. The ultimate source of reduction by this method is of course the same as in the preceding cases, viz.: the organic matter carried down the crevice from the surface and that implanted in the strata by original deposition.

If it be objected that the amount of organic matter carried into the crevices, and consequently its reducing action, either directly or by means of its oxidation-products, is small in amount, it must doubtless be conceded, if the amount present at any given time only be considered, but it may be observed in full offset, that the amount of metallic matter brought into the crevice at any given time, by waters penetrating the beds, is exceedingly small and there is need for only so much as will precipitate the infinitesimal metallic ingredient that may be present. And if, as in the case of the leaching out of the metallic substance from the rocks, the possibilities of the enormous lapse of time, during which the deposits, according to our hypothesis, have been taking place, are duly considered, the quantity of organic matter carried into the fissures will appear quite otherwise than insignificant.

But, in addition to the above methods, sulphuretted hydrogen may arise either from the decomposition of sulphides, or the reduction of sulphates, in ways too familiar to need discussion here. While the latter derivation, so far as applicable to this problem, is largely dependent upon organic matter, it is not confined to that which enters the fissure or originally belonged to the contact rock, but may arise from the more abundant supply of the adjacent or underlying strata. But, since it is prone to oxidation, this gas cannot be more than a transient product in situations freely accessible to oxygen, indeed the reduction of the sulphates implies absence of oxygen. It, therefore, should be a characteristic of the deeper, rather than the more superficial strata. This theoretical inference is sustained, in a general way, by the testimony of our deep artesian wells in whose waters it is generally prevalent, though it does not appear in the analyses, none of which were made on the ground with special reference to gaseous ingredients. It is on this basis that we have already made a broad classification of our subterranean waters into a superficial zone characterized by oxygenated waters and a lower one marked by slightly sulphuretted waters. The amount of the latter, in the deeper zone, is perhaps too small, in general, to warrant so pronounced a generalization, considered in any other attitude than that towards chemical changes, when an almost infinitesimal quantity, with the absence of free oxygen, will be sufficient to change the whole aspect of chemical action.

The main features of my conception of the mode of deposition may be illustrated in connection with the following ideal section, which represents a crevice descending from the surface, and taking the customary form of flats and pitches in the lower beds below which it

FIG. 62.



IDEAL DIAGRAM ILLUSTRATING THE ACCOMPANYING THEORY OF UNDERGROUND CIRCULATION.

encounters the yielding clays and shales of the Trenton formation. As the crevice is the main passage for the drainage that descends to the deeper strata the subterranean water-surface will incline toward it on both sides and the water that works its way through the interrupted jointage of the rocks, or percolates through their pores and capillary crevices, will gradually join it by oblique and lateral flowage, somewhat as indicated by the arrows. The descending waters may be distinguished into three general types: 1st, those that descend the crevice directly from the surface and carry atmospheric ingredients and organic matter; 2nd, those that more slowly penetrate the rock on either hand and carry in oxygen, carbonic acid and organic solvents (but not to any extent unoxidized organic matter which would be arrested and decomposed before penetrating far). These oxidize and dissolve the rock and its metallic contents and bear them onward in solution into the crevice. The greater part of this will pass laterally through the more open (because more acted upon by solvents) rock near the water level and join the main crevice in its upper portion (see figure), furnishing the possibilities of deposition near the water level. But a part will descend more nearly vertically and will constitute the third class. This portion will penetrate beyond the sphere of oxidation (having meanwhile also lost its own free oxygen), and will then dissolve such soluble substances — as entrapped oceanic salts, etc. — as it may come in contact with, becoming more and more saline — however small the totality — as it proceeds, suffering reactions, if any of these prove incompatible with its previous contents, and, coming in contact with organic matter, or other highly oxidizable compounds, suffer the reduction of its sulphates — mainly lime — to sulphides, these again, at least the calcium sulphide, to be decomposed by carbonic acid and water into lime carbonate, the calcite so common in these situations, and sulphuretted hydrogen which is borne onward until it shall be fixed in an insoluble compound by union with a metal, as in the occasional crystals of pyrite, blende and galena, in the midst of the rock, or mainly, at length, to reach the main crevice and there, mingling with the waters that have come along the two other courses, become a precipitating agent, or suffer oxidation, according to circumstances. It is probable that the ores, even as sulphides, are very slightly soluble in these impregnated waters, and that some — probably very small — amounts may be also carried out to the crevice to be there segregated.[1]

3. Location of Deposits in the Crevices, Effects of Feeders, etc.

All these lateral waters will, of course, mainly reach the master fissure through cross crevices, bedding joints, or porous beds. At such points of union, the effects of commingling ought to be observed, but not uniformly or universally so, since both the physical and chemical conditions of the two currents will affect the result. If the one contains metallic salts and the other a prompt precipitant, deposits will take place, at once, at their junction and the cross crevice will be said to "feed" the lode, and this is the most common case. But, if the precipitant be of the tardy sort, such as decomposing organic matter, the commingled waters may drift some distance away before action will be taken and the lode will be poor at the crossing but richer beyond, as often occurs. Again, if the flowage through the side crevice be strong, while that in the main opening be slack, because of its capacity, or for some other reason, the water issuing from the minor crevice may push back the waters from the former, and, instead of mingling at the junction, do so at some distance. On the other hand, if the flowage of both be very slight, as is probably the case usually, the waters would mingle, on the principle of diffusion, on each side of the crossing along both crevices, so that the deposits would extend some distance into the cross fissure, which is a common occurrence. In the cases of bedding joints, flat sheets would wedge out between

[1]Comp. Bischof's Chemical Geology and Hunt's Chemical and Geological Essays on these and preceding reactions.

the beds for a distance, and in the case of brecciated or cavernous rock, the deposits would extend laterally into them a certain distance.

It is further evident that better opportunities for the mingling of the waters and, especially for the action of organic matter, and the segregation of the precipitate in crystalline masses, will be afforded in the cavernous openings, or the interspaces of crushed layers, than in the more contracted portions of the crevice, and hence the tendency to accretion in such situations. Moreover, such openings are almost universally connected with a stratum that favors the bringing of the waters of the different channels together.

In addition to these sources of variations of a physical nature, it is evident that the chemical contents of the waters of the crevices will add others. The cross crevice may extend to the surface, like the principal one, and bear the same kind of water and hence no reaction take place on their mingling. Or its contents may be solvent, in nature, rather than precipitant.

It is quite common for the cross crevices — usually the norths and souths — to be found filled solidly with a vertical sheet of ore of a somewhat finer grain than that of the easts and wests and so distinguishable to the expert, even in the ore pile. Without insisting very much on the value of the explanation, I offer the following, consonant with the above views: These north and south crevices, being narrow, offer little facility for the introduction of organic matter, or even of much water, directly from the surface, so that they are mainly subject to the action of the two remaining classes of water. That from the zone of oxidation carries in the metallic salts in solution, while, below, there enter sulphuretted waters and the two, mingling, deposit the ore. This being a direct and prompt chemical action in a confined space, the precipitate attaches itself, at once, to the wall against which, in the initial instance it was probably formed, and so makes a compact sheet instead of aggregating in more massive crystalline form, as might happen in more indirect and deliberate formation in ampler space, as in the case of the reduction by decomposing organic matter in a cavernous opening.

4. Is the Process still in Progress?

In treating of the changes in the ores of the lodes now in progress, reasons were given, somewhat in detail, for the conviction that the metallic deposits of the upper part of the lodes are being oxidized, dissolved and borne downwards into the depths, and are there being redeposited, and that therefore both waste and deposition of the lode minerals are in progress. The same general principles of action, the same forces and agencies, essentially, may fairly be presumed to be active in their effects upon so much of the disseminated metallic material as may yet be involved in the strata. In that portion of the rock in which oxidation has proceeded to its full length as indicated by the change of color from the original blue or gray, to the present buff or yellow, it is not presumable that there remains any considerable amount of metalliferous substance, other than the iron oxides. But in the more deeply seated beds, where oxidation has not yet even accomplished the change of color, there is, demonstrably, a residuum of metallic substance, which may furnish material for the continuance of ore deposition. As oxygenation penetrates deeper and deeper, these disseminated ores are taken up, in infinitesimal quantities to be sure, borne into the crevices, and there finding, as before indicated, a suitable precipitate, are redeposited.

In support of these theoretical considerations, we may recite the facts to which attention has previously been called, viz.: that ores have certainly been deposited since the opening of the crevices to the surface and the introduction of the bones of mammals, since lead is found within their cavities; that the lead and zinc, as well as iron compounds, are intimately associated with calcite in the formation of stalactites and stalagmites of very youthful appearance; that the crystalline ores in certain situations present an untarnished and unmodified appearance, not to speak of the more questionable evidence cited in the chapter previously referred to. It is therefore our conviction, an almost necessary one from our theoretical views, that the ores are now growing by accretions derived from the original source of the deposits

5. Vertical Distribution of the Ores.

It remains to assign reasons, if possible, for the vertical order of the ores.

Since it is maintained that the ores were derived from the embracing strata, a seemingly natural explanation may be assigned by assuming that lead sulphide predominated in the higher sediments and the other ores in the lower, substantially in the same order in which they are found in the lodes.

This would, of course, involve the ulterior question, Why were the sediments impregnated in this order? which would be nearly equivalent to asking, Why were the waters of the ocean mineralized so differently at times so little removed from each other? The consideration of this question renders the suggested explanation as apparently improbable as before it seemed natural, for it appears incredible that the oceanic waters of the Trenton period should carry so large a relative amount of zinc while those of the Galena period should be almost exclusively enriched by lead. But still there may be some truth in the hypothesis. If the metalliferous solutions were derived in large measure from the leaching of the Lake Superior region, the extent to which the metalliferous formations of that region were exposed would be an important factor. During the Potsdam and Lower Magnesian periods, the iron- and copper-bearing formations were much more extensively exposed than in the later Galena and hence a larger contribution of copper and iron would be the result, and this is consonant with the larger relative amount of those ores in the lower horizons. But the absence of zinc and the paucity of lead, so far as present evidence goes, weakens the force of this coincidence, for they ought to have been contributed as abundantly as in the later date for aught that appears in the circumstances of the case.

When the accumulating sediments had encroached upon the region to an extent measured by 200 feet or 300 feet vertically and had buried the copper- and iron-bearing series to that extent, as in the Galena period, it is clear enough that they would contribute less to the ocean, but this does not afford a satisfactory reason why the deposits at this time should be so exclusively lead ore, nor do I know of anything in the geological conditions then prevalent that does.

While, therefore, the degree and nature of exposure of the contributing metalliferous area to leaching may cause some general variations in the metalliferous character of the depositing waters, they do not seem to offer any satisfactory solution of the marked distinctions observed in the order of the lode deposits.

There is a further fact that renders an explanation on any such basis improbable, viz.: that it is a very common circumstance for lead to yield to zinc in the lower parts of lodes. The general fact of one ore giving place to another in depth is well known.

Moreover, the special methods of occurrence of the ores in the lodes, while they do not perhaps afford very tangible objections to this hypothesis, yet do not seem well accordant with it.

The true explanation is to be sought, I apprehend, in *selective chemical affinity*. Picture an interrupted vertical crevice filled with water, into the upper portion of which are being introduced the several metallic solutions and at the same time precipitating agencies. The latter, however, are insufficient to reduce all the former, a statement sanctioned by the amount of ore that is found in the lower carbonaceous beds, having escaped precipitation above. The result would be, the selection of the metal for which the precipitant has the strongest chemical attraction, while the others would pass downward until, the favored metal having been extracted, they in turn are reduced by precipitants generated below, either from matter there embodied, as the hydro-carbonaceous constituents of the shales, or from organic matter from above that failed to sooner decompose and so become efficient, or from sulphates reduced, or from other sources. Although it is not quite certain what would be the precise condition of the precipitants in the upper horizons, there is thought to be sufficient ground for assuming that lead would be first selected, zinc next, and iron last of the three prevalent metals; and this is the predominant order of vertical arrangement.

But iron, from its prevalence and the easy decomposition of its sulphides, would doubtless enter the crevice at an earlier stage than its associates, and hence it extensively lines the walls of the openings. On the other hand, from the obstinate nature of its oxides, it will be likely to outlast its rivals and be the last to enter in quantity, and so frequently coats the other ores with a late deposit. More or less of mingling of the ores is, of course, inevitable under such conditions.

As denudation gradually carried the surface and the zone of oxidation and solution downward, the horizons of deposition of the several metals would descend correspondingly, and hence would overlap and the galena would at length overlie the zone of the previous zinc and iron deposits, so as to appear third in order as seen in the vein — so that while first in vertical order, it becomes last in lateral order in the lower portions of the lode.

This, though lacking much in precision and detail, is thought to embrace the essential circumstances that determine the vertical distribution of the ores, the central principle being selective chemical affinity.

This selective action doubtless played an important part in the extraction of the ores from the oceanic waters and so influenced the original impregnation of the strata.

The results of some experimental studies are reserved till greater fullness, precision and a closer imitation of the conditions of nature can be commanded.

CHAPTER III.

PRACTICAL CONSIDERATIONS.

Deep Mining. The long mooted question of the probabilities of profitable deep mining in the lead district presents itself for foremost consideration. In the history of opinion concerning this subject, it is to be observed that the earlier investigators, with large unanimity, incline to the affirmative belief, maintaining that the deposits would remain productive and probably increase in richness as traced into the lower formations, especially the Lower Magnesian limestone. The tendency of later opinion on the part of investigators of unquestioned ability has been decidedly in the opposite direction.

Dr. Percival, whose views have already been sketched, in outline, may be taken as a representative of the former; Prof. Whitney of the latter.

Dr. Percival believed that the Lower Magnesian limestone was "a good mineral-bearing rock." Prof. Whitney's views, expressed somewhat at length in his report of 1862, are summed up partially in the following words: "We are not prepared to admit that the Lower Magnesian ever has been, or is likely to be, profitably mined in for lead, either when it comes to the surface, or when it is overlaid by other rocks. For the purpose of determining this point, we have examined all the localities where galena has been reported as having been found in any noticeable quantity, and are able to affirm that, at the present time, no profitable mining is carried on in the Lower Magnesian, and that none ever has been for any length of time; and, further, that no well-developed crevices, or such as could be followed to any distance, have ever been found in it."

It is evident that the conclusions at which an investigator arrives concerning this question are necessarily dependent upon the views he entertains as to the methods and processes by which the ores were deposited.

Inasmuch as our views upon this subject differ quite radically from those of Dr. Percival, and, in some important particulars, from those of Prof. Whitney, our answer to the question here proposed must be divergent in like measure.

Instead of assuming, with the latter, that the Silurian ocean was generally rich in metallic solutions and that, therefore, the whole question of deposition depended upon the richness of the strata in organic matter, and that hence the ores cannot safely be presumed to have begun to be deposited before the appearance of a rich fauna and flora, and, hence, being led to an adverse opinion concerning the Lower Magnesian limestone, in which the remains of organic life are not abundant, we maintain that the essential circumstance of deposition is to be found in the local enrichment of the early seas by solutions derived from the disintegration and drainage of contiguous metalliferous territory. We assume that there was, in general, a sufficiency of organic life in any of the Silurian limestones to extract the metallic salts had they been present in abundance, and had favorable conditions for the extraction, retention and accumulation of ores been present.

And in support of this view, we appeal, not to cite other examples, to the existence of rich deposits of these ores in the neighboring Lower Magnesian limestone of Missouri, which is equally destitute of the remains of animal life; we say of the remains of animal life, not of its existence, for the limestone itself, in our judgment, bears testimony to the fact of abundant organic life, the remains of which, instead of retaining their organic structure, have passed into the form of granular dolomitic limestone.

The important circumstance upon which our judgment, in respect to the Lower Magnesian limestone, must rest is involved in the answer to the question, Were the seas of this region fed from the tributary lands in the Lower Magnesian epoch, in a similar manner and with similar richness to that which obtained in the Trenton and Galena periods? The answer to this question will obviously depend upon the probable course and character of the oceanic currents of that epoch. For it is evident, upon a moment's consideration, that the crystalline rocks in the Laurentian and Lake Superior regions were even more exposed to decomposition and drainage in that period than subsequently.

The only circumstance that I can conceive of, as probably lessening the amount of metalliferous substance carried down into the sea, would arise from possible variations in the deep-seated waters arising through fissures, such as may possibly have been connected with metalliferous fissures of the north shore of Lake Superior, which contain lead, zinc and other metals. These, for aught we know, may have been less or more important factors in this age, but as this is a wholly uncertain element, upon which we do not, in any essential respect, rest our views, or conceive that the deposits are, in any very large degree, dependent, it may be dismissed with this remark.

The contribution arising from the general decomposition and leaching of the Archæan areas, being at least equally great, the question reverts to that of oceanic currents. The general circumstances controlling these were manifestly essentially the same. No noticeable upheaval or subsidence, emergence or accumulation in the whole continental area has yet been discovered which could modify the contour or bed of the ocean to such a degree as to affect the general course of the currents, nor is there evidence of any climatic change that might have affected either its circulation or that of the winds.

The only known geological circumstances which could affect the case are the slow subsidence and slight oscillations of the land which permitted the progressive accumulation of the Silurian formations. These might be presumed to be competent to change the local features of the currents, but not their general course.

The main circumstance that seems to us important relates to the question whether the Archæan island of northern Wisconsin was connected with the Archæan axis of Minnesota at this period, as it certainly was in the earlier Potsdam. Without entering upon a full discussion of the data, which would require more space and a wider consideration of geological circumstances than are here permissible, we must content ourselves with the simple expression of our conclusion that near the close of the Potsdam period, the connection between Wisconsin Island and Minnesota Point was severed; that the later Potsdam seas swept through a shallow strait connecting the Lake Superior basin with that of the Mississippi river; that this strait was somewhat widened and deepened in the Lower Magnesian epoch, and that, therefore, oceanic currents entering the southeastern mouth of the Lake Superior basin (see Plate——) in part found exit through this strait, essentially as in the Trenton and Galena periods that followed. So that metalliferous solutions were borne from this northern region southward over the district under discussion from the later Potsdam period onward to the close of the Galena period, after which, we surmise, their courses changed, due to the new oceanic conditions which gave rise to the Hudson river shales.

These views are in perfect harmony with the facts before cited in reference to the occurrence of ores in the Lower Magnesian limestone in the area lying immediately north of the lead district where the formation is abundantly exposed to observation. The existence of these metalliferous deposits, north of the recognized lead region, whatever may be their economic importance — which is nevertheless greater than has sometimes been assumed — demands a rational explanation, since they are not common characteristics of these formations in their general distribution.

Now, it is a somewhat suggestive fact that the ores found in these beds are those of iron and copper. At the time that the strait, before mentioned, is believed to have been first opened, the copper-bearing formation of Lake Superior was still exposed over a considerable area, although much more buried than it is to-day, hence there would be derivable from it both cupriferous and ferruginous solutions, the latter being of course also derivable in abundance from other sources. And hence it is not remarkable that the oceanic waters of the vicinity, receiving drainage from these rocks, should have been unusually impregnated with these salts, and that the formations to the southward, that offered extractive agents, should have received notable ferruginous and cupriferous contributions.

But before the close of the accumulation of the Galena limestone, the copper-bearing series was probably nearly buried beneath Silurian sediment, and, therefore, yielded a feebler contribution.

It is perhaps worthy of mention, though we lay no great stress upon the fact, that the copper deposits found within the lead district lie mainly on its eastern margin. Now the copper-bearing rocks have their greatest elevation, as well as greatest area on the southern shore of Lake Superior, and it was mainly this portion probably that remained exposed during the Galena period. And hence the drainage from it would mingle with the waters on the south margin of the Lake Superior basin, and, as they found exit southward, would lie upon the eastern margin of the current, and so pass over the eastern tract of the lead district and be there precipitated.

While, therefore, the general conditions of deposition were essentially the same in the Lower Magnesian as in the Galena period, three circumstances may be mentioned which probably tended to render the ore deposition less rich.

In the first place the outlet from Lake Superior was probably narrower and shallower than in the later period, affording less free exit to the currents entering the lake basin, and causing a larger proportion of what water entered Lake Superior to re-curve upon itself and find exit from the southeasterly mouth. This also being narrower and shallower, less water would enter Lake Superior. In the second place, the agencies of extraction and precipitation may have been somewhat less abundant, and hence the deposition more prolonged and scattered. In the third place, the conditions of segregation appear to have been less favorable. In the upper group there was a thicker bed of purer magnesian limestone, and below this there lay a more compact limestone interstratified with clay and carbonaceous shales, which served to check and limit the downward flow of the solutions, and thus gave time and opportunity for deposition, and at the same time contributed organic matter and other extractive agencies. This latter circumstance may be an important consideration, for while it might be granted, that it took as much organic matter to produce the material of the Lower Magnesian limestone as an equal quantity of the upper limestone, though, from its more siliceous nature, this is not probably true, yet, if the organic substance was largely retained in the upper formation, but lost in the lower, there might be, in the latter instance, a lack of precipitating agencies adequate to the complete segregation and secondary deposition of the ore; so that, if it were granted on theoretical grounds that the Lower Magnesian limestone was equally impregnated with metallic substance originally, it might still fail to be retained when once leached out, for want of a stratum below to check too free drainage, and the want of organic and other agencies of precipitation. But it is, of course, an open question whether the agencies for the extraction of ores from oceanic suspension were as efficient in this northern region as they were in the lead region proper.

Concerning the probabilities of ore in the latter region, which is really the mooted question, the foregoing considerations lead us to these conclusions: First, that, if ore deposits exist, they are probably located beneath the present productive districts, for in our view, the depressions of the strata which were influential in localizing the deposits were depressions of the original ocean bed and had their primal origin in the irregularities of the Archæan floor, modified, of course, by the circumstances of oceanic accumulation, as heretofore, in part, indicated. This conclusion, based, as it is, upon definite reasons, would, of course, be of great importance in determining the points at which shafts should be sunk were an attempt made to test, by actual exploitation, the metalliferous character of the Lower Magnesian limestone, and the general principles upon which this conclusion is based would be of service in selecting from the numerous districts the one, or the few, which might offer the greatest probabilties of success.

In the second place, it is hardly probable that such deposits would be found relatively as rich as those of the upper horizon, for reasons similar to those assigned in reference to the deposits north of the lead district.

But the difference in the conditions of the two areas adds other elements to the already complicated problem, which render conclusions somewhat less certain than might be desired. But, we deem a fair estimate of the influence of known and definite circumstances, to be a vastly better basis for the formation of a trustworthy judgment, however complicated the problem may be, than vague generalizations based upon some assumed general law of ore deposits, where no such general law exists.

The first additional circumstance finds expression in the question whether the Lower Magnesian limestone might not be enriched by solutions descending from the formations above. Under the topic, Changes in Progress, evidence was cited to show that the ores of the Galena and Trenton limestones were being corroded, chemically changed, dissolved and carried away in the drainage waters. The general course of these waters is downward. In so far as such solutions are not arrested and deposited in the lower beds of the Trenton formation, they presumably penetrated deeper, for, notwithstanding the obstruction which the shales and close rock of the Trenton opposed to the descending drainage, it cannot be successfully questioned that the waters descend, at length, to the formation below. The St. Peters sandstone, however, intervenes between the Trenton and Lower Magnesian limestone and is a highly porous water-bearing formation. In general, the waters are passing through it in the direction of its dip which is here generally southwesterly. It is by no means certain, therefore, that metalliferous solutions, entering it from the Trenton limestone would pass directly downward through it into the Lower Magnesian limestone; on the contrary they possibly and in some situations, undoubtedly, would be borne away laterally in the direction of the dip of the formation.

Notwithstanding this, however, I deem it highly probable that a portion of the metallic salts borne down from above do enter the Lower Magnesian limestone. But this may also have taken place in the Highland district and in the region north of the Wisconsin river, and a portion of the ores there now found may possibly have been derived from the Trenton and Galena limestones that once overlay them.

Another element of the problem to be considered relates to the conditions of segregation. It is of no present practical consequence to believe that the Lower Magnesian limestone is rich in ore disseminated minutely through the rock; it must have been gathered and deposited in veins and lodes to be of any practical service. In our consideration of the method of concentration of the ores in the crevices, it was maintained that the solution of the disseminated ores was due to the action of oxygen, carbonic and humic acids, and other agencies derived from the atmosphere and organic life on the surface, and that the action of this was mainly within the zone of oxidation. Now, in the case of the Lower Magnesian limestone, buried 100 or

200 feet, at least, beneath the water level and not directly exposed to the easy penetration of organic matter to act as a precipitant, it is evident that the conditions that we have supposed to be efficient in the upper horizon, will be, at least, less effective here. These agencies, however, are not the only ones competent to concentrate ore. We apprehend, however, that a less proportion of whatever metallic substance exists in the Lower Magnesian limestone, where deeply buried, will be found to be concentrated in veins than in the more superficial formations.

On the other hand, the ores of the Lower Magnesian limestone at Highland and on the north of the Wisconsin river have been subject to considerable corrosion and loss from oxidizing and solvent agencies, and, therefore, they, on their part, do not fully represent the ores once present.

Gathering all these circumstances together and balancing their relative influence, as well as we may, we arrive at the general conclusion, above indicated, that the deposits in the Lower Magnesian limestone beneath the productive deposits of the lead region would not be found as rich as the latter.

There arises, then, the practical question, whether, under these circumstances, it is probable that mining in the Lower Magnesian limestone could be made profitable. One of the circumstances to be taken into consideration is the necessity of penetrating the St. Peters sandstone, a soft, friable, easily removed formation, in general, but, from its porosity, very highly water-bearing, so as to present, on this score, a grave obstacle to its penetration in most situations. The extent of this obstacle may be understood by anyone who chooses to refer to the chapter on artesian wells, in Volume II., pages 149 to 170, where it will be seen that at many localities there enter the sides of a bore of very moderate diameter very large supplies of water. It would be necessary in most situations to tube the formation, or, by other device, shut out the ingress of water.

The Lower Magnesian limestone, not having been exposed to disintegrating agencies, in its deeper situations, would present a very hard and difficult rock to work, a rock essentially like that of the average bar rock. Under these circumstances, it is quite improbable that mining in the Lower Magnesian limestone could be made practically profitable.

Practical Suggestions as to Prospecting and Mining. While many of the signs and rules current among miners are doubtless generalizations from a very narrow range of observation, or mere arbitrary inferences from associated phenomena that have no genetic connection, yet, to class all such rules, or even the more prevalent ones, thus, would be doubtless to do great injustice. It will, therefore, perhaps be serviceable to discuss some of these miners' maxims and determine, if possible, the *rationale* of their truth, and found them upon it.

(1) One of the most serviceable guides in prospecting, locating shafts, and in anticipating richness within the deposit, is held to be found in slight depressions of the surface. A little sag, which, perhaps, might not be noticeable except in the early morning or evening, when the slanting rays of the sun develop it by its deeper shadows, or the merest linear hollow, is looked upon as a favorable indication. The reason for this is not far to search. Decomposition of rock along the line of crevices, and the carrying down into it by drainage waters of the surface soil, very naturally gives rise to slight depressions. Wherever the disintegration is more marked than elsewhere, or where the drainage has concentrated and carried more material into the cavities below, there will be a more considerable indentation of the surface. It will be observed that these circumstances are precisely accordant with our views as to the method of deposition, that the very circumstances of decomposition and ready drainage-entrance into the crevices are those which have facilitated the filling of the the crevices by virtue of the precipitating agencies which have been thus carried in. This guide, of course, primarily points to a fissure and cavities below, and, in some cases, of course, may lead to nothing more, the crevice and opening being barren for the want of some other essential condition of deposition. Too great a depression, as in the instance of pronounced sink holes, is a less certain guide, probably because it indicates too open a passage way for the drainage, in consequence of which the waters pass rapidly through and no opportunity is allowed for the slow process of deposition, and, if such deposits have taken place, they have been subjected to too powerful corrosion. Pronounced sink holes, however, occasionally lead to deposits.

(2) Lines of peculiar vegetation of any sort, or a more vigorous growth along a narrow belt, are regarded as signs of crevices, and with good reason, since it is quite evident that the crevices offer greater depth of soil, and, what is probably more influential, a uniform supply of moisture; and further, being along the line into which the drainage gathers, the roots are somewhat fertilized by waters entering the crevices from the sides. This guide is, of course, less available since the cultivation and pasturage of the region than in its former native condition.

(3) The color of the soil is a subject of study to the prospector.

In the lead region, with the exception of the alluvial deposits, the soil is entirely derived from the disintegration of the under-lying rocks, is merely the residue of their decomposition and contains whatever they may have contained that has escaped disintegration. If any portion of the rock, therefore, was highly ferruginous, as that associated with the deposits often is, from the dissemination of iron pyrites, there would result from its disintegration, a soil of ocherous color. This might also result from the iron deposit of the lode itself. Belts of soil, therefore, notably marked by red or yellow ocher often indicate the position of a lode.

(4) The color of the crevice dirt is also looked upon as indicating favorable or unfavorable prospects, as it is encountered within the openings. If it is of a bright red color, it is regarded as an unfavorable indication, the ore having been "burnt out," as the miners phrase it. If of a more subdued yellowish color it is looked upon with more favor, but is subject to many local modifications and complicated with other rules for which the reasons are not evident, so that it is uncertain whether any of these possess much value.

(5) The presence of fragments of calcite in the soil sometimes points to a lode, the calcite, of course, being the undissolved portion of the gangue of the lode, and, in that respect, analogous to float mineral, as an indication, though of course less trustworthy, since the crevice may be mainly full of calcite and lean of ore.

(6) Float ore, that is, ore which has become detached from its original position and carried to a greater or less distance by water and other surface agencies, is, of course, the most direct and trustworthy indication of the near presence of a lode. As this region has never been swept over by the drift forces, loosened ore will rarely be transported by any other agency than water, and its attendant meteorological agencies, and except in a ravine subject to floods, it will not usually be drifted far from the parent lode, and, therefore, the finding of loose ore usually directs the prospector to the lode, whence it was derived.

(7) The drainage phenomena often afford valuable suggestions, though such indications are less direct and trustworthy than those above indicated. The lines of the crevices, as we have attempted to show, are lines of fracture toward which the adjacent strata slope, and, therefore, they become important drainage lines, and, after being cut across by the valleys of the region, naturally become the passage-way of under-ground veins of water which issue in springs and thereby indicate the location of the crevices. Manifestly, however, many springs rise independently of such association, and therefore, this is a guide which must be followed with much circumspection.

(8) The relations of deposits to the surface contour is a fruitful vein of miners' wisdom. While I allow no one to surpass me in impatience with the oft-repeated dictum, "I should think *by the lay of the land* that there ought to be mineral here," and, while the general surface contour in the lead region is no means of distinction, whatever, between the productive and barren areas, since both are in all discernible respects alike, yet the productiveness of crevices in their different parts is held, and, seemingly not without reason, to be correspondent to the nature of the overlying surface.

It is commonly asserted by miners that a lode does not "make" well because it is too shallow, or because it is running too much under the hill. The general conviction of miners, doubtless the result of their experience, is, that the crevice "makes" better at medium depths and under the receding portion of the brow, than at the summit or at the foot of a hill. In other words, in entering a crevice from the side of a hill, it is not, we are assured, usually very rich in the shallow ground, but develops best under the brow of the hill and generally pinches up under the summit. If traced onward to the opposite slope, the phenomena are often reversed. If the lode runs by easts and wests and quarterings alternately along the side of a ridge, as in the case of the Atkinson range at Muscalunge, so that, at times, it is running parallel to the level line drawn on the surface above and at others running toward the summit of the hill, it is claimed that it will usually be most productive in the parallel portions, that is, that portion of the crevice which, if mapped out upon the sloping surface of the ridge, would run along it "like an eave-trough." The wide unanimity of the testimony of miners to these rules, or essentially the same differently stated, leads to the conviction that they represent broad generalizations from facts.

Recurring to our views of the method of formation, it will be evident the crevices, so situated, are those in most favorable position for the reception of ores. Those crevices which come to the surface parallel to the side, "like an eave-trough," catch the drainage and carry it below. Furthermore, the water level within the ridge almost uniformly conforms, in a measure, to the surface contour, in other words, the water-level is higher under the summit of the ridge than along the flanks, or in the adjacent valleys, and the tendency of the subterranean water is, of course, seeking its level, to flow towards the sides of the ridge, and thus the drainage that enters the summit and descends deeply through the beds, turns outward, and entering the crevice, there mingles with that caught at the surface and carried downward, thus furnishing one of the conditions of ore concentration previously described. On the other hand, if the crevice runs into the ridge at right angles to its axis, it is universally traversed by cross-seams, which run parallel to the sides, and which, in like manner, collect both the surface and the deeper waters and carry them into the main fissure, to which they act as feeders. Thus heavy deposits do occur in crevices running at right angles to the ridge. If, however, both systems are much oblique to the face of the ridge there is greater liability of the waters to escape in divergent courses without being brought together in a situation suitable for deposition. These rules do not seem, however, to be universally applicable, and could scarcely be supposed to be so, since numerous other circumstances modify the internal drainage of a hill, and drainage, not contour, is really the influential element. The special rules, here stated, may be included in a more general one, namely, that whenever the conditions are most favorable for bringing together (1) waters derived directly from the surface, and (2) waters that have penetrated considerable depths of rock, there rich deposits are most likely to occur, other things being equal.

While these rules, therefore, find a rational explanation in the theory of ore deposition here advocated, and, in their turn, lend some additional testimony to its truth, it is evident that they are quite without explanation on any theory that looks to deep-seated causes, since thermal springs and gaseous emanations can have been in no essential respect affected by the surface contour.

This will be especially evident when it is considered that the present topography could not have been assumed at the time of deposit, if that was due to either of these agencies, particularly thermal springs, for these crevices often come out to the surface at lower levels than that at which the deposit takes place, as for instance the "65 foot opening" of Muscalunge Diggings comes to the surface in the side of a bluff at heights of 15 feet above the bottoms and downward, while 65 feet above this lies the "12 foot opening." Now it is quite evident that springs rising from below and reaching the "65 foot opening" would flow out to the surface, as the drainage waters do now, and it would be utterly impossible under hydrostatic laws for them to rise to the "12 foot opening" and produce a deposit there. To explain these deposits by thermal waters, it must necessarily be assumed that the "12 foot opening" was formed before the valley of the Rattlesnake was cut down below it. Similar facts are common throughout the whole region. It is, therefore, incredible that the topography should have modified the ore deposit, or that any rule based upon surface contour should have any trustworthy application, at least, in a case like this where the ore deposits themselves have had no appreciable effect in producing surface contour.

(9.) According to testimony received from various sources, the influence of valleys is two fold. If the valleys are very deep, the ores are cut away and the openings in the face of the bluff often bar up and become feebly productive. Where lodes cross small ravines near their head, the ore is said generally to "make strong," presumably due to the concentration of drainage. The rock beneath the valleys, especially that occupied by water courses, is often very hard or, in miners' parlance, barred. In the Hazel Green district this appears to be conspicuously so. See section on Atlas Plate XXXIX. The accompanying figure may serve to illustrate the probable explanation of this:

FIG. 63.

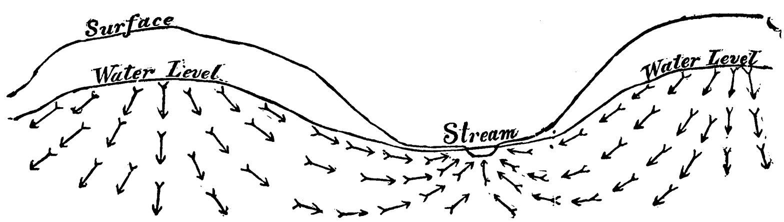


DIAGRAM ILLUSTRATING TENDENCY OF UNDERGROUND CURRENTS.

The water level beneath the ridge rises to a greater or less height above that of the valley according to the amount of obstruction interposed by the rock. The tendency of this water is to flow in the direction marked by the arrows, except so far as it may be modified by inequal obstacles imposed by the rock. The descending waters are charged with oxygen, carbonic and humic acids, and other solvents, and tend to disintegrate the rocks through which they pass, until these chemical agencies are exhausted. The rock, therefore, traversed by the descending currents is softened. In the valley, however, there are no descending currents, but rather the opposite, as demonstrated by the frequent occurrence of springs *rising* in the bottom of the valley or the stream. These ascênding waters having been already charged in their descent with lime salt, and, perhaps, some metalliferous substances will be disposed rather to deposit, and, therefore, harden the rocks, than to dissolve and to disintegrate them. As they are rising from greater to less pressures, their solvent power will be reduced, though the effect of this may be very slight. At the least, however, it appears that the rock beneath the stream will be less softened than that at the same level in the interior of the hill. If this conclusion be correct, and it seems to correspond with observed fact, it is one of no little importance in the driving of adits for the unwatering of mining territory. It is quite customary to drive the adit up the valley for some distance before striking in beneath the bluff, under the general impression that the labor of excavation will be less. Precisely the opposite method of procedure is indicated, for, besides the greater ease of driving the adit, there is the possibility of crossing new leads along its course.

We apprehend, however, that under the summit of the ridge the rock would likewise be found hard, and that the greatest probabilities of encountering soft rock, and of making new discoveries of ore, would be found beneath the brow of the ridge, and that, therefore, whenever practicable, it is best to drive the adit neither beneath the bed of the valley, nor the summit of the ridge, but at the intermediate position indicated.

10. *How to follow leads.* It is a not uncommon occurrence that, in following a lead, it is lost. A common case is that in which a crevice ceases at the intersection of a cross crevice and the lode is transferred to a fissure on the one side or the other, and must be sought for either at the right or the left, the phenomena being known as a "shift," "throw," or "heave." It is, of course, of much practical importance to the miner to know in which direction to search for his lost lead. It should be understood that these "throws," or "heaves," in our region are not of the same nature as those to which these terms are properly applied, namely, to cases in which the rock has actually been shifted by fault and the identical crevice has been shoved to one side. Ours are simply cases in which the fracture ceased at a crossing and another fracture, at one side or the other, took its place. It is manifest, therefore, that no definite rule as to the distance at which the lode may be found can be laid down, as in the case of regions where the shift has been caused by faulting, for the extent of a fault, when once determined, is found to be practically uniform for the district, but the point at which the fracture may occur would be uncertain. In the case of faulting, the direction of the shift is absolutely uniform and certain for any given system. It is not so certain that any absolute rule is applicable to our mines. Yet the current testimony of miners, so far as we have been able to gather it is, that the shift is to the left. The real guide, however, in these cases is the direction of the original drainage since the subterranean waters are the source of the deposit. The course which that pursues can generally be determined by close inspection of the phenomena of the lode.

Oftentimes, where there is no copious drainage, the oozing of moisture on one side rather than the other, or greater dampness, will suggest the line of drainage, though these indications may occasionally prove fallacious. Again, leads are sometimes lost because they drop below or ascend to a higher stratum. To these cases the same rule derived from the drainage is applicable. In general, the vertical shift will be in the direction of the dip of the strata, for the manifest reason that this generally controls the direction of descent of the depositing waters. Oftimes the course which a lode has taken will be indicated by little sheets of ore that have branched off on one side of the lode previous to its giving out. These will be found to mark the channels through which the water has passed to a parallel lode which takes the ore. Of course, in no case is there a better guide than to follow seams and strings of ore, where such can be found.

To these are to be added local rules of doubtful application in general.

Probabilities of ore below given horizons. Where lodes have been mined in the upper measures of the Galena limestone, and work has been suspended by reason of water or other practical difficulties, there is strong presumption of valuable deposits below. These may be shifted along the crevice or to one side, according to the drift of subterranean drainage. The relations of the "twelve foot opening" deposits to the "sixty-five foot opening" at Muscalunge may be studied with profit on this point.

In the middle and lower portions of the Galena limestone where lead ore alone has been found at higher horizons, we deem it altogether probable that mixed lead and zinc ores occur. The progress of mining seems to indicate that zinc ores are more widely and abundantly distributed in the lower beds than has been heretofore supposed. It may be quite unsafe to assume that beneath all the lead deposits there is a corresponding formation of zinc, and that every crevice that is lead-bearing in its upper reaches will develop zinc below, but such is the general tenor of evidence, and the general presumption is in favor of this as a rule. It would manifestly be of the greatest importance, if it were possible, to determine any definite ratio between the amount of lead in the upper beds and that of zinc below. In our previous discussions, pages 472, 488, we have alluded to this subject and have given some facts bearing upon it, facts which, we think, have not been generally known, or appreciated, in their bearing upon this important practical question. If the results of experience in a few of the most important mines of the whole region, from which the most of reliable statistics have been obtained, are to be taken as fair representatives of the general fact, which may be doubted, we shall be justified in concluding that an amount of zinc equivalent to that of lead might not be far from the general rule. But I must say, candidly, that I deem such a deduction too uncertain to be much trusted. But that greater richness in zinc in the lower beds is being, and is likely to be developed, than has heretofore been indicated by some of my official predecessors seems to me scarcely questionable. I incline to the judgment, therefore, that this region, in which the annual zinc product already far surpasses that of lead, and which should rather be called now the zinc district than the lead region, will continue to develop an increasing relative importance in the latter resource.

APPENDIX.

STATISTICS OF COPPER PRODUCTION AT MINERAL POINT.

Quite recently some old memoranda relating to copper production at Mineral Point have been found, and Mr. W. T. Henry has kindly collated the following items:

COPPER MADE AT "PRESTON & CO.'S" FURNACE AND SHIPPED EAST.

		Pounds.
1841.	First lot, shipped via Galena, Ills	6,982
Jan., 1842.	Second lot, shipped via Milwaukee, Wis	13,505
Jan., 1842.	Third lot, shipped via Milwaukee, Wis	10,000
Nov., 1842.	Fourth lot, shipped via Galena, Ills	21,604
May, 1843.	Fifth lot, shipped via Galena, Ills	43,278
May, 1843.	Sixth lot, shipped via Galena, Ills	3,000
Oct., 1843.	Seventh lot, shipped via Galena, Ills	21,043
Nov., 1843.	Eighth lot, shipped via Galena, Ills	5,494
Feb. 15, 1844.	Sent to Galena, Ills., to A. C. Davis	14,866
June, 1844.	Sold to Smith & Carter, Galena, Ills	11,515
Aug. 18, 1844.	Sent to A. C. Davis, Galena, Ills	6,206
Aug. 23, 1844.	Sent to A. C. Davis, Galena, Ills	1,623
Oct. 23, 1844.	Sent to A. C. Davis, Galena, Ills	5,444
Nov. 23, 1844.	Sent to A. C. Davis, Galena, Ills	6,021
Nov. 23, 1844.	Sent to A. C. Davis, Galena, Ills	7,699
June, 1845.	Sent to Smith & Carter, Galena, Ills	11,502
July 15, 1845.	Sent to Smith & Carter, Galena, Ills	4,242
Sept. 17, 1845.	Sent to Smith & Carter, Galena, Ills	8,740
April, 1846.	Sent to Smith & Carter, Galena, Ills	9,135
Oct. 21, 1846.	Sent to A. C. Davis, Galena, Ills	1,389
Oct. 30, 1846.	Sent to A. C. Davis, Galena, Ills	4,459
	Metallic copper	217,702

COPPER ORES RECEIVED FROM CHARLES BRACKEN.

		Pounds.	Per Cent. Yielded.
Sept. 3, 5, 1842.	First pile	40,000	
Sept. 3, 5, 1842.	Second pile of smalls	107,200	
Sept. 3, 5, 1842.	Second pile of prills	25,486	
Oct. 10, 1842.	Prills	22,500	33
Oct. 11, 1842.	Smalls	81,777	9
Nov. 23, 1842.	Smalls	57,684	12
Nov. 23, 1842.	Prills	18,720	32
Feb. 15, 1843.	Prills	17,692	29½
March 16, 1843.	Prills	15,000	30
April 6. 1843.	Prills	3,500	
May, 1843.	Smalls	32,034	10
July 21, 1843.	Smalls	160,731	10½
July 24, 1843.	Prills	34,510	34
Oct. 23, 1843.	Smalls	80,850	10⅝
Oct. 23, 1843.	Prills	19,617	23½
April 24, 1844.	Smalls	51,224	11
April 24, 1844.	Prills	11,520	28½
May 27, 1844.	Smalls	39,598	7½
May 27, 1844.	Prills	11,400	32½
May 27, 1844.	Prills (mixed with galena)	3,686	13
Nov. 7, 1844.	Smalls	28,861	7
Nov. 7, 1844.	Prills	14,644	24
	Copper ores	878,244	

COPPER ORE PURCHASED IN 1844.

	Pounds.	Per Cent. Yielded.
From James Wasley & Co., prills	6,708	30
From James Wasley & Co., gossans	48,600	10
From Sterling & Phillips, gossans	20,916	10
From Sterling & Phillips, prills	6,720	30
From S. B. Ballard, prills	3,060	29⅝
From S. B. Ballard, prills	9,000	17½
From James Wasley & Co., prills	142,285	30
From Iowa Copper Co., prills	805	8
From Iowa Copper Co., gossans	520	21
From James Wasley & Co., gossans	30,955	10
From James Wasley & Co., gossans	25,575	10
From James Wasley & Co., prills	10,815	30
From Stephen and J. Prideaux, prills	7,985	30
From Stephen and J. Prideaux, gossans	25,095	9
From Iowa Copper Co., prills and gossans mixed	5,836	11½
From Johnson Glanville, prills	5,050	16
From S. B. Ballard, prills and gossans mixed	25,000	8
From John Prideaux & Co., gossans	3,040	9
From John Prideaux & Co., prills	390	26
From Iowa Copper Co., gossans	2,775	8
From Iowa Copper Co., prills	500	21
From John Prideaux, prills and gossans	9,950	11½
From Johnson Glanville	1,066	4½
From Kenall & Co	2,880	28½
From Kenall & Co	10,245	15¾
From Kenall & Co	9,017	9¾
From Kenall & Co	810	10
From Kenall & Co	2,403	24½
From Kenall & Co	5,600	9¾
Copper ore	295,471	

COPPER ORE PURCHASED IN 1850.

	Pounds.	Per Cent. Yielded.
From Joseph Stevens, May 20, 1850	3,020	45
From Joseph Stevens, May 20, 1850	13,923	15
From Robert Richards, June 8, 1850	1,158	31
From Robert Richards, June 8, 1850	1,759	11½
From George and Richard Odgers, June 10, 1850	1,906	20½
From George and Richard Odgers, June 10, 1850	6,820	5
From George and Richard Odgers, June 17, 1850	610	23¾
From George and Richard Odgers, June 17, 1850	3,954	8
From Woodman, June 17, 1850	1,312	22
From Woodman, June 17, 1850	5,809	5½
From G. Odgers, July 1, 1850	10,407	11
From G. Odgers, July 1, 1850	2,593	27
From Joseph Stevens, July 3, 1850	3,793	15½
From Joseph Stevens, July 3, 1850	1,125	46
From C. Beach, Sept. 16, 1850	11,438	19
From C. Beach, Sept. 16, 1850	21,373	7
From Joseph Stevens, Oct. 2, 1850	1,957	39
From Joseph Stevens, Oct. 2, 1850	3,518	15
Copper ore	99,475	

COPPER ORES SHIPPED BY TOAY & SPENSLEY TO POPE, COLE & COMPANY, BALTIMORE, MD.

Oct. 15, 1875.	18,352	lbs. produce 7 1-10 per cent; price, $2.80 per unit	$208 48
		Freight	93 80
		Net	$114 68
Nov. 2, 1875.	15,377	lbs. produce 21 6-10 per cent.; price, $2.80 per unit	$531 43
		Freight	102 00
		Net	$429 43
Jan. 18, 1876.	19,050	lbs. produce 20 8-10 per cent.; price, $2.80 per unit	$633 98
		Freight	120 00
		Net	$513 98
Apr. 28, 1880.	82,826	lbs. produce 7 3-10 per cent.; price, $2.80 per unit	$846 48
		Freight	565 11
Ores	135,605	Net	$281 37

COPPER ORE SHIPPED BY WM. T. HENRY TO RANEY, CHASE & CO., CHICAGO, ILLS.

Nov. 4, 1880. 21,033 lbs. assay 24.02 per cent.; price, $2.30 per unit.
Nov. 4, 1880. 2,260 lbs. assay 9.75 per cent.; price, $1.80 per unit.

PART V.

THE QUARTZITES

OF

BARRON AND CHIPPEWA COUNTIES.

COMPILED FROM THE NOTES OF MESSRS. STRONG, SWEET, BROTHERTON AND CHAMBERLIN.

QUARTZITES OF BARRON AND CHIPPEWA COUNTIES.

Out from the prevalent drift of the region there stand forth a few ridges and domes of quartzite which portray the existence of a formation which might otherwise be wholly unsuspected in the region in which it occurs. Of these, a single massive ridge lies south and west of the great bend of the Chippewa river (T. 32, R. 7 W.), and it is doubtless this resisting mass lying athwart the course of the Chippewa river that has caused the notable deflection of its course at this point. The remainder of these quartzite protuberances are closely clustered in the eastern margin of Barron county, in the townships of Sumner and Rice Lake. (T. 34 and 35, R. 10 and 11 W.) A single low outcrop in Sec. 16, T. 38, R. 8 W. indicates a northerly extension of the formation, and completes the meager means of information at our command. To the eastward, in close proximity, lies the great central area of the Laurentian granitic series. To the south and west, in equally close proximity, lies the Potsdam sandstone as the prevalent superficial formation. To the northwest lies the Keweenawan or copper-bearing series. These relations, together with the lithological character of the rock, lead to the presumption that these are but points on the outcropping margin of the great Huronian series which here comes forth to the surface on the margin of the Laurentian area, being buried on the southwest by the Paleozoic, and on the northwest by the Keweenawan series.

If we search for similar outcropping marginal portions, we may find them by passing southeastward over an interval of 140 miles to the quartzites of the Baraboo region, or southwestward, about an equal distance, to the quartzites of New Ulm, Minn., or still farther to the southwest, to the Sioux quartzites of Iowa. The probable geological equivalent of this may also be found in the Penokee range, distant only about thirty-five miles to the northeastward. And again in the Menominee range, directly across the Laurentian area, 130 miles to the eastward. Or, taking the Laurentian nucleus as a point of view, the quartzites in question border it on the west as the Penokee range does on the north, the Menominee range on the northeast, and the Baraboo ranges on the south. The reference to the Huronian age is sanctioned by this relationship to the Laurentian area and the Paleozoic formation, and by the lithological similarity to the quartzites of the areas already mentioned, and, more remotely, to the Huronian of Lake Superior.

The quartzite range of the great bend of the Chippewa was first described by Mr. E. T. Sweet, in 1875.[1] The following is his description:

"A new quartzite locality was discovered on Sec. 6, T. 32, R. 6 W., during the descent of the Chippewa. It forms a hill about three hundred feet in height, and three or four miles in circumference. The lowest stratum of the formation is reddish metamorphic conglomerate, having a thickness of three hundred feet. The pebbles are seldom over an inch in diameter and are either jasper or amorphous quartz. The matrix consists of reddish grains of quartz. Above the conglomerate is a bed of reddish quartzite four hundred feet thick. The grains of quartz of which the layers are composed are much more distinct than in specimens of quartzite from the Baraboo Hills of Sauk county. A depression in the side hill one thousand feet across, comes in above this quartzite upon which exposures were not found. The space is probably occupied by some softer rock than quartzite. Above this arises the main hill of the quartzite. In every respect the rock is similar to that mentioned above. The entire thickness of the formation is not far from five thousand feet. Both the conglomerate and quartzite are distinctly and heavily bedded. The strike is north twelve degrees west, and the dip sixty degrees to the west. Careful observations were taken with the dip compass, and also with the magnetic needle, with a view to discovering magnetic ore deposits. No undue attraction, however, was observed.

"One and three-quarters miles from the exposures of quartzite, syenitic granites which may be assumed Laurentian in age were found in the banks of the Chippewa striking north fifty degrees east, and dipping high to the north. From the persistency of the strike here and at Little Falls, two miles below, it may be assumed that the quartzites and conglomerates unconformably overlie the Laurentian granites and syenites."

Mr. Strong visited this range in 1877, and described an outcrop of quartzite on the S. E. ¼ of the S. E. ¼ of Sec. 2, T. 32, R. 7 W., the rock of which is of a light red color, very hard, and composed of in-

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[1] Notes on the Geology of Northern Wisconsin. Transactions of Wisconsin Academy of Sciences, Arts and Letters, Vol. III.

durated sandstone, the individual grains of which were sometimes perceptible. The mass is intersected by numerous veins and irregular patches of milky white quartz. One series of joints has a strike of S. 50° W., dip 90°. Another series bears N. 60° W., and dips 77° southwest. Still another series of planes dip 37° S., 60° E. These Mr. Strong regarded doubtfully as the planes of bedding. Some portions of this quartzite are conglomeratic, the pebbles varying in size, but always small. On the N. E. ¼ of Sec. 1, T. 32, R. 7 W., the hill reaches the greatest altitude of the region, being about 500 feet above the Chippewa. This portion is composed of quartzite, like that already described, the planes of bedding and occasional lines of stratification being at one point very plain. The strike is N. 38° E., and dip 64° N. W. About 100 feet eastward of this, Mr. Strong notes the strike as varying from north and south to north 18° E., and the dip 60° to N. W. The mean of a large number of observations subsequently taken on this ridge gives a strike of N. 10° E., and a dip of 60° N., 80° W.

The writer visited this locality in 1879, but with too little time at command to add much to the foregoing description, further than to increase the observed variations in dip and strike, which indicate considerable warping of the formation, and suggest the vicinity of an anticlinal axis.

In Barron county, the quartzite exposures lie southeast of Rice Lake, and east and northeast of Sumner, and are nearly all inclosed within an area of about six miles in diameter. The most northwesterly and one of the most conspicuous consists of a high prominent ridge starting in the N. W. ¼ of Sec. 31, T. 35, R. 10 W., and stretching thence northeasterly. The southeast face is steep and covered with a vast multitude of loose blocks which have fallen from above and almost completely concealed all the undisturbed beds. The range exposes this talus-covered face for over a mile along its southeasterly front. Near the summit of the range, rock *in situ* shows a dip nearly due north of about 17°. The north slope of the range is more subdued, and is concealed by ordinary soil and drift. From the dip and brittle, though resistant, nature of the rock, it is not difficult to understand the abrupt and broken southeasterly face, it being but the fractured edge of the obliquely protruding strata. A similar and nearly parallel range commences at the N. E. ¼, Sec. 31, T. 35, R. 10 W., and continues along a general trend of about N. 30° E., for nearly four miles, with frequent outcrops of quartzite along its course. These exposures are quite numerous along the old Court Oreilles Indian trail, and on all the small ravines cutting down to the creek.

The quartzite of these two ranges, and, indeed, of the whole region, with trivial variations, is a hard, red, well metamorphosed rock derived from quartzose sandstone, the constituent grains of which are often clearly discernible. The original bedding planes, lines of lamination, and occasional ripple-marks remain as witnesses to its original sedimentary origin. The induration has been such, however, as to obliterate, in many cases, its original granular structure, and, in almost all cases, to have destroyed its original cleavage and given to it the irregular glassy fracture common to homogeneous, vitreous rock. Its brittle character and great endurance of meteorological agencies have undoubtedly given rise to its conspicuous tendency to cover all its precipitous slopes with immense accumulations of bare, angular blocks thrown down by water, frost and other meteorological agencies.

These are the accumulations which are appealed to by the awe-struck tyro as manifest tokens of some great volcanic eruption by which these were hurled up on the sides of an evident crater.

To the northeast both these ranges coalesce in the general rolling heights of that region, but become concealed by drift soil and only indicate their presence by quartzite fragments mingled with the soil.

At a few points among the quartzite ledges small seams of hematite appear.

Somewhat to the east of these lies the pipestone belt, embracing the locally celebrated catlinite locality. The pipestone appears at several localities, but the renowned Indian quarry is located in the S. E $\frac{1}{4}$ of the S. E. $\frac{1}{4}$ of Sec. 27, T. 35, R. 10 W. The pipestone here is very dark red, soft, sometimes ripple-marked, seamed and banded with light colored quartzite. This stone also graduates into a siliceous, schistose rock unfit for pipes. At the quarry, which occupies the summit of a hill, the Indians have broken up the surface layers over an area of about twenty-five feet square, but nowhere have they dug more than three feet below the surface; so that the quarry is rather one of renown than of extension. The upper layers are the more schistose, the interior beds being less so and softer. The catlinite is easily and successfully wrought when fresh, but hardens somewhat on exposure to the air.

In the S. E. $\frac{1}{4}$ of Sec. 25, T. 35, R. 10 W. is a very dark red, siliceous rock, somewhat harder than the pipestone (hardness about 2.50), but quarries in large regular pieces often three or four feet in length, and one to six inches in thickness. Its surfaces are beautifully ripple-marked. It seems to have a constitution closely similar to the pipestone, but is harder and contains very small scales of white mica. It would form a very handsome building stone. Its entire thickness was not exposed. It is underlain by the usual quartzite.

Near the center of Sec. 29, T. 35, R. 9 W. occurs a small ledge of red quartzite in the valley of the Pokegoma creek. To the eastward of this no exposures have been actually observed by us, though from the constitution of the drift there is little doubt that it extends eastward.

Quartzite is reported on the Soft Maple creek, a tributary of the Chippewa, and in the vicinity, lying four or five miles west of the Chippewa river, but this has not been verified by us.

In T. 34, R. 11 W., on the west side of the Pokegoma creek, there is a conspicuous ridge of quartzite about three miles in meridional diameter, and about two in width, the rock of which, so far as exposed, presents the characteristics above described.

To the east of Sumner, the N. E. ¼ of Sec. 31, T. 34, R. 10 W., are outcrops of a singular and interesting conglomerate. The fragments are composed of light red quartzite in angular or very slightly rounded forms. These masses lie closely but very irregularly disposed toward each other, with numerous joints, fissures, and irregular angular interspaces between them as though they were the talus of an adjacent cliff of quartzite, though no such cliff is now to be seen. The fragments in general are conspicuously angular, though some have been somewhat rounded, indicating moderate attrition at the time of their accumulation. The matrix consisted originally of sand, somewhat lighter in color than the quartzite fragments. This is notably less indurated than the inclosed quartzite, and yet is quite solid and firm. Its constituent grains have not, however, been obliterated. In induration and compactness it lies about midway between the quartzite and the Potsdam sandstone, which is reached in wells in the immediate vicinity. The induration of the matrix seems to the writer to be rather due to cementation, than to thermal or mechanical metamorphism. Its hardness was such, however, as to lead Mr. Strong to the conviction that it should be classed with the Huronian. My own inclination, however, is to regard it a Silurian conglomerate formed along a beetling cliff of quartzite standing forth in the Potsdam seas, and, of course, contemporaneous in origin with the adjacent Potsdam sandstone, its exceptional induration being due, as before suggested, to cementation. No simple quartzite, however, was observed in the vicinity, though the extent of the exposure was not such as to make this negative observation of much weight.

The above descriptions are based mainly upon the notes of Mr. Strong. Beyond question other exposures than those here noted might be discovered upon a more minute search, but the dense clothing of the forest, the resulting vegetable debris, and the general concealment by the drift, render miscellaneous search tedious and unprofitable. With the clearing away and settlement of the region, and the excavations incidental thereto, additional details, among which the junction of the Potsdam with the Huronian will very likely be developed.

An attempt to trace the northward extension of this formation, made in 1877 by Mr. Brotherton, resulted only in the discovery, in Sec. 16, T. 38, R. 8 W., of a ledge of red, granular, and in part conglomeratic quartzite, in every respect resembling that of the pipestone region, and undoubtedly belonging to the same series, indicating that the outcropping portion of this formation has a north and south extent of about forty miles, with a probable width of not more than twelve.

It is by no means certain that there is a surface connection between the quartzite range near the big bend of the Chippewa river and those in the vicinity of Rice Lake, nor between these and the last named outcrop to the northward. It is not impossible that the Potsdam sandstone reaches across to the Laurentian between these and conceals the connecting portion of the Huronian quartzite. That it once did so is rendered more than probable by the occurrence of the sandstone on Elder Creek in the N. W. ¼ of the N. W. ¼ of Sec. 29, T. 35, R. 7 W. The formation here occurs in a low exposure in the banks and bed of the stream, and consists of a gray sandstone, streaked in places with red; hard upon the exterior, but friable within. No fossils were discovered, but, from its position and character, it is referred with confidence to the Potsdam period.

Though possibly therefore incrusted with Potsdam sandstone, the fact that, between the known exposures of quartzite, high rolling ground, in general, intervenes, leads to the presumption that quartzite immediately underlies the drift throughout most, if not all, the intermediate region. It has been therefore so mapped, but, except in the vicinity of the exposures described, the outline is to be regarded as entirely hypothetical.

The main circumstance to which this general concealment of a formation which, from its resistant character, is wont to be notably protuberant, is due, is the fact that the belt is overlain by a great moraine, whose location here may perhaps have been in some measure determined by the high quartzite rim of the Chippewa basin, which was already presented as an obstacle to the ice stream descending the valley. The moraine, which is continuous with the kettle moraine of eastern Wisconsin, crosses the Chippewa just below the quartzite range at the great bend, and shortly curves to the northward, running near the line between Barron and Chippewa counties, and so overlying the supposed connection between the quartzite on the Chippewa and that in Barron county which lies on the west side of the moraine.[1] On either flank of the moraine, the bowlder clay and lacustrine and fluviatile modified drift extensively occupy the region, being rarely interrupted except by the protuberant domes and ridges of quartzite.

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[1] See Plate XXXVII, Vol. III, p. 383.

PART VI.

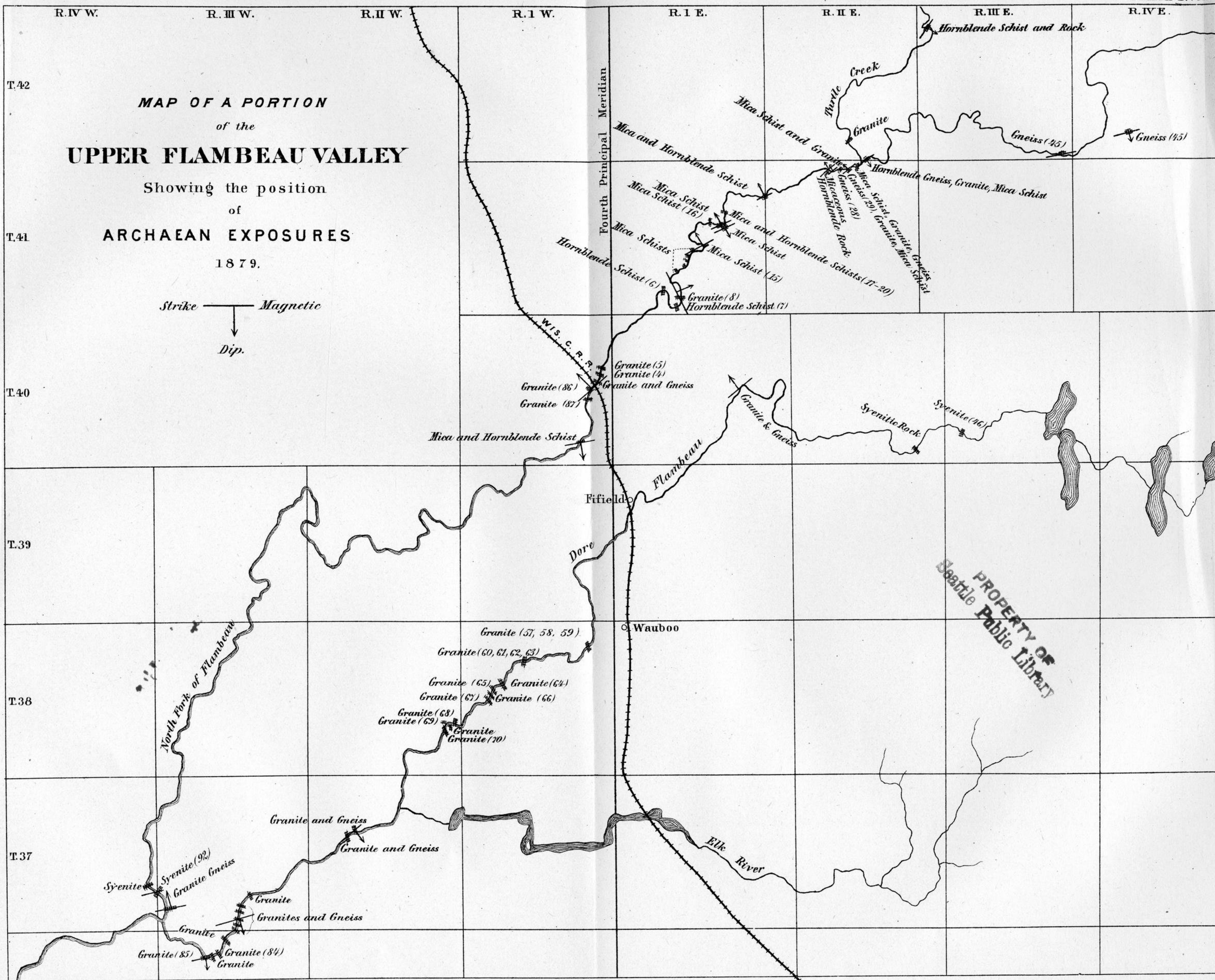
GEOLOGY

OF THE

UPPER FLAMBEAU VALLEY.

BY F. H. KING.

PLATE No. XII


MAP OF A PORTION
of the
UPPER FLAMBEAU VALLEY
Showing the position
of
ARCHAEAN EXPOSURES
1879.
Strike
Magnetic
Dip.
R. IV W.
R. III W.
R. II W.
R. I W.
R. I E.
R. II E.
R. III E.
R. IV E.
T. 42
T. 41
T. 40
T. 39
T. 38
T. 37
Fourth Principal Meridian
WIS. C. R. R.
Turtle Creek
Hornblende Schist and Rock
Granite
Mica Schist and Granite
Hornblende Gneiss, Granite, Mica Schist
Gneiss (45)
Gneiss (45)
Mica and Hornblende Schist
Micaceous Hornblende Rock
Gneiss (28)
Gneiss (29)
Mica Schist, Granite, Gneiss, Granite, Mica Schist
Mica Schist
Mica Schist (16)
Mica and Hornblende Schists (17–20)
Mica Schist
Mica Schists
Mica Schist (15)
Hornblende Schist (6)
Granite (8)
Hornblende Schist (7)
Granite (5)
Granite (4)
Granite (86)
Granite and Gneiss
Granite (87)
Mica and Hornblende Schist
Granite & Gneiss
Syenitic Rock
Syenite (46)
Flambeau
Fifield
Dore
Wauboo
North Fork of Flambeau
Granite (57, 58, 59)
Granite (60, 61, 62, 63)
Granite (65)
Granite (64)
Granite (67)
Granite (66)
Granite (68)
Granite (69)
Granite
Granite (70)
Granite and Gneiss
Granite and Gneiss
Elk River
Syenite
Syenite (92)
Granite Gneiss
Granite
Granites and Gneiss
Granite
Granite (85)
Granite (84)
Granite

INTRODUCTION.

What might have been presented in the place of the following report had not that fatal accident occurred which closed the labors of the lamented Moses Strong can only be conjectured; as it is, the work that has been done in the upper Flambeau valley can be looked upon as little more than a reconnoissance of its two main streams. The small amount of time which circumstances left available for this work, the large amount of wholly uninhabited territory to be traversed, unfavorable weather, low water in the streams, making it necessary often to drag or carry the canoe over considerable distances, the inaccuracy and incompleteness of the government survey throughout much of the region, all conspired to make anything like complete work impossible.

The field work was done during the fall of 1877, and was taken up October 4th, at Flambeau, where Mr. Strong had dropped it. From Muskalonge Falls, at Flambeau, the ascent of the North Fork was made to the mouth of Turtle Creek, and the latter stream then followed to its source in Turtle Lake. After returning to the mouth of Turtle Creek, the course of the Manadowish was pursued through Cross, Island and Boulder Lakes to Sec. 16, T. 42, R. 7 E., where a portage of four miles was made to Trout Lake. Trout Creek was then followed to Sec. 8, T. 41, R. 6 E., where a second portage was made to Swamp Lake. Pokegama Lake was next reached, by two portages and an intervening lake, from which we passed to Lake Flambeau; and here another portage of some eight miles was made, to a small lake in T. 39, R. 4 W., from which a small stream leads through Squaw and Pike Lakes into the Dore Flambeau. It had been our plan to descend the Dore to its mouth, and then return to Flambeau by the North Fork; but a log jam about four miles in length, beginning at the center of Sec. 17, T. 37, R. 2 W., made a change desirable, and we returned to Fifield and crossed to the North Fork at Flambeau. On the night of November 5th, when we had reached the center of Sec. 22, T. 39, R. 2 W., the river closed with ice. This necessitated the abandoning of the canoe, and the packing of specimens, provisions and camp equipage, and rendered it desirable to avoid all travel not absolutely essential to the work before us. As it appeared probable from the heavy drift accumulations that few, if any, exposures of rock would be found along the "Big Bend" of the Flambeau in T. 39, Rs. 2 and 3 W., the course of the stream was abandoned at a point in Sec. 19, T. 39, R. 2 W., and taken up again in Sec. 26, T. 39, R. 3 W., and pursued to its confluence with the Dore. On reaching the mouth of the two streams, a considerable fall of snow made it necessary to close work, and left but a single day for the examination of the unexplored portion of the Dore Flambeau. This stream was examined, therefore, only as far as the center of Sec. 27, T. 36, R. 3 W., and there still remains an unexplored gap of about six miles, along which several outcrops probably exist.

While it is not probable that any considerable number of rock exposures exist between the two forks of the Flambeau away from the immediate vicinity of the water courses, silence in regard to this territory is due to the fact that, with few exceptions, no excursions were made back from the streams more than half a mile; and throughout the report which follows, all statements, unless otherwise indicated, are to be regarded as based upon such observations as were made from the canoe, or from the banks of the streams. It is to be understood, too, that no tributary to either of the two main branches of the Flambeau was examined except where mentioned.

In regard to previous literature relating to the geology of the region under consideration, there is to be mentioned the "Report of a Geological Reconnoissance of the Chippewa Land District," by David Dale Owen, made to the senate in 1848.

Some of the lithological specimens collected were of so fine a texture as to require microscopic examinations for satisfactory descriptions and classification ; and of these, thin sections were prepared by Julien, and described by Prof. Irving. His descriptions are added as an appendix to this report.

It is due to Mr. Mark Stevens, an expert woodsman of Eau Claire, who acted as assistant and guide, to say that he did all that could be expected of a faithful and willing servant.

F. H. K.

RIVER FALLS, WIS., November, 1879.

GEOLOGY OF THE UPPER FLAMBEAU VALLEY.

THE ARCHÆAN ROCKS.

The rocks here considered probably all belong to the Laurentian series. These, for convenience of treatment, will generally be taken up in the order of their discovery.

About twenty rods above the Wis. C. R. R. bridge which crosses the North Fork of the Flambeau river, the stream breaks over a rather heavy exposure of **Gneissoid Granite** (1), forming a long, steep rapids known as Muskalonge falls. The great bulk of this exposure, lying mainly on the north side of the river, is a coarse, faintly pinkish and bluish white rock, which has so resisted disintegration as to retain upon its surface some of the glacial scorings.

The granite beds are composed of feldspar, presenting both plain and striated facets, those of the former being sometimes 6 c. m. across and occasionally imbedding quartz crystals of considerable size; irregular bunches of smoky and limpid (rarely greenish) quartz; and ferrite-stained muscovite, irregularly and sparingly distributed in thin plates, sometimes 5 m. m. or 10 m. m. in diameter.

Associated with the above are masses of coarse, light, flesh-red **Pegmitic Granite** (2), which possesses a nearly uniform texture and slightly jointed fracture. It is composed of large cleavable, ferrite-stained orthoclase crystals; lengthened, sometimes irregularly parallel, bunches of dusky quartz, and a few flakes of muscovite.

Adjacent to the granite masses are bands of gneiss, showing decided close contortion, and thinner bands of **Mica Schist** (3), which present a shimmering surface, finely speckled with black, brown and white. This schist is composed of about equal parts of evenly scattered, limpid and dingy, small rounded and somewhat angular grains of quartz, and small plates of black and brown biotite averaging about 1 m. m. in diameter.

The strike is not accurately determinable, but is evidently north of east, and probably lies somewhere between E. 15° N. and E. 25° N.

Passing up the stream, from Muskalonge falls to the center of Sec. 13, T. 40, R. 1 W., a second exposure of **Granite** (4), lying on both sides of the river, is reached. The outcrops on both sides of the stream are small and low, presenting no bedding planes; but the one upon the east bank lies farther north, suggesting a strike to the east of north, and an intervening bed of softer rock, which has been cut away by the stream. This granite has a very coarse texture, deep, flesh-red color, mottled with black and light, and an irregular fracture. Orthoclase, varying in color from bluish white to deep flesh-red, and presenting facets 4 c. m. to 5 c. m. in diameter, comprises about two-thirds of the rock mass. The deep red color is due largely to deposits of ferrite upon and between the cleavage planes. Large and small bunches of dingy and limpid quartz are scattered between the crystals of orthoclase, and are sometimes imbedded in them. Disseminated sparingly and irregularly, are also to be seen large and small plates of dingy yellowish and silvery muscovite.

A little west of the N. E. qr. of Sec. 13, T. 40, R. 1 W., up the stream from the last exposure and on the west bank of the river is another low, small outcrop of **Granite** (5), differing from the last only in having the quartz and mica relatively more abundant, and the orthoclase crystals smaller and more uniformly of a deep flesh-red color.

Crossing the principal meridian, there occurs at the N. E. corner of Sec. 32, T. 41, R. 1 E., a low small exposure of **Silicious Hornblende Schist** (6), whose dark, weathered surface is deeply and profusely pitted with small, conical cavities. The rock has a fine-grained, uniform texture, and yields with difficulty to the hammer, breaking with an uneven fracture. The fresh surface is black, glistening and closely but vaguely dappled with white, which becomes yellowish on weathering. Small plates and blades of hornblende, which are both greenish and brown by transmitted light, make up about seven-tenths of the rock, the remainder being composed largely of small, irregular and rounded, limpid and stained grains of quartz, uniformly scattered through the mass, and small bunches of shalite, from 1 m. m. to 2 m. m. in diameter. To the latter the dappled appearance and pitted, weathered surface are due. A few small patches and bands, more exclusively hornblendic than the mass of the exposure, and composed of larger, lengthened, sometimes greenish needles, are crossed occasionally by small, indistinct, light streaks bearing a few grains of iron pyrites. Specimens 2 e and 3 of the appendix are from this exposure.

A short distance up the stream from the last, in the S. E. corner of the N. E. qr. of the S. W. qr. of Sec. 33, T. 41, R. 1 E., there is another exposure of **Silicious Hornblende Schist** (7), rising scarcely above the bed of the stream. It differs from (6) in being less micaceous in structure, finer grained, and more brittle, in having a somewhat jointed fracture, and in wanting the peculiar aggregations of shalite. Some portions of the exposure, too, apparently contain some mica. Specimen (4) of the appendix is from this outcrop.

Where the river passes southward a little to the west of the center of Sec. 33, T. 41, R. 1 E., its channel is divided by an outcrop, and before the two branches meet again, an island of about 25 or 30 acres is inclosed. Across and up the stream, in the bend and on its south bank, in a direction E. 50° N. from the head of the island, is another exposure, rising some 15 feet above the bed of the river, and extending but a few rods back. The rock of the two outcrops is essentially the same,— a grayish white, darkly-blotched, coarse-grained **Granite** (8), which has a very uneven fracture, and weathers almost white.

A grayish white feldspar, with facets from 2 m. m. to 6 m. m. in diameter, some of which are striated and present a somewhat vitreous luster, comprises about six-tenths of the rock. Both dusky and translucent quartz are present in large and small irregular bunches. Muscovite plates, sometimes 12 m. m. in diameter and 2 m. m. thick, are scattered abundantly through the rock. Biotite plates are also present, but they are smaller and less numerous than those of the muscovite.

In the granite upon the island there occurs a mass of handsome light flesh-red **Pegmatite** (9), which weathers lighter, and possesses a somewhat jointed fracture. The quartz is arranged in long, wavy, wedge-shaped, nearly parallel blades, which have most of their bases looking in the same direction, and some of them split so as to clasp portions of the orthoclase which constitutes about seven-tenths of the rock. Only a few flakes of muscovite are seen in the specimen. Upon the east (?) side of the island there is a small patch of slightly arenaceous, glistening, thickly-speckled, black and gray **Silicious Mica Schist** (10), which weathers duller, and in which the biotite plates average 1 m. m. in diameter. It appears to be the remnant of a bed that has been cut away by the stream. The biotite plates are often perforated with holes resulting from decomposition, and are associated with a considerable amount of muscovite.

The fourth and last exposure noted in Sec. 33 is situated near the N. W. corner of the N. E. qr. At this point the river breaks over the outcrop, forming a long rapids, at the foot of which is a small, rock-fronted island. Eight rods above the island in the bed of the stream, and barely rising above low water, is a mass of glistening, vaguely-mottled black and gray, coarsed-grained **Mica Schist** (11), which assumes a dark, pitted and warty surface after weathering. It contains an abundance of black mica whose very brittle plates vary in diameter from 1 m. m. to 3 m. m. Colorless, sometimes rose-tinted, grains of quartz from 1 m. m. to 2 m. m. in diameter are plentifully scattered through the mass or aggregated in bunches to which a part of the vague mottling is due. Kyanite crystals of considerable size and often much altered are abundant, and there is a greater abundance of what may be smaller, silvery — sometimes greenish — almost foliaceous crystals of the same, the two together equaling the quartz in abundance. Imperfect crystals of staurotide also occur. Scattered through this schistose rock at irregular intervals are numerous large masses of yellowish and dusky **Quartz** (12), resembling large nodules or rudely imitating veins, in which may occasionally be seen mica plates and dusky oval masses. Congregated about these masses of quartz are numerous small, impure garnets, together with crystals of kyanite.

Across the stream from the exposure now considered, on the east bank, is another **Mica Schist** (13), whose structural and lithological features are very similar to (11). It differs, however, in the absence of large quartz masses and in the uniform distribution of garnets. No staurotide was observed in (13). The **Mica Schist** (14) upon the island presents a glistening, mottled, black, gray and brown fractured surface, and an extremely warty and weathered appearance. It differs from (11) in possessing a much greater quantity of staurotide, in the smaller amount of garnet, in the larger kyanite crystals and in the absence of large quartz masses.

The staurotide has a dark brownish-red color, and though sometimes presenting well defined angles and occasionally displaying the crosses, usually it is little more than a mere aggregation of that material. The staurotide crystals appear to have formed last, and, if we may judge from appearances, under the greatest difficulties. So tardy was their beginning that the molecules, obliged to elbow their way among the already rigid material, have only been able to huddle around the centers of crystalization without having the power of definite arrangement, or of expelling foreign elements. The result is that quartz, garnets and mica are included in these staurotide masses. Where, however, the molecules were able to combine their energies to better advantage, there has been an evident displacement of quartz and mica, for these materials are now arranged in contorted layers about the crystals of staurotide.

Across the channel from the head of the island, on the east side, there is an exposure of mica schist differing from (14) only in presenting evident bedding planes which dip 56° E. 36° N. and trend N. 36° W.

From the north line of Sec. 33 to near the center of Sec. 22, T. 41, R. 1 E., slight rapids follow one another at short intervals, and at several of these small outcrops of mica schist barely protrude from the banks above the water's edge. These schists, so far as observed, differ from those just described only in the absence of staurotide and in being coarser grained. At two points, however, well defined, light colored feldspar crystals were observed standing in close proximity to large masses of quartz.

Just N. E. of the center of Sec. 22, T. 41, R. 1 E., there is another exposure of rather fine-grained, slightly arenaceous, glistening, black and gray **Mica Schist** (15), whose texture is firmer along certain planes than others. This has resulted in the formation of nearly vertical ridges in the rock where it is worn by the water. Biotite is the characteristic mineral, and its plates rarely attain a diameter of more than 2 m. m. Limpid colorless grains, partly quartz, but I think largely kyanite, are only less abundant than the mica. If a portion of this rock is abraded with the point of a knife and the powder examined under the microscope after being mounted in Canada balsam, many of the light colored grains are seen to be distinctly crystalline plates, rather than rounded or angular grains. These plates in polarized light exhibit colors very similar to those of kyanite, and in some instances the characteristic cleavage planes of that mineral were observed.

At this exposure the bedding planes trend E. 27° N., and dip to the northward 89°.

At the point where the river crosses the west line of Sec. 14, T. 41, R. 1 E., there is another exposure of **Schist** (16), whose essential characteristics are the same as those of (15), the only observed difference being a little firmer and less arenaceous texture.

Some 40 rods above the last exposure there occurs another, whose lithological features, as indicated by my field notes, are identical with the last. Here the strike is E. 27° N., and the dip to the northward 86°.

The third and last outcrop of mica schist, observed in Sec. 14, lies just west of the center of the section on the south bank of the stream, where it presents an exposure about 20 feet above the bed of the channel. No specimens of it were taken, but it was observed to differ from the others only in being the finest grained and most durable rock of the three. Strike, E. 25° N. Dip, south, 68° to 72°.

The exposure which is situated near the center of the north line of Sec. 14 takes on features different from those presented by the outcrops lower down. It is a bunchy, hornblendic and micaceous accumulation, of varying texture and durability. On the bank the rock yields with difficulty to the hammer and presents a tolerably even surface; but in the bed of the stream where it is washed by running water the micaceous portions have been abraded so as to leave the surface covered with deep, cavernous holes and pockets of the most varied and irregular contours, showing to good advantage the bunchy grouping of the two classes of material, and suggesting that a similarly heterogeneous arrangement of debris has contributed to the present crystalline structure. The hornblendic portions of this rock are represented by Nos. 17, 18, 19 and 20.

The first is a faintly glistening, finely speckled, fine-grained **Silicious Hornblende Schist** (17), which presents a uniform texture and irregular fracture, and weathers gray. Small amphibole needles, green by transmitted light, sometimes brought together in bunches, comprise about six-tenths of the specimen, the remaining portion of this rock being mainly quartz. A little mica, and perhaps some feldspar, is also present. The next is a **Hornblende Rock** (18), differing from (17) in being coarser-grained and in possessing a greater proportion of amphibole. No. 19 is also a **Hornblende Rock** which contains more biotite than (17), but has a similar texture. The last of these specimens is a dark, dappled and speckled, glistening, rather coarse-grained **Micaceous Hornblende Rock** (20), which has an uneven fracture and weathers grayish. The quartz is present in small, limpid, somewhat angular grains. That portion of the exposure in which hornblende is wanting is a **Garnetiferous Mica Schist** (21), essentially the same as (13), except that kyanite may be absent. No. 17 is specimen 23 of appendix.

After crossing the line into T. 41, R. 2 E., near the west line of Sec. 7, a heavier exposure than the last is seen rising, in places 25 feet above the bed of the stream. Although a mica-bearing rock like the last, it contains more hornblende, which is distributed in bands or beds rather than in bunches, and for this reason the river-eroded portion presents long, hornblendic ridges separated by micaceous troughs, instead of the cavernous pockets of the last. The micaceous portions are essentially like those just described, while the hornblendic beds differ mainly in presenting patches of longer, coarser, and often radiating, needles than any found below. Specimens (22) and (23) are from this point. Strike, E. 30° N. Dip, 72° S.

Between the S. W. corner of Sec. 5, T. 41, R. 2 E., and the mouth of Turtle Creek, the mapping of the stream upon the plat does not conform to fact. A correction of the plat so far as it was possible was attempted, and while the following outcrops may be assigned positions not rigidly correct, it is believed that they will be found approximately true. Along the portion of the North Fork just limited, six rock exposures were observed, all of which are low and small. The first occurs near the center of Sec. 4., and, considered as a whole, is a micaceous hornblende rock, which breaks with difficulty where unaffected by the water. The portions in the bed of the stream, however, soften and show a decided schistose structure. Considered in parts, a considerable variation in texture and composition is to be noted. One portion is a dark green, rather coarse-grained **Hornblende Schist** (24), having an irregular fracture, and composed largely of lengthened, dark green, glistening crystals of hornblende.

Another portion is a dark, fine-grained **Diabase** (25), having a slightly conchoidal fracture, a slightly rusty-brown, even weathered surface and a faintly glistening, finely-speckled, fractured aspect. The rock contains augite, altering to uralite and a "plagioclase feldspar, optically near labradorite."

A third variety is a cryptocrystalline, slightly schistose, dark, finely and densely speckled, even-grained **Hornblende Rock** (26), having a conchoidal fracture, a dark-brown, weathered surface, and much external resemblance to the last. In the place of the plagioclase crystals of the last, however, there are numerous semi-angular, light grains, which change from a slight orange yellow to a deep clear blue under the nicols, and which cleave in thick, brittle plates as hard as kyanite. The rock has a specific gravity of 2.91. At this exposure the bedding planes trend, in different portions, from E. 35° N. through E. 45° N., to E. 50° N., and dip about 82° to the northward.

About 200 feet southeast from the last exposure, along a line at right angles to the strike, there is another schistose rock containing more mica than the last. There are also thin beds of granite bearing much quartz which is often aggregated in large masses. Here the bedding planes dip to the northward and strike E. 45° N.

About forty rods west of the east line of Sec. 4, and just south of the quarter line on the south bank of the stream, there is a low, small outcrop of light-colored, faintly-pinkish, highly silicious, rather fine-grained, even-textured **Gneiss** (28), which weathers darker and fractures evenly. In it, the predominating ingredient is quartz, which exists in large, distinct, rounded and angular, colorless and dusky grains. White and faintly-pinkish, sometimes iridescent, often strongly-striated feldspar, presenting cleavage planes 1 m. m. to 2 m. m. in diameter, and lengthened bunches of black mica composed of scales equalling in size the feldspar facets, are the principal remaining ingredients.

A little S. W. of the center of the N. W. qr. of Sec. 3, T. 41, R. 2 E., there is a considerable exposure of dark, rather coarse **Mica Schist,** containing rather heavy beds of granite, gneiss and large, irregular bunches of quartz. A portion of the **Gneiss** (29) is almost identical with the one just described — the only difference being the absence of the pinkish tinge. Another portion (30), though essentially the same rock, appears quite different. It is black, dotted and blotched with pinkish and grayish-white, coarser than 28, the weathered surface being uneven. Black mica is abundant and combines with the darker, often striated, more strongly iridescent feldspar, to produce a gneiss in appearance unlike the one with which it is associated. At one point on this exposure there was observed a large cluster of black tourmaline crystals imbedded in quartz, with which was associated both feldspar and green talc. Some of these crystals were an inch long and three-tenths of an inch thick. An interesting feature presented by one of them was that of being bent nearly at right-angles without being much fractured, showing that a considerable amount of motion has taken place since the formation of the tourmaline crystals.

At this exposure the dip is again northward and the bedding planes strike east 45° N.

About seventy rods nearly due N. E. from the last exposure is the sixth one referred to above. The greater part of this rock is a dark, speckled, yellowish-gray, rather coarse-grained **Silicious Mica Schist** (31), in which there is much of a white, cleavable mineral, having a hardness of 5. This may be kyanite.

Associated with this schist are fine to medium-grained **Granite** and **Gneiss** (32), which are speckled and banded, and contain much plagioclase feldspar, having striated facets. The gneiss closely resembles (28) and (29).

At the rapids in Turtle creek, near the center of the N. W. qr. of Sec. 34, T. 42, R. 2 E., there is, on the east bank, what appears to be a nearly submerged ledge of uniform, rather fine-grained, even-weathered, light red and white **Granite** (33), scantily flecked with black. In this granite there is a small amount of mica, and possibly some plagioclase.

Near the S. E. corner of Sec. 34, T. 42, R. 2 E., there is an outcrop just above the mouth of the Turtle on the North Fork, presenting along a line at right angles to the strike, a width of 110 feet, in which four quite distinct beds are readily distinguished. These beds, beginning with the most northern and passing toward the south, are as follows: (1) A black, finely speckled with white, uniform, even-weathered, indistinctly laminated, somewhat splintery, much fractured **Hornblende Gneiss** (34), composed of about six-tenths of hornblende, much feldspar and some quartz. (2) A dirty, resinous, gray, very uneven, easily and irregularly fractured **Granite** (35), which, in some parts, is very coarse, in others fine and sometimes almost schistose. It is composed largely of a dull resinous-gray feldspar and quartz. Mica is not abundant, except where the rock is schistose. (3) A rather fine-grained, even, somewhat shaly, mottled, vaguely green-tinted, reddish-gray **Gneiss** (36), having a slight plumbaginous luster on the fractured surface, and which is composed largely of much-altered orthoclase and quartz, together with some plagioclase and "veridite." Its sp. gr. is 2.69. (4) A yellowish, glistening, gray-and-black, rather coarse-grained, uniform, somewhat friable **Mica Schist** (37), composed of yellowish-brown and black mica, with quartz and a little feldspar.

The bedding planes at this exposure are not very readily determined, but they appear to strike E. 22° N. and to dip southward about 68°.

Specimens 75 and 77, described in the appendix, are (34) and (36) respectively.

Leaving the North Fork for the present and passing up Turtle creek to Turtle falls, a little east of the center of Sec. 6, T. 42, R. 3 E., the stream is seen to make a short, steep descent across the bedding planes of a hornblende bearing rock, whose general appearance is very different from any that has been described. The bedding planes are usually not evident, and where they can be seen they are greatly obscured by a confused network of fissures, on account of which much of the rock is broken into small chips of varying sizes and shapes. At one point where the bedding planes are better made out than elsewhere, they strike E. 55° N., and have a southward dip of about 89°. Assuming that this measured strike is possessed by all of the exposures in the vicinity, a total thickness of about 192 feet was observed. Within this belt there may be distinguished six variations sufficiently marked to merit special descriptions here.

The first and southernmost occurs at the foot of the falls, and is a rather fine-grained **Hornblende Rock** (38), containing considerable mica, and breaking with difficulty into irregular fragments. The next bed is a dark greenish-black, distinctly crystalline, uniform, vaguely-mottled **Hyposyenite** (39), which after weathering presents a dark, reddish-brown, vaguely-mottled surface. It is about three-tenths hornblende in the form of small, slender, greenish needles, separately visible only in thin sections, and six-tenths feldspar, which is rather coarse and of yellowish-brown color. Associated with the feldspar, and having a similar color, is a rather soft mineral, which blackens and becomes slightly magnetic when heated, dissolves in hot nitric acid, and gives the reaction for iron with borax. It appears to be *chalybite*. Small grains of iron pyrites are of frequent occurrence, and the seams in the rock are often thinly coated with calcite. This rock is described in the appendix under 42.

About 100 paces from the river, on the south side, there occurs an exposure of very fine-grained, dimly-sparkling, greenish-black, even **Hornblende Schist** (40), which weathers to greenish, and is composed of small, slender dichroitic needles of hornblende, among which are disseminated grains of iron pyrites. A little feldspar is also present. The bedding planes are not readily determined, but assuming that they trend as indicated above, they cross the river about 10 paces above the bed last described, but are not there exposed. About ten paces north of the last exposure is another vaguely-banded **Hornblende Schist** (41), which differs from (40) only in containing a few small, scattered masses of quartz. It is described in the appendix under (44). Some 40 paces above the foot of the falls and 50 paces from the stream, in the direction of the strike, on the south side, there is a large quantity of light-green, fine-grained, uneven, splintery **Hornblende Schist** (42), which, if not in place, has not been moved far. In some portions of the rock the hornblende needles can be seen with the naked eye, while in others the one-fifth objective is required to resolve them. A little mica is present, and some of the hornblende appears to be passing into chlorite. The sp. gr. of one of the specimens is 2.97. The rock is described in the appendix under specimen 45. About 95 paces above the foot of the falls there is a short rapids caused by bowlders, which may be lodged upon the submerged portion of a ledge lying 60 paces from the stream on the north side. The exposure is a banded, light-green, somewhat shaly-fractured **Hornblende Schist** (43), containing a little quartz. The rock, except in certain bands, is very fine-grained and has a sp. gr. of 3. It is here that the measurements of strike and dip were obtained. Specimen 46 of the appendix is from this outcrop. Following the line of strike from the last exposure southeastward, it crosses the rapids mentioned above and leads to another outcrop, situated about 100 paces from the river on the south side. The rock is a **Hornblende Schist** (44), which differs from the last only in being less distinctly banded, and rather more shaly, in containing some iron pyrites and in presenting upon the weathered surface, in places, rather large reddish spots.

We have now to return to the North Fork. Whatever indurated rocks may exist above Turtle falls beneath the heavier drift accumulation of that region, the less swiftly flowing streams, opposed by the forest growths, have not laid them bare. The waters of the Flambeau, too, come leisurely down to the mouth of the Turtle, through a long and tortuous channel, only hastening occasionally over small and widely separated bowlder rapids. At one of these rapids, a little west of the center of Sec. 29, T. 42, R. 3 E., the first resemblance of an outcrop occurs. The rock is a dark, coarse mica schist, which, where it is washed by the river, is worn into parallel ridges, trending E. 58° N., and dipping to the southward. It appears to be a gigantic bowlder, partly uncovered.

Near where the river crosses the east line of Sec. 34, T. 42, R. 3 E., there is another doubtful mass of rock protruding from the northeast side of a low knoll into the stream. The rock is a rather coarse-grained, light colored **Gneiss**, whose bedding planes trend E. 36° N., and dip some 89° to the northward. The exposed portion of this mass is 20 by 30 feet. About 40 rods up the stream there is, in the bed of the river, a bowlder whose dimensions equal those given above.

Not far from the center of the S. E. qr. of Sec. 35, T. 42, R. 3 E., and on the north side of the N. W. qr. of Sec. 33, T. 42, R. 4 E., there are exposures of a light colored, banded and speckled-with-black, uneven textured, coarse grained, irregularly fractured **Garnetiferous-Kyanitic Gneiss** (45), which weathers lighter, and is sometimes slightly schistose, closely resembling the kyanitic schists already described. Quartz is abundant in this rock in large, usually colorless, angular grains, aggregated in bunches and layers. Plates of biotite from 1 m. m. to 4 m. m. in diameter are grouped in irregular layers or scattered plentifully through the mass. The feldspar crystals are usually small, light colored, sometimes striated, and occasionally faintly irised. Small, impure garnets are numerous, and often imbedded in the crystals of kyanite, showing that the kyanite was last formed. The kyanite crystals vary in color from nearly white to bluish gray, and in size, from small, to those an inch or more long and a quarter of an inch wide. They are usually impure and imperfect and often abundant.

At the first exposure a strike E. 10° N. was measured, and at the latter one E. 12° N. The dip at the former is to the south. It should be mentioned in this connection that several large angular bowlders of a rock almost identical in composition with that just described, occur in the stream at the mouth of Island lake, 80 rods north of the center of Sec. 13, T. 42, R. 5 E., and it is, perhaps, a significant coincidence that these bowlders, which evidently have not been moved far, and the two outcrops just considered, lie nearly in the line of the strike of the two exposures.

The portion of the route included between the last two exposures and the S. E. corner of the S. W. qr. of Sec. 29, T. 40, R. 3 E., on the Dore Flambeau, presents no outcrops that were observed. At this latter point, on the north bank of the stream, there is a low exposure of light colored, blotched, black and grayish, coarse, uneven fractured, uniform, rough-weathered **Syenite** (46), composed of slender needles of black hornblende grouped in bunches; evenly scattered small grains, and large, compact bunches of colorless and dusky quartz; and large and small crystals of light feldspar, some of which present striated facets.

A few rods back from the stream is what may be an exposure of a rock very similar to the one just described; it is, however, surrounded with erratics of a different kind, and may itself be a large bowlder. This **Syenite** (47) differs from 46 only in containing rather larger feldspar crystals.

Passing down the river into the S. E. corner of the next township, there is, about 80 rods east of the center of Sec. 35, T. 40, R. 2 E., a second low exposure of syenitic rock lying on both sides of the stream. This rock presents considerable variation in texture and composition, and in places rather large aggregations of quartz. Some portions are rather coarse grained, thickly and coarsely speckled with black, grayish and reddish-white, and composed of about five-tenths glistening, black, fibro-micaceous hornblende, three-tenths bluish-white and faintly pinkish crystals of plagioclase, from 1 m. m. to 3 m. m. in diameter, some of which present striated facets, and two-tenths dusky crystalline quartz aggregations, in which hornblende is sometimes imbedded. This portion is the **Diorite** (48), specimen 133b of the appendix. Another portion is fine grained, black, faintly and finely speckled with light, weathering gray to a depth of 4 m. m., the inner portion being lightest and in sharp contrast with the unaltered portions. It is composed of about six-tenths hornblende, three-tenths light feldspar and one-tenth quartz. There are also to be observed small, indistinct seams of quartz, containing iron pyrites and a few bunches of quartz scattered through the rock. This portion is the **Hornblende Rock** (49), specimen 133c of the appendix. A third variation is lighter, coarser, and less uniform in texture than (49) and more irregular in fracture. The weathered portion is darker, too, and confined wholly to the surface. Hornblende is less abundant, and is sometimes thinly scattered in lengthened needles. A few faces of feldspar show striated faces. The rock is the **Syenite** (50), specimen 133e of the appendix. A fourth and last variation is the **Quartz Schist** (51), specimen 133f of the appendix. It has a light, ashy-gray color, finely specked with black and indistinctly dappled with white, weathering lighter to a depth of 2 m. m. It is fine grained, having a slightly arenaceous texture. It is composed of numerous very fine grains of quartz, which may be removed by rubbing with the finger and relatively small amounts of biotite, hornblende and feldspar. A small amount of magnetite, in rather large particles, sometimes octahedral, is also to be observed.

On the bank of the river, where it flows north through Sec. 34, T. 40, R. 2 E., there are four very large bowlders situated from 10 to 20 rods apart, about which are scattered smaller fragments of the same kind. They are all highly silicious, compact **Syenitic Rocks** (52), (53), closely allied to those just described. One of them presents much the aspect of a quartzite; all contain iron pyrites and magnetite, and one of the specimens of 53 sparkles with the latter mineral. It appears probable that a bed of this rock exists not far to the northeast of these bowlders, perhaps in Sec. 6 of the same town.

Near the S. E. corner of Sec. 15, T. 40, R. 1 E., there is an exposure of very coarse granite, with alternating beds of gneiss, which measures along a line at right angles to the strike 450 feet. The strike cannot be readily determined with accuracy, but is not far from E. 40° N., and the dip is to the northward some 50°. It was possible to make out four beds of granite, varying from 40 feet to 140 feet in thickness, with as many much thinner alternating bands of gneiss.

The **Granite** (54) is all extremely coarse, and composed of large, irregular masses of colorless and dusky quartz, broad, thick plates of black and silvery mica, and coarse crystals of red and pink feldspar, grouped in widely varying proportions. The **Gneiss** is both hornblendic and micaceous, always much finer grained than the granite, and composed of pink feldspar, quartz and mica alone or hornblende alone (56), specimen 143 of the appendix, or with both combined (55).

At the center of the S. E. qr. of the S. E. qr. of Sec. 2, T. 38, R. 1 W., there is on the north bank of the stream a low exposure of **Granite** (57), (58), (59), in which no bedding planes are seen, but which presents two systems of fissures trending N. 28° W. and N.

85° W., respectively. The rock is medium grained, but presents considerable variation in texture and color; 57 is rather coarse grained, and composed of about six-tenths pink feldspar, three-tenths quartz, in which are imbedded large bluish-white crystals of striated feldspar and a few scattering plates of black mica; 58 differs from the last in being finer-grained, in possessing smaller crystals of striated feldspar and a greater abundance of biotite, and consequently in having a darker color; 59 has the finest grain and darkest color of the three, and like the other specimens contains striated feldspar. The three specimens were taken within three feet of one another.

A little below the center of Sec. 9, T. 38, R. 1 W., is Rocky Carry rapids, one of the longest and roughest on the Dore Flambeau. And it is appropriately named, for it is literally one bed of almost naked gigantic bowlders, about 20 rods wide and 50 rods long. In the midst of this confusion there are five masses of granite, whose magnitude suggests that they are rock in place. Their close proximity to one another, their diversity of shape, and their much-rounded or much-fractured condition suggest that some of them may have been dislocated at least, if not carried bodily over a considerable distance.

The most eastern and smallest mass is an uneven, coarse-grained, flesh-colored **Gneissoid Granite** (60), having an irregular fracture, and weathering light. Feldspar in large crystals is the predominating ingredient, black mica being scanty and least abundant. Here the bedding planes appear to strike E. 75° N. A short distance north of the last, there is a mass of warty-weathered, coarse-grained — finer than 60 — rather dark **Porphyroid Granite** (61), which weathers lighter. Feldspar is the principal ingredient; biotite is abundant. The porphyroid character and warty, weathered surface are due to large crystals of striated feldspar scattered through the rock. The next mass lies some 300 feet west of the first, and presents an exposed area about 100 feet square, in which bedding planes trend N. 5° W., and dip some 88° to the southwest. It is a coarse-grained, rather light colored **Gneissoid Granite** (62), very similar to 60, and contains little or no striated feldspar. At the foot of Rocky Carry there is a mass of medium-grained, yellowish gray, thickly flecked with black **Gneissoid Granite** (63), which contains striated feldspar, whose facets are much smaller than those of 61. At this point the bedding planes appear to strike E. 75° N.

A little S. E. of the center of Sec. 17, T. 38, R. 1 W., on the south side of a peculiar bend in the stream, there is a low exposure of rather coarse-grained, even-fractured, uniform **Granite** (64), which is flesh-colored and thickly flecked with black. Orthoclase, much of which presents glistening, rectangular facets varying from 3 m. m. to 10 m. m. in diameter is by far the most abundant ingredient, and biotite plates from 1 m. m. to 2 m. m. in diameter are plentifully scattered through the mass, some of which may also be seen imbedded in the larger feldspar crystals. Three systems of fissures were noted at this exposure, trending respectively, N. 20° W., N. 66° W., and N. 75° W.

About 70 rods from the last exposure near the center of the S. W. qr. of Sec. 17, there occurs another exposure of **Granite** (65), which differs from 64 in being finer-grained, and in containing, besides orthoclase, striated feldspar. Here a close system of fissures trending N. 15° E. and dipping some 86° southward were noted.

On the same quarter section with the last exposure and about 30 rods from it, there is a **Granite** (66), identical with 64 in its main features, except that it contains a little striated feldspar.

Near the center of the N. W. qr. of the N. W. qr. of Sec. 20, due south from the last exposure, for the stream is not laid correctly upon the plat, there is a mass of **Granite** (67), forming the east bank of the stream for 12 rods, and rising about 20 feet above its bed. The rock differs from 66 only in containing a large amount of striated feldspar. Where the rock has been blasted to clear the channel, the large blocks show a quite regular fracture. Two fissure systems trending respectively N. 50° W., and N. 70° W., occur at this exposure.

In the N. W. qr. of Sec. 25, T. 38, R. 2 W., there is another series of granite outcrops, four in number, all of which are low and small. The most northern of these is crossed by the north line of the section and is a medium-grained, fragile, white **Granite** (68), thickly flecked with black, and stained yellowish. It is composed of about equal parts of irregular, colorless grains of quartz and white feldspar, which stains yellowish. Mingled with these is evenly scattered an abundance of black mica. The exposure possesses less uniformity of texture than is indicated by the specimen.

The second outcrop lies on the east bank of the stream, about 12 rods below the last. It is but a small, low exposure from which no specimens were taken, and of which no other notes appear to have been made.

Near the S. E. corner of the N. W. qr. of the N. W. qr. of Sec. 25, the third outcrop referred to above is found. The rock varies from a medium to a very coarse-grained **Granite** (69), almost destitute of mica and containing far more feldspar than quartz, which gives to the rock a flesh-red color. One system of fissures at this point trends N. 70° W.

The last exposure is situated near the S. W. corner of the N. W. qr. of Sec. 25, and appears only in the bed of the stream. It is a **Granite** (70), very similar to 66, from which it differs only in being slightly finer grained.

In the N. W. corner of Sec. 17, T. 37, R. 2 W., there are two exposures of granite and gneiss, about 20 rods apart. The direction of the upper outcrop from the lower is E. 40° N.; this is also the strike observed at both places. The bedding planes of the northern exposure dip toward the S. E.

If the heavy masses of very coarse, red **Granite** (71), composed of large irregular bunches of quartz and feldspar crystals, some of which are from 2 to 4 inches in diameter, and which contain but little mica in rather large plates, represent beds, five may be made out at the lower and three at the upper exposures. At the upper outcrop the easternmost bed is a rather fine-grained, flesh colored **Granite** (72), containing but little mica (muscovite), and both orthoclase and white striated feldspar, the latter presenting the larger and more glistening facets. The second bed is a pinkish gray, medium-grained **Porphyroid Gneiss** (73), containing black mica, and both kinds of feldspar mentioned above. The striated facets are in this case large and brilliant, giving to a fresh surface a neat, mottled appearance. The third bed (?) is the coarse **Granite** (71), already described.

At the lower exposure the most eastern bed is a **Granite** (74), in no essential respect different from 66. Next to this bed lies a dark colored, medium grained **Hornblendic Gneiss** (75), which contains some biotite and is somewhat schistose in places. The specimen is more especially typical of the schistose portion. The third bed is a **Gneiss** (76), differing from 73 only in the smaller crystals of striated feldspar, which renders the porphyroid aspect of the other rock very indistinct in this. The next bed (?) — the fifth — which is separated from the fourth by a space where the rock has been cut away by the stream, is a coarse-red granite not different from 71.

It was below the last exposure that the long "log jam" referred to in the introduction began, and at this point we turned back to do the remaining portion of the river from below. Unfortunately, however, circumstances forebade the ascent of the Dore from its mouth beyond the center of Sec. 27, T. 36, R. 3 W. There is, therefore, between this point and the center of Sec. 17, T. 37, R. 2 W., a portion of the river which has not been examined, and along which it is probable that several exposures of rock exist.

A little south of the center of Sec. 27, T. 37, R. 3 W., there occurs, on the south bank of the stream, a rough-fractured, rather coarse-grained, grayish-white, thickly flecked with black **Granite** (77), in which striated feldspar forms the greater part of the feldspathic material. The rock is quite similar to portions of (67).

From the N. W. corner of Sec. 34, T. 37, R. 3 W., to the S. E. corner of Sec. 33 in the same township, the river dashes southward over an almost continuous granite bed, making in its course three somewhat precipitous leaps, of between 20 and 30 feet each. Much as it was desired to give this section careful study, circumstances permitted only a hasty walk over it. A few specimens only from different points of the exposure were obtained. A little south of the center of the N. W. qr. of Sec. 34, quite a large portion of the rock is a very neat gray, medium-grained, firm, regularly-fractured **Hornblendic Gneissoid Granite** (78), in which the feldspar is the bluish-white, striated variety. The brilliant feldspar facets, together with the duller quartz grains, among which are scattered a profusion of black mica and very dark hornblende, give to the rock a handsome variegation. In its lithological features the rock closely resembles 60, from which it differs mainly in being coarser grained, and in containing hornblende. The bedding planes strike E. 15° N. and dip to the southward about 88°.

At the South falls, on the west side of the S. W. qr. of the S. W. qr. of Sec. 34, the **Granite** (79), (80), (81), (82) presents a considerable variation in texture and color. All specimens, however, are alike in containing striated fieldspar; 79 is a white granite, variegated with black, medium-grained and crumbly, having an irregular fracture, and a dingy, yellowish-white, weathered surface. It is very similar to 68, being only a trifle coarser and containing a little more biotite; 80 is intermediate between 64 and 77, bearing the strongest resemblance to the latter; 81 stands close to 70, but contains a little more mica; 82 is faintly pinkish-white, medium-grained, has an irregular fracture, and contains less mica than any of its associates except the last.

About 40 rods south of the center of the N. E. qr. of the N. E. qr. of Sec. 4, T. 36, R. 3 W., there is, on the east bank of the stream, a **Granite** (83), varying from a little more than medium-grained to very coarse, and containing no striated feldspar. It is flesh-colored, contains much more feldspar than quartz, and a small amount of biotite, in rather large plates, scattered uniformly through the mass. No very closely allied rock was observed on the South Fork.

Near the center of the north line of the N. W. qr. of Sec. 9, T. 36, R. 3 W., there lies, on the east side of the channel, an exposure of rather fine-grained, slightly-porphyroid, reddish **Granite** (84), containing a considerable amount of biotite. The porphyroid character, not possessed by the whole exposure, is due to a sprinkling of larger crystals of striated feldspar through the orthoclase mass. The portion which is not porphyritic contains less orthoclase and is very similar to (64).

Not far from the center of the N. W. qr. of Sec. 9, there is a small exposure of rather coarse, flesh-colored **Granite**, containing biotite, from which specimens were taken, but they appear to have been lost.

The last exposure observed upon the Dore Flambeau lies a little west and south of the center of the north line of the N. E. qr. of Sec. 8, T. 36, R. 3 W. It is a light colored — sometimes pinkish — rather fine-to-medium-grained, irregular, roughish, fractured, darkly variegated **Granite** (85). All portions of the rock contain striated feldspar, the pinkish parts only containing orthoclase. At one point a band of gneiss exists whose bedding planes strike E. 11° N. and dip about 55° to the southward.

Returning again to the North Fork near Flambeau crossing, and not far below Muskalonge falls, in the S. W. corner of the S. W. qr. of Sec. 24, T. 40, R. 1 W., there occurs, upon the east bank, and in the bed of the stream, an exposure of coarse-grained, uneven, irregular, fractured **Granite** (86), closely resembling that at Muskalonge falls, but differing from it in being less gneissoid in structure. It is composed largely of feldspar — both orthoclase and the striated varieties, the latter bluish white, the former flesh-colored — muscovite in large plates, sometimes 2 c. m. in diameter, sparingly distributed, and large, subtranslucent bunches of quartz in considerable abundance. The gneissoid portions show evidence of decided contortion. The bedding planes cannot be made out with accuracy, but they dip toward the northwest and appear to strike not far from E. 40° N.

At the center of the N. W. qr. of Sec. 25, T. 40, R. 1 W., there are two outcrops of very uneven, coarse-grained, irregularly-fractured, flesh-colored **Granite** (87), a portion of which is pegmatitic (88), and identical with (2) and (9). The greater part of the exposure is very closely allied to (4) and (5). The two outcrops are about 20 rods apart, the lower being S. 26° E. from the upper. Muscovite is the only mica present, and adjacent to the larger aggregations of quartz it presents plates an inch or more square.

At the S. W. corner of the N. W. qr. of the N. E. qr. of Sec. 35, T. 40, R. 1 W., there is an exposure of mica and hornblende schists, the two being arranged in irregular, alternating beds, a foot or two in thickness. Those in the bed of the stream are rendered strikingly distinct by their varying resistance to erosion. The **Hornblende Schist** (89) [184 of the appendix] is rather fine grained, nearly uniform, greenish and grayish-black, often vaguely mottled with rusty spots. It is composed of lengthened plates and blades of hornblende, minute crystals of orthoclase and plagioclase feldspar, together with small, angular and rounded grains of quartz. This rock finds its closest observed ally in the exposure in Sec. 7, T. 41, R. 2 E., from which (22) and (23) are taken. The strike here is E. 11° N. and the dip to the southward 79°.

A little N. E. of the center of Sec. 35, T. 40, R. 1 W., there are some large, dislocated, angular masses of coarse granite, piled one upon another, and rising about 20 feet above the bed of the stream. One portion of the rock is a very coarse, flesh-colored **Granite** (90), similar to (87), and may have been moved from that point. Another portion is a compact bluish-gray **Granite** (91), composed largely of plagioclase feldspar showing striated facets, which bears a close resemblance to (86). These blocks, which are very large, lie upon masses of rock similar to themselves, which may possibly be in place.

After leaving the last point no rock in place was observed until near the confluence of the two streams. It should be borne in mind, however, that below Sec. 20, T. 39, R. 3 W., the work was done on foot. This made it impracticable to examine the banks as thoroughly as would have been possible could we have floated down the stream in our canoe. It is believed, however, that few if any exposures exist at present upon the North Fork which are not mentioned in this report.

At the S. W. corner of the N. W. qr. of Sec. 30, T. 37, R. 3 W., there is a rather coarse grained, uneven, irregularly fractured **Syenite** (92), which is thickly and coarsely blotched with black and often stained yellowish, becoming lighter as it weathers. It is composed of coal-black hornblende in masses sometimes 2 c. m. long, bluish-white striated feldspar, whose facets are usually indistinct, and comprising about one-third of the rock, together with quartz in large, irregular, dusky, glassy bunches. In places the exposure presents a slight gneissoid structure. About 30 rods above this outcrop, on the opposite bank, there is another which could not be examined.

In the N. W. corner of the N. E. qr. of Sec. 31, T. 37, R. 3 W., there is an exposure of coarse red granite and gneiss, in which the bedding planes strike E. 11° N. and dip about 70° or 75° west of north. The outcrop presents a total thickness of over 300 feet, 250 feet of which is the coarse red **Granite** (93). It is closely similar to (4), (5) and (87), and like them contains a meagre amount of muscovite and a small amount of quartz. The **Gneiss** (94) is rather fine grained, light, pinkish-white, striped and banded with black, and contains both biotite and silvery muscovite in somewhat separate bands.

The facts which were obtained regarding the indurated rocks of the Upper Flambeau Valley have now been presented. It would be especially desirable to correlate these observations and limit the several much denuded folds that probably exist in the valley. The facts that have been gleaned, however, appear to be too meagre and the exact location of the outcrops too uncertain to warrant any but provisional statements regarding the subject. There will be an attempt, therefore, to point out only a few features that may possess more or less significance.

1. There are no outcrops observed in the valley of either fork that suggest the existence there of Huronian beds, unless it be the highly silicious and very slightly magnetic syenitic rocks observed in T. 40, Rs. 2 and 3 E.

2. Rocks containing little or no hornblende are the most common and characteristic in both valleys.

3. Plagioclase feldspar with striated facets is quite abundant and more characteristic of the rocks than orthoclase.

4. Biotite is the most abundant and most common mica, and occurs wherever plagioclase feldspar is found, unless hornblende takes its place.

5. Muscovite is the chief or only mica found where plagioclase feldspar is wholly wanting.

6. Kyanite, staurotide and garnet are of frequent occurrence in the biotite schists and gneisses and are associated together.

7. Sahlite is found in considerable abundance at two exposures not far distant from each other on the North Fork. It also occurs in the rock at Turtle falls.

8. Other accessory minerals are tourmaline, augite, chlorite, viridite, pyrite, apatite, calcite, magnetite, hematite, ochre and titanic iron.

9. Granites and syenitic rocks, or gneissoid variations of them, are the only rocks observed on the Dore Flambeau.

10. So far as observed, rocks of a schistose structure are characteristic of, and peculiar to the North Fork valley, the less common gneisses being schistose and the still less frequent granites being generally gneissoid. This fact doubtless accounts, in part, for the greater depth of the valley.

11. With two exceptions, one of which is doubtful; the bedding planes of all exposures which have been determined strike between east and east 56° north — magnetic.

12. The greatest number of strikes fall between E. 40° N. and

E. 50° N., and the next greatest number between E. 10° N. and E. 15° N.

13. There are two valley systems to be hereafter pointed out which trend approximately in the direction of the average of the two prevailing strikes, and the largest and deepest valleys take the average direction of the commonest strikes.

14. All of the most nearly east and west strikes lie either in or look up nearly east and west valleys.

15. Regarding Turtle creek as the beginning of the North Fork, there are upon that stream four clusters of exposures looking up as many more-or-less marked and continuous eastward-trending valleys. The only other exposures observed upon the stream are situated in T. 41, R. 1 E.

HYDROLOGY AND TOPOGRAPHY.

The Flambeau river and its tributaries, as a central channel, with the East Fork of the Chippewa on the north and the Jump river on the south, drain an area whose topographical features appear peculiarly interesting, and, could they be worked up in detail, would no doubt be found highly instructive. Its river and lake systems are equally peculiar and suggestive.

The most general feature of the Flambeau slope, as limited above, is its gently but irregularly undulating surface, sloping rather rapidly nearly due southwest, for more than 90 miles, and maintaining throughout a nearly uniform width of half its length. If a curved line, convex to the southwest, be thrown across this incline, extending from Turtle falls a little to the south of Pike, Squaw and Squirrel lakes, it will mark a division of the slope into two portions. That portion upon the upper side of the line is, in its general aspect, more nearly level than the remainder, and will be denominated the Upper Lake Region. The portion lying on the south side of the curved line, and having a rather strong southwest slope, will be spoken of hereafter as the Lower Valley.

It will be seen by a study of the rivers of the region that the Flambeau slope is ribbed and furrowed longitudinally by four nearly straight, parallel, and more or less continuous valleys with their three dividing ridges. The upper portions of the axes of the four valleys are indicated upon the map and designated AA, BB, CC and DD. The axis of the northern valley lies along a line drawn from Sec. 22, T. 44, R. 1 E., through the center of Sec. 14, T. 39, R. 6 W., and is crossed or touched by the East Fork of the Chippewa eight times in the course of 40 miles, and the stream departs from this line in a single case 3 miles. The axis of the Flambeau valley lies along a line about 93 miles in length, extending from the N. W. corner of Sec. 24, T. 44, R. 4 E. to the center of Sec. 30, T. 34, R. 7 W. Regarding the Flambeau river, the North Fork to the mouth of Turtle creek, and Turtle creek as one stream, for such they really are, it is seen to cross the axis 19 times, and in no case to depart from it more than 5 miles. The axis of the Dore Flambeau valley lies along a line stretching from Sec. 24, T. 44, R. 5 E., through the N. W. corner of Sec. 34, T. 33, R. 7 W. The Dore, excluding that portion which comes from the eastward and then sweeps northward through Sec. 24, T. 40, R. 1 E., and including the small stream which comes in where the Dore bends to the southwest, and Deer Tail river, lie along this axis, and the two streams, in the course of 75 miles, touch the line 25 times. It may be mentioned also, in this connection, that Mud creek, on the other side of the Chippewa, comes in from the southwest along the same line. This third valley is continuous below the Upper Lake District, except just below the mouth of the Dore Flambeau, where it is choked by an accumulation of drift which deflects the stream from its course into the main channel. The southern valley, whose axis lies along a line stretching from Sec. 33, T. 44, R. 3 E., through Sec. 19, T. 31, R. 6 W., is not so evident and continuous; but near its axis, and trending in the same direction, lie portions of Maine, Fisher, Elk and Dore Flambeau rivers.

Another parallelism in the drainage system of this slope deserves attention here, and has already been referred to; it is, however, less marked than the last. The Elk river, the upper portion of the Dore Flambeau, and the upper portion of the North Fork, including the Manadowish, all flow in the same general direction, deviating a little from east and west lines, and it may be mentioned that the South Fork of Jump river, including Silver creek, approaches the fourth valley in nearly the same direction. These must be regarded as minor valleys leading into the more profound ones that have been pointed out.

It remains now, in regard to the direction of the streams of the slope under consideration, to call attention to a quite marked and prevalent system of similar bends which occurs to some extent in all of the valleys that have been pointed out. It will be noticed where there is a strong departure of the streams from the direction of the main valley axes, that the flow is oftenest to the northward in a direction nearly at right angles with that of the valley axes, and that the return to the southward is along lines more oblique to the axes of the valleys.

As types of these bends there may be mentioned the two strong flexures of the Chippewa in T. 42, Rs. 1 and 2 west; the two similar bends of the North Fork, and those of the Dore Flambeau and Skinner creek, all of which lie in a line trending a little west of south; the same feature is again repeated by the Elk river near Phillips in the south valley. Other examples may be found by referring to the map of the region, and these features will be reverted to when the glacial deposits of the region are considered.

In regard to the two branches of the Flambeau, it may be said that they make their way southwestward over a series of steps, most frequent in the lower valley, caused usually by bowlder dams, but also by ledges of indurated rock. Over these dams the water forms numerous lengthened chutes and rapids which probably average 8 feet or 10 feet in height, and furnish in the aggregate an almost unlimited water power. At present they are serious obstacles to lumbermen, causing log-jams whenever there is low water.

Mr. Price has attempted to avoid the jamming during low water by putting in a dam at the mouth of Round lake on the Dore Flambeau, in order to hold the water for a time and use it at pleasure. How successful his effort has been I am not informed, but it would appear that were there a series of dams put in at the mouths of several lakes on the two forks and on the Turtle, and these worked in concert, there would be no difficulty in carrying out all of the logs that might be put in during any year.

The water is soft and carries but little sediment, but is colored dark during wet periods by the leachings from forest leaves. When the North Fork began to freeze in November of 1877, there was first noticed a coating of ice upon the stones and sticks below the water as it broke over the rapids. At the same time there were forming upon the surface a profusion of ice stars, often an inch or two across, which were tossing about making fruitless endeavors to join one another. As these crystals tumbled down into the stiller water they formed floating sheets of ice, which drifted on to the next rapids, forming ice jams which in a few hours, in some places, extend back several miles, covering the quiet portions of the stream.

A careful study of the distribution of lakes in the region under consideration reveals a grouping of them quite as marked and extensive as is the symmetry of arrangement that has been shown to exist among the rivers. Considering the long valleys that have been pointed out as extending from the Michigan line across the Chippewa to the lakes beyond, it will be seen that nearly all of the lakes of the region cluster in linear series along the four valley-axes, and that there is such a grouping of lakes along these lines as to throw them into three rather broad belts, stretching across the valleys nearly at right angles to their axes, which are convex toward the south and concave toward the north. There lies, then, in the valley before us, an Upper Lake Region, a Middle Lake Region, and a Lower Lake Region, the first two lying above the confluence of the two forks of the Flambeau. These land archipelagoes are highly suggestive, and the upper two are divisible, it is believed, into minor concentric bands, which are shown upon the map and will be pointed out in another place.

Nearly all of these lakes, so far as observed, possess the characteristics peculiar to those of broad, morainic belts. They are beautiful sheets of water, clear, soft and deep, encircled by bold, fantastic rims, and dotted with tree-clad island cones of such varied beauty in the autumn season, that as one toils in unexpectedly upon them up the rapids of the narrow shaded rivers, he forgets his fatigue and revels in an exquisite garden of foliage plants. Sometimes a fringe of white cedar lies upon the water's edge; higher up a wreath of white birch, then a belt of poplar, and, capping the rounded hill-tops, maple and yellow birch, throughout all of which there is a generous setting of rich green white and Norway pines. Gravelly beaches and weedless sandy bottoms are the rule, and small marshes are of rare occurrence. Muskalonge and yellow pike-perch are common, and it is said that the lake trout is found in Trout lake. If the State Park were put in communication with railroads, hotels built upon it, and the lakes stocked with choice fish, there appears to be no reason why it would not be one of the finest pleasure resorts in the northwest.

Fantastic as are the contours of many of the lakes, especially in the Upper Lake Region, there is, after all, something of regularity in the distribution of bays, capes and islands, as well as in the positions of the longer axes of many of the lakes. The majority of those lakes which are longer than wide have the longer axes generally trending N. E. and S. W., or in the direction of glacial movement, and the stronger land and water indentures often lie in pairs, and trend in the same direction. In Trout lake there is a chain of islands trending N. E. and S. W., and in Island lake another trending nearly at right angles to the last. The lakes in the Upper Lake Region appear to be but the deeper portions of a once continuous sheet of water, in which the hard-wood ridges referred to above stood as so many islands. As this lake gradually drained over its curved southwestern rim, the finer argillaceous material moved off with the water or dropped into the deeper basins, thus leaving the kettles more or less obliterated, and spread with a mantle of sand through which but few bowlders protrude. The tamarack swamps and cranberry marshes in this region are but ancient lake beds, over whose sandy bottoms is spread a very shallow stratum of peat, through which an occasional large bowlder is seen.

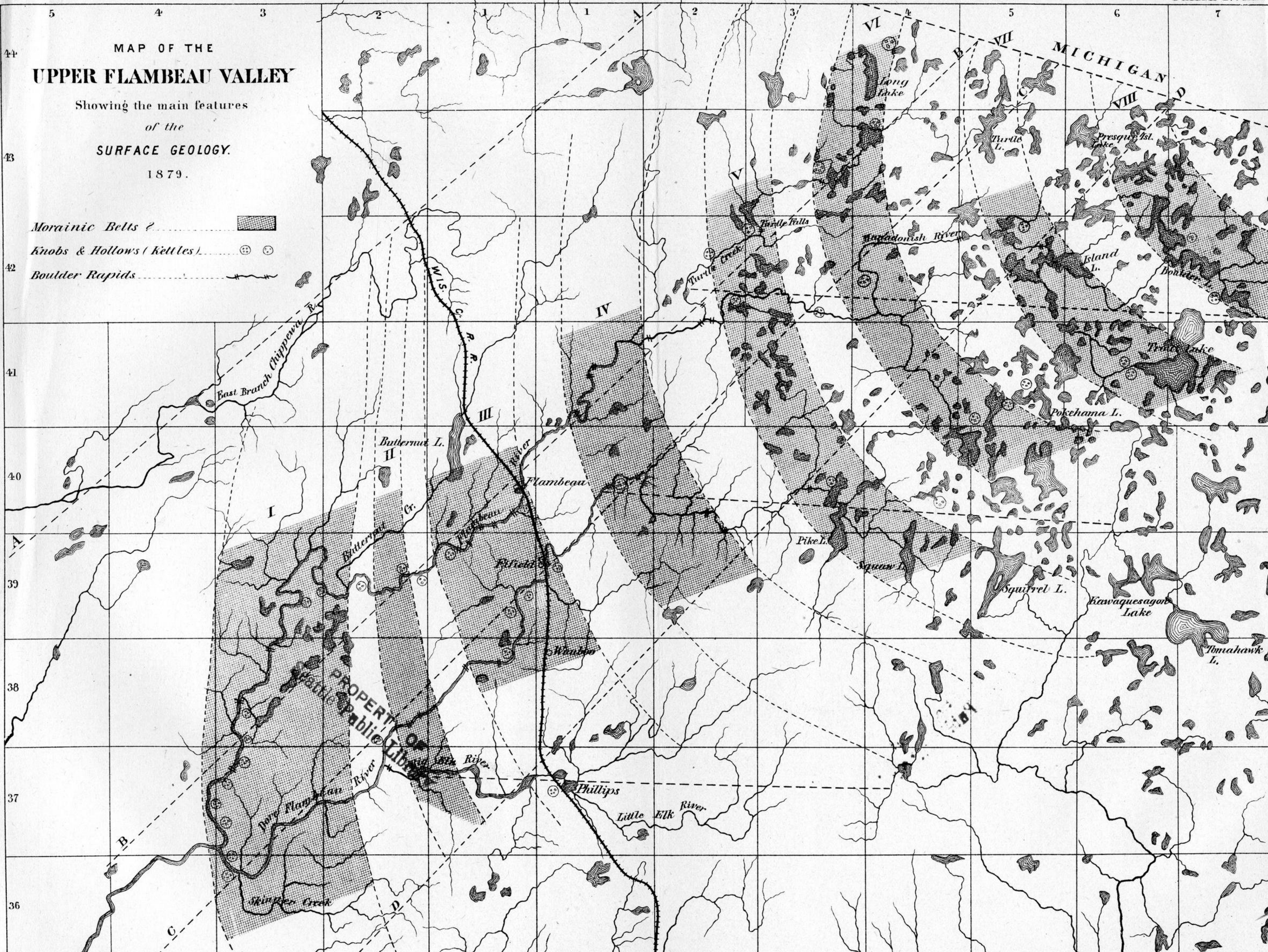
GLACIAL FEATURES.

While at only two points in the Flambeau valley ice-scorings were noted, and at these points not sufficiently marked to furnish accurate data as to the direction of movement, yet the other evidences of glacial action are so numerous throughout the region that there can be no doubt but that a gigantic ice stream moved across this portion of the state, from the northeast toward the southwest. Above the confluence of the two forks of the Flambeau, about twenty-two areas showing distinct kettles were noted, and sixteen areas showing parallel drift ridges or isolated knolls. Their position is shown upon the map. The extent of the kettle areas in a direction at right angles with that of the valley axes can only be conjectured at present, but their extent along the line of the streams, so far as observed, is never more than a mile or two, and is usually less. Occasionally the kettle knolls attain an elevation of 100 feet, but they are seldom more than 20 feet or 30 feet in height, and very often the merest hollows and hills. In the Upper Lake Region they are usually nearly obliterated, and are generally covered with a mantle of rather fine, yellowish sand, containing a little gravel, which hides most of the bowlders except where the kettles are cut by the streams or washed by the lakes. A few of the kettles appear to be mostly composed of sand and gravel. Those kettles in the Upper Lake Region which are not coated with, or composed of sand, appear to stand above the general level of the country; they are steeper and more strongly marked than others of the region, and are clad with a dense growth of maple, elm, hemlock and yellow birch; woodmen speak of them as "hardwood ridges," and the Indians appropriate them for sugar bushes. One of these areas north of Turtle lake has points 100 feet above the water level, and about Pokehama lake there are kettles of this sort 60 feet in height. In the Lower Valley, however, the reverse of what has been said is true; there the kettles, though generally small, are more marked and rarely sand capped. In Sec. 10, T. 38, R. 3 W., there are hills rising 80 feet and 100 feet above the Flambeau, which flows at their feet. Occasionally long bowlder-ridges and isolated knolls are seen standing in the marshes, or other generally level tracts. These elevations attain a height varying from 20 feet to 110 feet, and trend from S. 40° E.

through due north and south to S. 40° W. The highest ridge of this sort noted trends north and south through Sec. 34, T. 38, R. 2 W. Along the east side of this flows the Dore Flambeau, 110 feet below its crest. Some of these knolls and ridges are evidently "hog-backs," like those in Jefferson county and other portions of the state, but others I am inclined to regard as portions of transverse drift accumulations, homologous with terminal moraines.

The till of this region, if we may judge from appearances along the river beds, contains a very large amount of very coarse material. Many of the bowlders are so large as to be readily mistaken for rock in place, when partially covered with earth. On the north shore of Bowlder lake there is a large erratic, 43 feet long, 24 feet wide and 20 feet high. If the masses of rock at Rocky Carry rapids, and those below Flambeau, which have been referred to are bowlders, some of them have two dimensions more than double the largest given above. This very coarse material does not present an even upper surface, but appears to be thrown into lengthened ridges trending generally N. W. and S. E., across which the streams break usually after having flowed some distance parallel with them, forming the bowlder rapids that have been referred to, and of which about thirty prominent ones have been noted and their positions indicated upon the map. It should be said in this connection, as suggesting a considerable linear extension of these bowlder ridges, that the bowlder rapids often lie in pairs on the two forks on lines not far from vertical to the valley axes. A further proof of the linear distribution of these bowlders is found at Bowlder lake, whose north shore trending W. 40° N. is one continuous wall of granite blocks, piled as steeply as they will lie and extending more than a mile. The lake itself is deep, free from islands and wholly without bowlders upon its southwest shore, even at the water's edge, while a mile and a half to the southwest, at the mouth of the lake, there is a bowlder dam which holds back the water of this lake; a line, too, drawn from the rapids parallel to the north shore of the lake, cuts across the kettle area between Sandy-bottom and Trout lakes.

It will be well here to attempt the correlation of some of the facts that have been presented, and in what follows it will be assumed as probable that the marked kettle areas which have been noted, the bowlder rapids, the peculiar stream-flexures and most of the lakes in the region under consideration indicate more than usual accumulations of drift material where they occur. Indeed, most of the strong bends of the North Fork and of the Dore Flambeau are due to morainic deposits, along the bases of which the streams flow until


MAP OF THE
UPPER FLAMBEAU VALLEY
Showing the main features
of the
SURFACE GEOLOGY.
1879.
Morainic Belts
Knobs & Hollows (Kettles)
Boulder Rapids
MICHIGAN
Long Lake
Turtle L.
Presque Isl. Lake
Turtle Falls
Turtle Creek
Manitowish River
Island L.
Trout Lake
Pokehama L.
East Branch Chippewa R.
Butternut L.
Flambeau
Fifield
Pike L.
Squaw L.
Squirrel L.
Kawaquesagon Lake
Tomahawk L.
Elk River
Phillips
Little Elk River
Dore Flambeau River
Skinner Creek
Butternut Cr.
W.I.S. C. R.R.
Flambeau River
I
II
III
IV
V
VI
VII
VIII
A
B
C
D

they can finally break over them and return again to their respective valley axes; and from what has been said in regard to the bowlder rapids, it would appear that those piles of coarse blocks are but the remnants of larger accumulations of debris, from which the finer material has been removed by the streams and deposited so as to produce slack water at the head of the rapids below them.

It has been shown that the lakes of the Flambeau slope, including the four clusters west of the Chippewa river, form linear series lying along the axes of the four valleys that have been pointed out, and that they are further grouped into three broad concentric belts, convex to the southward and extending across the valleys nearly at right angles to their axes. It is now to be shown that the upper and middle lake belts are divisible into minor concentric ones which are also convex to the southward, and approximately perpendicular to the valley axes; and, that in these belts are found most of the kettle areas and bowlder rapids, observed by the writer, as well as many of the peculiar stream-flexures that have been referred to. These features are indicated more clearly and concisely upon the map than they can be described. It will be seen that these belts are eight in number, and that they appear to span the four valleys, except in the Upper Lake Region, where they lie further to the south. These eight belts are further divisible, it is believed, so as to make in all at least twelve or fourteen, though a larger map of the region than the one accompanying this report would be required to make the subdivisions apparent, and more detailed work would be necessary to establish them.

It is not affirmed that the facts in regard to topography, lakes, rivers and glacial deposits here presented, and correlated as they have been, amount to demonstration, but it is believed that they strongly support the following propositions:

(1.) A broad and probably continuous sheet of ice moved southwestward through a four-grooved valley with the central portion usually keeping the lead.

(2.) The front of the ice-sheet made a long oscillating halt during which were developed the morainic deposits in the Lower Lake Region, and probably by similar causes, though less pronounced, the accumulations of the Middle and Upper Lake Regions took place.

(3.) The three stages at least indicate three periods favorable to glacial accumulation upon the Flambeau slope.

(4.) The eight transverse belts that are indicated upon the map are believed to be morainic in character.

(5.) These morainic belts are regarded as indicating so many minor periods of glaciation embraced within the three periods referred to above.

SOIL AND VEGETATION.

As the Upper Lake Region and the Lower Valley are diverse in their glacial and drainage features, so they are as regards soil and vegetation. As might be inferred from what has already been said, the soil in the Upper Lake Region is a rather fine, nearly uniform yellowish sand, containing very little argillaceous material, and but a small amount of vegetable mold; even in the tamarack swamps, where peat is found, so far as observed, it is only a foot or two deep. Those kettle areas, however, in this region, which have never been submerged, possess a soil that is a warm, argillaceous, sandy and gravelly loam. Passing down the Lower Valley the transition appears gradual from a very sandy soil containing but little mold through a warm sandy loam to a more substantial soil containing much reddish clay mingled with sand, gravel and bowlders. It should be borne in mind, however, in regard to these statements, that so much of washing has taken place along the river bottoms that the features there presented are not likely to be characteristic of the generally higher land a half mile or more from the streams. At one place on the South Fork, in a heavy forest of pine, hemlock and yellow birch, forty rods from the river, so much of erosion has been accomplished since the present forest occupied the soil, that now yellow birches may be seen standing upon their roots four feet above the ground. Often the river bottoms are little more than bowlder beds, upon which the trees obtain so insecure a footing as to be easily overturned by the heavy winds which sweep up the valleys.

Considering now the vegetation in the two regions, the contrast is seen to be strong. In the Upper Lake Region the trees are small, stunted and scattering; in the Lower Valley they are large, vigorous and dense. Norway and scrub pine prevail in the former; white pine and hemlock in the latter. White cedar in the swamps of the latter are replaced by stunted tamaracks in those of the former. The paper birch stamps the strongest feature upon the face of the Upper Lake Region, while the yellow birch is found mainly in the Lower Valley. Spruce and balsam are found in suitable places over the whole slope, but the latter is most abundant and most vigorous toward the south. Upon the unmodified kettle summits at the north, and over much of the high land further south, maple, elm, ironwood and basswood are found. A few small butternuts were observed near the mouth of the Dore Flambeau, and scrub black oaks were seen growing about the southern portion of Pokehama lake. Black alder and kinnickinnic fringe the streams, and upon some of the flats small black ash, elm and soft maple grow. The wild grass and sedge marshes are few and small, extending usually in narrow strips along the streams; the largest of these occur on Turtle creek below the falls, and on the North Fork between the mouth of Turtle creek and Sec. 19, T. 42, R. 4 E. The latter marsh attains in places a width of a mile or more, and through it the river takes a very tortuous course, often making new channels for itself. Many of the small, open swamps in the Upper Lake Region bear a few cranberries, and it is said that J. S. Hoxey owns a cranberry marsh in Secs. 1 and 36 of Ts. 41 and 42, R. 7 E., which he thinks of improving.

The aggregate amount of choice pine land in the Upper Flambeau slope is considerable, but it is confined mostly to the Lower Valley, there being but little in the Upper Lake Region. More than 60,000 acres of this land is owned by the Cornell University and offered for sale. Comparatively little of the choice pine lands lie in immediate contact with the main channels, a "haul" of half a mile or more being the rule. The amount of pine that has been wasted in this region by injudicious cutting probably exceeds that which has been marketed. It has been the practice of lumbermen to go through their pine and select only the largest trees, leaving much really valuable timber standing. The result is that fires get into these choppings and destroy what trees have been left standing, and often spread over untouched sections.

It is interesting to note how long the trunk of a large white pine will withstand disintegration when it falls in a damp, shaded forest. On the North Fork, there was seen a yellow birch sixteen inches in diameter, growing with its roots astride a white pine log more than two feet in diameter and 50 feet long, which still retains its outline sharply. Of course the seed of the birch must have fallen upon the pine log after it had become moss-clad and had decayed sufficiently to furnish nourishment and support for the young birch until its roots could penetrate the earth.

APPENDIX.

MICROSCOPIC EXAMINATION OF A SUITE OF SPECIMENS FROM THE FLAMBEAU RIVER COUNTRY, WISCONSIN, BY R. D. IRVING.

The collection submitted, eighteen specimens in all, includes hornblende-schist and hornblende-rock, syenite, diorite, diabase, quartz-schist and gneiss. Most of the specimens belong to the first named kinds; the remaining kinds being represented by only one specimen each.

Hornblende-Schist and Rock.

Here belong numbers 2e, 3, 4, 23, 42, 75 and 184, which are black and very fine-grained but still macroscopically crystalline schists; 44, 45 and 46, which are dark grey, aphanitic schists, as also 133c and 143, which are black, minutely crystalline hornblende-rock. In nearly all of the schistose specimens here included, the groundmass is predominatingly quartzose, usually making up but a small portion of the rock. In this respect, however, the groundmass varies somewhat, as also in the coarseness of its constituent granules, which are commonly very minute. The hornblende, always the main, and in nearly every case the greatly predominating constituent, is of the usual greenish variety (as seen in the thin section), and is present in minute blades, often distinguishable by the naked eye, which commonly lie with the foliation of the rock. In some sections there is also a general tendency to an arrangement of the hornblende-needles with their longer axes in one direction. Other sections show this mineral in radiating tufts, and others again in interlacing blades. Orthoclase is present in nearly all of the specimens, but is generally much less abundant than the quartz, though in a few slices equaling it in quantity. The following accessories were noted in the several sections: plagioclase, biotite, augite, sahlite, garnet, chlorite, magnetite, titanic iron, a white decomposition product of titanic iron, hematite, ochre, apatite and calcite. In most respects these hornblende-schists resemble those described by Dr. Wichman in Vol. III of these reports, as occurring largely in the Huronian of the Marquette and Menominee regions.

The last two specimens mentioned above, Nos. 133c and 143, from their more massive appearance and lack of arrangement of the hornblende prisms — which are, moreover, much larger than in the schistose specimens — would seem to belong to hornblende-rock, the first named specimen having a feldspathic base, the latter a predominatingly quartzose one.

The following are brief descriptions of the several thin sections:

Specimen 2e. A nearly black, very fine-grained, but macroscopical by minutely crystalline, compact schist. Minute shining needles of hornblende appear to make up most of the rock. Round whitish patches, $\frac{1}{30}$th inch in diameter, are studded over the fracture.

U. M. *Hornblende*, in minute blades, greatly predominates. The blades appear mostly to lie in the plane of the section, a few only showing the prismatic cleavage. There is also evident a tendency of the blades to arrange themselves with their longer axes in one general direction. *Quartz*, with some *orthoclase*, both in minute particles, makes up the groundmass. The whitish spots above alluded to as seen macroscopically are made up of clusters of brilliantly polarizing particles of *sahlite*. These particles are evidently in many cases fragments of larger single crystals, as shown by their corresponding optical orientation and cleavage directions. *Magnetite* is present in a few minute crystals and in fine dust.

Specimen 3. Both macroscopically and microscopically similar to the preceding specimen. In this case, however, the hornblende prisms are cut for the most part transversely by the plane of the slice.
The groundmass is finer than in 2e, and the sahlite is not so plenty.

Specimen 4. Macroscopically this rock resembles the two preceding, having, however, a much closer grain.

U. M. Minute blades of *hornblende*, in a ground mass of *quartz*, with some *orthoclase*. A few patches of *calcite*.

Specimen 23 (17). A black, minutely crystalline, very fine-grained rock, not showing any schistose tendency in the small fragment sent.

U. M. Greenish *hornblende* greatly predominates, its blades interlocking and at times excluding the base. In other parts of the slice are large patches of the groundmass of *quartz* and *orthoclase*. *Biotite*, in numerous small blades, *apatite*, in many minute rods and hexagons, and a little magnetite are also present.

Specimen 42 (39). A nearly black, very fine-grained rock, showing minute whitish and reddish spots.

U. M. *Hornblende*, in radiating tufts of pale greenish blades, is the main constituent. The white patches of groundmass are chiefly *orthoclase*, with some *plagioclase*, and but very little *quartz*. A few clusters of magnetite particles are to be seen.

Specimen 44. A dark grey, aphanitic schist, mottled with minute white patches.

U. M. Chiefly a network of interlocking fibres and fibrous crystals of *hornblende*. The very sparse groundmass is composed of *orthoclase* and *quartz*, which are occasionally aggregated into white patches of some size. A few of the orthoclase particles exhibit the characteristic twinning. *Sahlite* is present in brilliantly polarizing blades and irregular particles. Clinodiagonal sections of this mineral show an angle of 39° (augite angle) between vertical and elasticity axes. Besides the imperfect prismatic cleavage of augite, the characteristic basal and orthodiagonal cleavages of sahlite are well marked. A very little *magnetite* is present.

Specimen 45 (42). A dark grey aphanitic schist.

U. M. The slice is almost altogether made up of minute interlocking needles of green *hornblende*. A little of the usual groundmass, *magnetite* and *sahlite* are also to be recognized.

Specimen 46. A schist resembling 44 and 45.

U. M. Almost completely made up of interlaced microliths of *hornblende*. A small quantity of the usual *quartz-orthoclase* groundmass, *sahlite* or *augite*, and *hematite* are also to be seen.

Specimen 75. A black, very fine-grained schist, sparkling with minute hornblende blades.

U. M. The *hornblende* lies mostly in the plane of the slice. The groundmass is of *quartz* and *orthoclase*, some particles of the former exhibiting cavities with minute fluid inclusions. *Augite*, *titanic iron* or *magnetite*, and *apatite* are the accessories.

Specimen 82. A black schist resembling 75.

U. M. The *hornblende*, which lies mostly in the plane of the slice, is much less abundant than in any of the foregoing rocks. The groundmass is chiefly of *quartz* with a little *orthoclase*. *Chlorite* is present in bluish-green, non-dichroitic or feebly dichroitic scales, as large as the hornblende particles. Pinkish *garnet* appears in a few clusters of irregularly outlined particles, .045 m. m. to .140 m. m. in diameter. *Titanic iron* is abundant in more or less distinctly hexagonal shapes. *Hematite* and very rare *apatite* are also to be recognized.

Specimen 184 (89). A black, fine-grained, highly crystalline schist resembling 75 and others of the above described rocks.

U. M. The greatly predominating *hornblende* needles, averaging .45 m. m. long, lie wholly in the plane of the section. The intervening white matter is chiefly *quartz*, but *orthoclase* and *plagioclase* are both recognizable. *Magnetite* appears in a few clusters, and *ochre* stains are to be seen at a few points.

Specimen 133c (49). A black, highly crystalline rock, not so very fine-grained as the preceding. With the lens can be recognized hornblende, quartz, pyrite and a white feldspar.

U. M. *Hornblende* makes up most of the slice. It does not show any tendency to a single direction, the blades presenting all sorts of sections and lying in all directions. The blades have the usual jagged edges and are often as much as .65 to 8 m. m. wide. The other ingredients are: *orthoclase*, much altered to *kaolinite;* rarer *quartz; titanic iron*, largely altered to a greyish white substance; and *apatite.*

Specimen 143. A black, highly crystalline, fine-grained, non-schistose rock.

U. M. *Hornblende*, in crystals often 0.75 m. m. in length, and not lying in any definite direction, is the main ingredient. In the intervening white spaces *quartz* predominates, but with it may be recognized a few *plagioclase* particles. There are also present *titanic iron*, with its characteristic white alteration-product, and *apatite.*

Syenite.

Specimen 133e (50). A black-and-white-mottled, moderately fine-grained rock. Both hornblende and orthoclase can be recognized macroscopically.

U. M. Interlocking blades of *hornblende*, and much kaolinized *orthoclase*, in larger particles than those of the hornblende (sometimes 3 to 4 m. m. across), are the main ingredients. There is also present *chlorite*, resulting from an alteration of the hornblende.

The lack of any fine groundmass, and presence of large orthoclases, make this rock properly a syenite.

Diorite.

Specimen 133b (48). A moderately fine-grained, massive, black rock. The hornblende and feldspar can both be recognized macroscopically. The powdered rock effervesces quite briskly in hot hydrochloric acid.

U. M. The *hornblende* is in quite large crystals, compared with those of the hornblende-schists, and exhibits very intense absorption and dichroism. *Plagioclase* appears in large, much altered crystals. Traces only remain of the characteristic banding in the polarized light, a few grains, however, showing it plainly. There are also present secondary *calcite* in quite large grains, *quartz*, *augite* and *magnetite.* The rock is a "quartz-diorite."

Diabase.

Specimen 26. A fine-grained, compact, very minutely crystalline, massive, black rock.

U. M. The constituents are: *Augite*, largely altered to *uralite*, which is met with surrounding cores of the augite, and penetrating it along fissures; *plagioclase* optically near labradorite, and often much altered, yielding then an aggregate polarization; and *magnetite*, which is abundant and often in distinct crystals. The rock is a "uralitic diabase."

Quartz-Schist.

Specimen 133f (51). A very fine-grained, arenaceous, light grey schist. The particles can be crumbled apart with the fingers.

U. M. The greatly predominating sandy groundmass is made of minute *quartz*-granules. In this groundmass are numerous very narrow blades of *biotite*, *hornblende* and *chlorite*, named in order of relative abundance. Sparsely scattered *magnetite* in distinct octahedra, and single rolled quartz-grains, much larger than the constituent grains of the groundmass, are also to be seen.

Gneiss.

Specimen 77. A fine-grained, dark-greenish-gray, schistose rock, in which quartz, pinkish cleavable orthoclase, and a soft, bright lustred, dark greenish grey micaceous mineral can be recognized macroscopically, the last named constituent coating the schist plane.

U. M. The main ingredients recognized are: Much altered *orthoclase; quartz*, like the quartz of granite; with numerous liquid-filled cavities, many showing a bubble; *plagioclase;* and a greenish *chloritic substance* (viridite). The latter ingredient cannot be assigned to any known mineral. It occurs for the most part in quite large areas having an imperfectly fibrous structure. Faint traces of dichroism can be observed in some of the fibres, but nearly all of the greenish areas remain wholly dark in all positions between crossed nicols, or are dark with a few minute patches of light. A very few of these areas show traces of cleavage and then a more distinct dichroism. A few of them show no inclusions, but most contain numerous brown, opaque needles, crossing each other, and radiating, but on the whole appearing to emphasize the cleavage of the original mineral. This would seem to have been hornblende. Minute particles of hematite and biotite and a few good sized apatite crystals were noticed.

PART VII.

CRYSTALLINE ROCKS

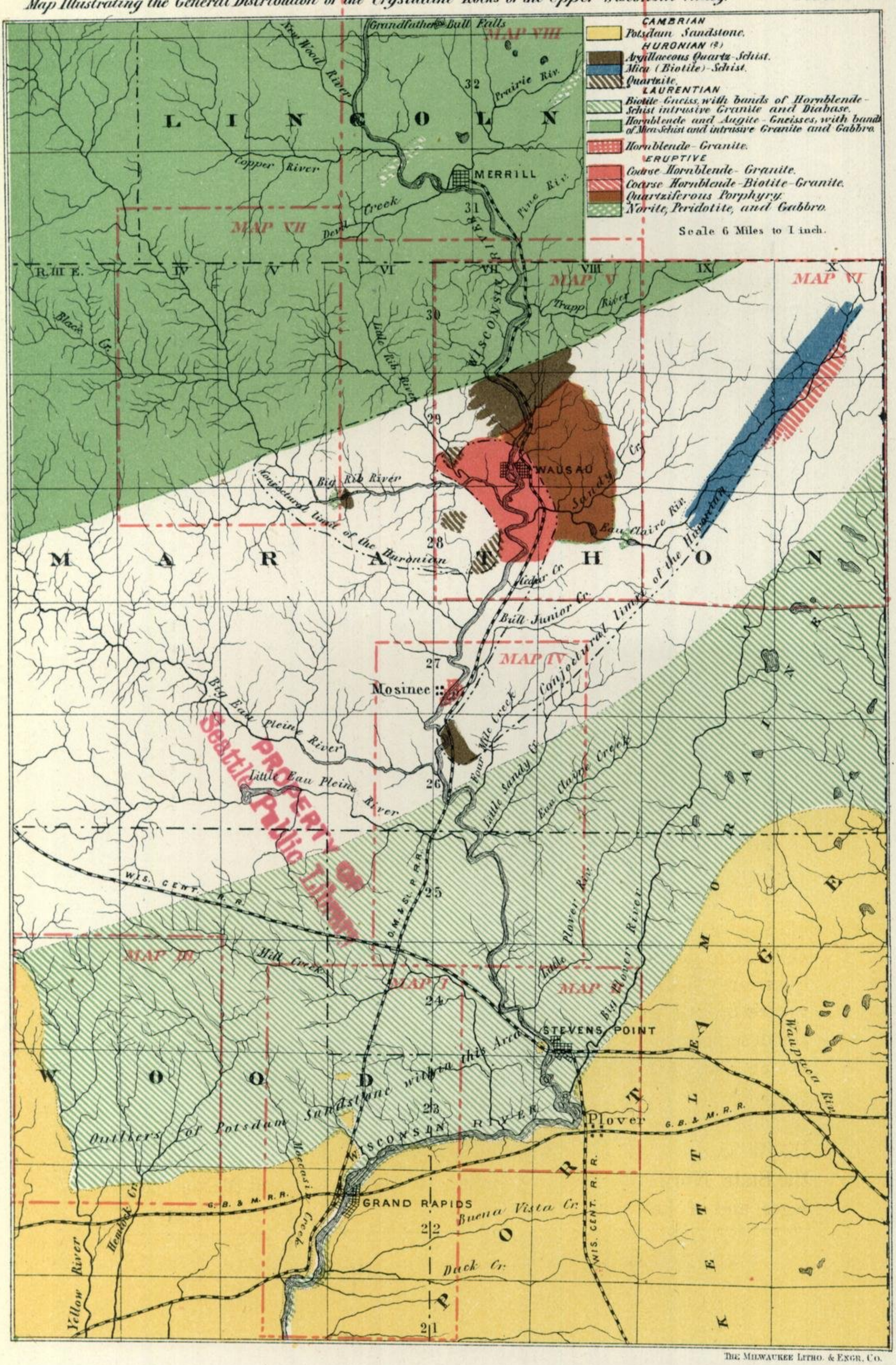
OF THE

WISCONSIN VALLEY.

BY R. D. IRVING AND C. R. VANHISE.

(FIELD OBSERVATIONS BY R. D. IRVING AND A. C. CLARK.)

Map Illustrating the General Distribution of the Crystalline Rocks of the Upper Wisconsin Valley. Plate No. I



THE MILWAUKEE LITHO. & ENGR. CO.

PREFACE.

In Vol. II of this series of reports, I have described briefly the crystalline rocks of the Wisconsin river valley so far as the field explorations then completed made it possible. The lithological descriptions were based upon the older methods, being only in a few instances reinforced by incomplete microscopic examinations by C. E. Wright.[1] Subsequent to the publication of that volume, further explorations in the region about Wausau, and thence northward, were made by A. C. Clark of that place. Mr. Clark's note books and specimens were placed in my hands in the early part of 1880, with the request that I should examine his collections microscopically. The opportunity was then taken to include in this study all the specimens which I had myself collected in this region in 1874, and thus to prepare a report which should embody all the material collected up to this time.

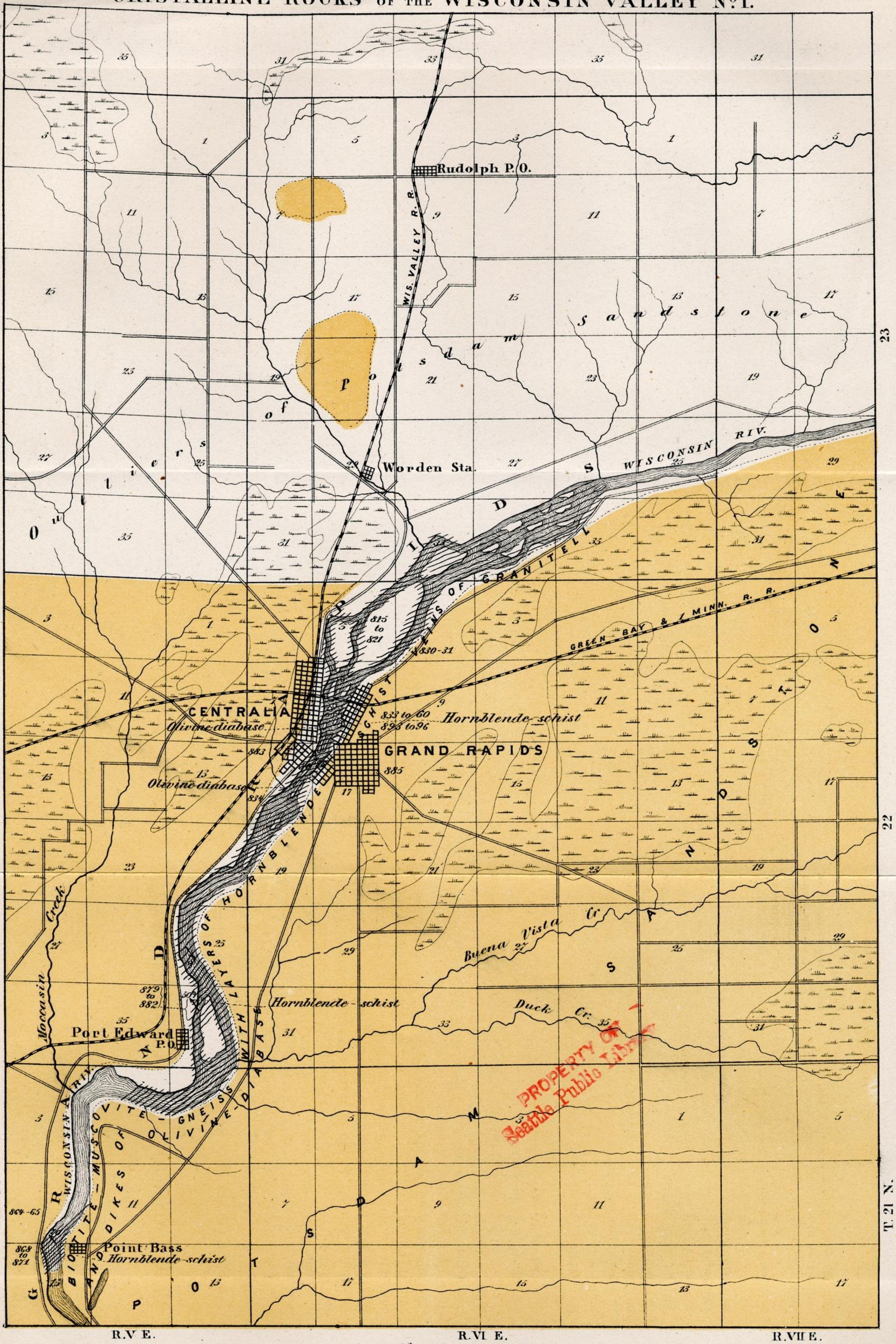
In the summer of 1880, after having made a first general examination of most of these specimens with the microscope, I found my hands so full of other work that it became necessary for me, in order to complete this study, to call in the aid of Mr. C. R. Vanhise. Mr. Vanhise's work has consisted in the detailed examination of all the sections for the tables of microscopic descriptions of the following pages. My own share of the work has consisted in the constant supervision of the microscopic work, in the correlation of results, and in the preparation of the maps and text of this report.

Many rock exposures in the Wisconsin valley remain yet unexamined; so that what is here given can be regarded only as a record of results to date rather than as a complete presentation of all of the obtainable facts with regard to the crystalline rocks of the region in question. This report, then, being so largely in the nature of a simple record of progress, I have thought it more appropriate to group the descriptions so as to correspond to the accompanying series of sketch maps. The numbers used in the tables of microscopic descriptions are the original collection numbers, the specimens corresponding to which will be found in the cabinets of the State University, and of the Wisconsin Academy of Sciences, and, less completely, in those of the State Normal Schools, of Beloit, Racine, Ripon and Milton Colleges, and of Lawrence University.

R. D. IRVING.

[1] See Vol. II, p. 637.

CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY No. I.



Scale $1\frac{1}{3}$ miles to 1 inch.

Numbers attached to exposures refer to specimens

CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY.

ROCKS OF THE VICINITY OF GRAND RAPIDS.

SKETCH MAP I.

The crystalline rocks of the area represented upon Sketch Map I make their principal exposures in the bed of the Wisconsin river from Point Bass almost continuously to the eastern line of the map. In the southern half of this map, everywhere away from the river, they are buried beneath a rather thin covering of the Potsdam sandstone. In the northern half of the map, the Potsdam sandstone presents itself in detached and as yet ill-defined areas, which grow smaller and rarer towards the north. In the intervening spaces, the crystalline rocks appear everywhere to be near the surface, the small cuttings, for instance, upon the line of the Wisconsin Valley Railroad, stripping them continually. Although so near the surface in these areas, they nevertheless make but few and unsatisfactory exposures, being either covered with marsh peat or weathered down into soil.

The general characters of the rock exposures of the Wisconsin river above and below Grand Rapids have been given somewhat fully in Vol. II.[1]

The descriptions there given represent these rocks as a series of micaceous gneisses, trending from N. E. by E., to E. by N., and often decomposed into kaolin, with a very high northerly or southerly dip; interstratified with which, in subordinate quantity, are hornblende schists, and intersecting which are masses and veins of granite and granitell. Our subsequent microscopic study modifies this description only so far as to include intrusive masses of black olivine-diabase, which, at the time of the original examination, were not separated from the macroscopically similar hornblende rocks.[2] The intrusive

[1] Geology of Central Wisconsin, pp. 466-477. See, also, for description of sandstone of this vicinity, pp. 529 to 530, 563 to 565.

[2] The hornblende rock of Figs. 7 and 8, p. 473, Vol. II, is an olivine-diabase. Both the diabase and the red granite-like rocks of these figures are to be taken as intrusive. The rock mentioned at the bottom of p. 475 (884) is also olivine-diabase, as is also that of Bed 10, Grand Rapids section, p. 473.

granite, also, is all rather in the nature of a granitell, often tending towards a granitic-porphyry. In the following tabulations, the results of the microscopic study are given separately for the gneisses, schists, granitells, hornblende schists, and olivine-diabases, in the order named.

The gneisses are coarse-grained to fine-grained. In color, the coarse kinds are commonly mottled white and black, or pink, white and black, while the finer kinds tend to a more uniform gray or pinkish-gray color. The feldspar, quartz and mica are generally recognizable, the feldspars including both flesh-colored and white kinds, while the mica is either or both of black biotite or silvery muscovite. In kinds holding much chlorite, that mineral is perceptible in minute greenish particles, or produces a general greenish hue. A schistose structure is always strongly developed and is emphasized by the aggregation of the mica along certain planes.

Under the microscope the feldspars and the quartz of these gneisses always make up the larger part of the rock. The former commonly predominates, although in some sections the quartz forms as much as four-fifths of the whole. Of the feldspars, orthoclase, except in one section, is the predominating one, and occasionally excludes entirely the triclinic kinds. It is nearly always more or less clouded and whitish from alteration, the alteration being not unfrequently carried very far. Its common inclusions are apatite, in the usual needle-shaped crystals, and augite or epidote in rounded particles. Oligoclase nearly always accompanies the orthoclase, but is commonly subordinate to it in quantity. As to appearance and inclusions it closely resembles the orthoclase, from which it is commonly indistinguishable in ordinary light.

The quartz commonly makes up from a fourth to a half of the section, only occasionally running up to three-fourths or four-fifths of the whole. Its most usual mode of occurrence is in large irregularly shaped interlocking individuals, which bear such relations to the other ingredients as to indicate its relatively late crystallization. In some sections, however, the large quartz areas seen macroscopically resolve themselves into aggregates of minute rounded particles. The most common inclusion in the quartz is the apatite, in the usual needles. Rutile needles, rounded grains of augite and liquid-filled cavities — in some sections of unusual size — are also found.

The micas, which come next in order of abundance, are always in quite subordinate quantity, the biotite being much more common than muscovite. The ordinary mode of occurrence is in aggregates of irregular blades, these aggregates in some sections including rounded grains of augite, which mineral, either in a fresh condition or more or less altered to chlorite, is a very common accessory in all of these rocks. Other accessories are hornblende, seen only in two sections; titanite, which is quite often met with in the usual wedge-shaped or rounded pieces, sometimes with a border of grayish material; titanic iron, surrounded by the usual decomposition product, in which at times titanite is found as if a secondary crystallization from the gray substance; chlorite, in small particles, probably always as an alteration product of augite; ochre, in small brownish particles, often resulting from the alteration of biotite; and bright-red hematite particles.

The granitell veins and masses, which penetrate the Grand Rapids gneisses, present two kinds of rock. The most common of these is very fine-grained and compact, and of a pinkish color. Under the microscope, it is seen to be composed almost entirely of quartz and orthoclase with some microcline and oligoclase, in addition to which are minute quantities of muscovite, apatite, magnetite, hematite and ochre. In this rock we have an intermediate phase between the aphanitic felsites and the coarser granites. The other kind is externally of a bright red color and shows numerous large sized, deep red facets of feldspar and translucent quartz. Under the microscope the feldspars are found to predominate. They are orthoclase and oligoclase, both much decomposed and reddened. Quartz occurs in large patches as well as in smaller areas within the feldspars. There are also present between the feldspar crystals patches of a finer-grained matrix-like substance also charged with quartz, much if not all of which mineral through the section is of secondary origin. Minor ingredients are augite, chlorite, titanic iron. In many respects this rock bears a close resemblance to the red granite-like rocks of the Keweenawan series of Lake Superior which I have elsewhere described under the name of augite syenite.[1]

The hornblende schists which are interbedded with the Grand Rapids gneisses present a very fine grain and a black color. Under the microscope, hornblende and orthoclase are seen to be the chief constituents. In addition to these occur as accessories: augite, in numerous small grains; apatite, in very abundant crystals; quartz, filling a few corners; biotite; hematite; and ochre. An analysis of one of these hornblende schists by Mr. M. Swenson yielded the following results: silica, 52.39; alumina, 16.13; soda, 2.59; potassa, 1.42; iron sesquioxide, 1.64; iron protoxide, 1.44; iron in sulphide, 0.34; lime, 8.76;

[1] "The Copper Bearing Rocks of Lake Superior," Publications of the U. S. Geological Survey, 1882.

calcium in phosphate, 0.815; magnesia, 4.70; manganese oxide, 0.82; sulphur, 0.39; phosphoric acid, 0.28; water, 0.17; chlorine, trace; fluorine, trace=100.085. These constituents Mr. Swenson, from a study of the thin section, distributes as follows: hornblende, 65.21; orthoclase, 19.19; oligoclase, 9.13; apatite, 0.405; biotite, 2.04; magnetite, 0.41; pyrite, 0.73; limonite, hematite and water, 1.27; quartz, 1.70=100.00. Augite did not occur in the section examined by Mr. Swenson, and does not therefore appear in his analysis. It is to be regarded as quite a common constituent of these rocks, which furnish, however, only one instance of the all but universal presence of augite in the hornblende-bearing rocks of the Wisconsin valley region.

The intrusive diabases of the Grand Rapids gneisses are externally fine-grained, black and heavy. Under the microscope, they are seen to consist chiefly of triclinic feldspar (labradorite) and augite. The crystals of the latter mineral, as so common in similar rocks from regions, inclose many feldspar individuals. Both feldspar and augite are commonly quite fresh. Olivine occurs in numerous irregularly bounded particles which are sometimes quite fresh, but in other cases are completely altered to serpentine, with which occur magnetite and hematite in such a way as to suggest that they also are alteration products of the olivine. Magnetite also occurs abundantly as an original ingredient. Apatite crystals are abundant in both feldspar and augite, though much more plentiful in the former. This olivine diabase resembles many of the finer grained olivine-diabases of the Keweenawan series of the Lake Superior region, presenting, however, a rather more confused section.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE GNEISSES OF GRAND RAPIDS AND VICINITY.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
864	467	Muscovite-biotite-gneiss.	Point Bass.	10	21	5 E.	Coarse-grained; pink-white-and-black-mottled; compact. Flesh colored feldspar, quartz and black mica are recognizable.	*Orthoclase* predominant, much decomposed,—while the mass of the crystals show a uniform color, a considerable portion is kaolinized; much *oligoclase*, also decomposed; *quartz; biotite*, abundant; *muscovite*, in a few patches; *apatite; limonite; titanic iron*, in large quantity, largely decomposed to the ordinary gray alteration-product.
868	468	Biotite-gneiss.	Whitney's Rapids.	S. W. 10	21	5 E.		*Orthoclase* and *oligoclase*, both decomposed; *quartz; biotite;* very little *muscovite; apatite; magnetite; hematite.*
869	466	Augitic biotite-gneiss.	Whitney's Rapids.	15	21	5 E.	Fine-grained; white-and-black-mottled; massive; strongly schistose. Feldspar, quartz and mica flakes, recognizable.	The feldspar chiefly *orthoclase;* some *oligoclase; quartz; biotite; augite*, partly altered to *chlorite;* much *apatite* as an accessory in both the feldspar and quartz.
879	468	Augitic biotite-gneiss.	Edwards' and Clinton's mill, foot of Grand Rapids.	25	22	5 E.	Coarse-grained; pink-light-gray-and-black-mottled; massive. Pink and light gray feldspar and dark colored quartz recognizable.	Feldspar and quartz make up almost the entire mass of the rock. *Orthoclase*, decomposed; some *oligoclase; quartz*, the grains holding numerous large vapor-, and liquid-filled cavities, many of the latter containing bubbles, which are so large that they are plainly visible when magnified 78 diameters; *biotite; augite*, and its decomposition product *chlorite*, present in small quantities; patches of *hematite* and *limonite; apatite.*

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE GNEISSES OF GRAND RAPIDS AND VICINITY — Con.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
882	469	Augitic biotite-gneiss.	Edwards' and Clinton's mill.	25	22	5 E.	Medium-grained; pale pink, light gray and dark green mottled; massive. Feldspars, quartz and lustrous chlorite, recognizable.	Very like the above; chlorite more plenty; cavities in the quartz larger, some being .04 mm. across.
833	472	Augitic biotite-gneiss.	Section at Grand Rapids. Station 1.[1]	8	22	6 E.	Fine-grained; light pink to greenish gray; compact. Feldspar, quartz, and mica, the latter concentrated in layers along the schistose planes, are recognizable.	*Orthoclase*, the chief feldspar; some *oligoclase; quartz*, bearing little apatite and much augite as inclusions; *biotite* and *augite* abundant, commonly packed together; *chlorite* as a decomposition product of augite; *apatite;* brown stains of *limonite*.
836	472	Augitic biotite-gneiss.	Section at Grand Rapids. Station 2.	8	22	6 E.	Coarse-grained; white and black mottled; massive. White feldspar, pellucid quartz, and black lustrous mica, recognizable.	*Orthoclase* and *oligoclase* both present, former in much the larger quantity, both bearing as inclusions numerous rounded grains of augite or epidote, and many of apatite crystals; *quartz*, containing a few grains of the above mentioned minerals as inclusions, and black needles of rutile; *biotite*, very abundant; *augite*, *hornblende*, little *chlorite*, *apatite*, *titanite* in few large brownish-yellow individuals, in some cases surrounded by a gray decomposition product which is apparently identical with that formed by the decay of titanic iron.

838	472	Augitic gneiss.	Section at Grand Rapids. Station 3.	8	22	6 E.	Fine-grained; light yellowish gray; compact. Feldspar, quartz and mica, recognizable.	*Feldspar* much decomposed; *quartz*, grains very small; *augite* as chief accessory, and as decomposition product; *chlorite; apatite; limonite.*
839	472	Chloritic augite-gneiss.	Section at Grand Rapids. Station 2.	8	22	6 E.	Fine-grained; light-pink to yellowish green; massive. Feldspar, quartz, and shining mica, recognizable.	Feldspar much decomposed, probably for the most part *orthoclase; quartz* in aggregates of small grains; little *biotite; muscovite; augite* in every part of the section in small rounded grains, many in part altered to *chlorite; chlorite* in considerable quantity; *apatite; hematite; limonite.*
840	472	Augitic biotite gneiss.	Section at Grand Rapids. Station 3.	8	22	6 E.	Fine-grained; uniform dark gray; very compact. Quartz, feldspar and mica recognizable.	*Orthoclase* and *oligoclase* both present, very fresh, the last predominant; *quartz* composing four-fifths or more of the entire mass of the rock; *biotite; augite* often in aggregates of rounded grains; chlorite as an alteration product of augite; *apatite; titanic iron* abundant, often decomposed, being changed in one place to its common gray decomposition product (titanite of calcium), which has been further changed by the addition of silica to *sphene; limonite.*
844	472	Augitic biotite-muscovite-gneiss.	Section at Grand Rapids. Station 5.	8	22	6 E.	Fine-grained; bright gray to black; compact. White quartz, feldspar and mica in light gray shining flakes are recognizable.	The feldspars, quartz, biotite, augite and the accessories, limonite and chlorite, occur precisely as in 840; muscovite is rather abundant, but there is no titanic iron or sphene.
847	473	Chloritic biotite-gneiss.	Section at Grand Rapids. Station 15.	8	22	6 E.	Coarse-grained; massive; pink. Flesh-colored feldspar, clear quartz and greenish black chlorite are recognizable.	More than half feldspar, *orthoclase* and *oligoclase; quartz* containing little *apatite*; little *biotite;* a good deal of *chlorite; limonite* stains.

[1] These stations are 50 feet apart, measured on a line running N. W. from the shore of the river near the Rablin House, Grand Rapids. See Vol. II, p. 600.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE GNEISSES OF GRAND RAPIDS AND VICINITY — Con.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
850	473	Gneissoid biotite-granite.	Section at Grand Rapids. Station 19.	8	22	6 E.	Coarse-grained; massive; pink and white. Feldspar, quartz and black mica, recognizable.	*Orthoclase* and *oligoclase* predominant, considerably decomposed; *biotite*, greenish and often changed in part or wholly to chlorite; a little *apatite;* decomposed *titanite*, one large wedge-shaped piece 1.4 mm. long; other smaller pieces rounded; *limonite; titanic iron;* very little *muscovite.*
853	474	Biotite-gneiss.	Section at Grand Rapids. Station 21.	8	22	6 E.	Very coarse-grained; massive; white-pink-and-gray-mottled. Feldspar, quartz, and greenish black mica, recognizable.	*Orthoclase* and *oligoclase; quartz,* comparatively free from apatite; a good deal of *biotite;* little *chlorite; magnetite* or *titanic iron.*
856	474	Biotite-muscovite-gneiss.	Section at Grand Rapids. Station 30.	8	22	6 E.	Medium-grained; texture not very compact; pink to greenish gray. Large feldspar crystals, white quartz, and black mica recognizable.	*Orthoclase; microcline; oligoclase; quartz; biotite,* abundant; *muscovite; chlorite;* little *apatite; magnetite; hematite; limonite.*
858	474 482	Augitic biotite-gneiss.	Section at Grand Rapids. Station 38.	8	22	6 E.	Differs but little from 856.	This rock is not different from the above, except that it bears augite while 856 does not; the other minerals are the same.
860	475	Biotite-muscovite-gneiss.	Section at Grand Rapids. Station 44.	8	22	6 E.	Fine-grained; compact; pink to greenish gray. Feldspar, quartz, and mica, recognizable.	This rock contains the same minerals as 856. It differs from it only in being much finer grained and containing more apatite.

885	475	Chloritic biotite-gneiss.	Centralia.	8	22	6 E.		*Orthoclase* in large crystals, partly decomposed; quartz in numerous small rounded granules, many making up a grain as seen macroscopically; *biotite; chlorite; apatite* abundant in the quartz; a few minute scales of *muscovite; magnetite; hematite; limonite.*
965	477	Biotite-muscovite-gneiss.	Ten miles south of Junction City on line of Wisconsin Valley Railroad.	29	23	6 E.		*Orthoclase; microcline; oligoclase; quartz* most abundant mineral; *biotite;* less *muscovite;* scattering grains of *augite;* little *chlorite; apatite* very plenty, some of the crystals of unusual size; ochre stains.

TABULATION OF MICROSCOPIC OBSERVATIONS ON GRANITELL OF GRAND RAPIDS.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
880	468	Granitell.	Edwards' and Clinton's mill.	25	22	5 E.		*Orthoclase* and *oligoclase*, the latter predominant; *quartz;* very small quantities of the following: *muscovite, magnetite, hematite, limonite.*
859	474	Granitell.	Section at Grand Rapids. Station 36.	8	22	6 E.	Fine-grained; very compact; bright pink. Feldspar and quartz recognizable.	Composed almost wholly of feldspar, and *quartz*, the latter predominant; *orthoclase; microcline;* very litttle *apatite; magnetite; hematite; limonite.*
894	473	Granitell.	Grand Rapids.	8	22	6 E.	Very coarse-grained; massive; bright red. Large deep-red feldspar crystals and patches of translucent quartz are visible.	*Orthoclase* and *oligoclase*, both much decomposed, the latter predominant; little *biotite; chlorite; augite; titanic iron* in a few large patches, shown to be this by its gray decomposition product; *apatite; oxide of iron* staining the feldspars; *quartz* in large patches, in part secondary. Beside the ordinary quartz and feldspar, there are present masses of a matrix-like substance which contains smaller crystals of feldspar and secondary quartz.

TABULATION OF MICROSCOPIC OBSERVATIONS ON HORNBLENDE-SCHISTS OF GRAND RAPIDS.

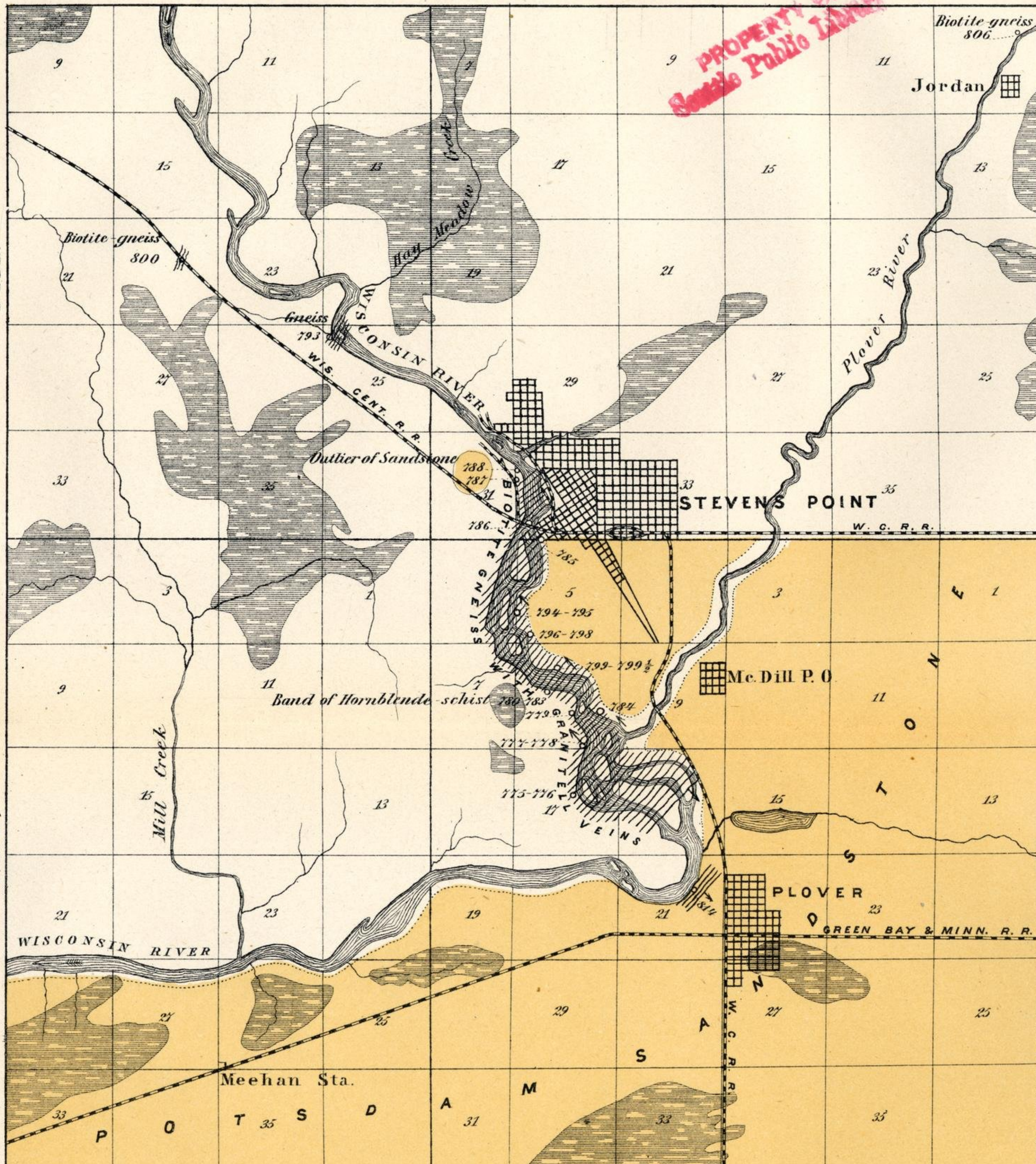
No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
870	466	Augitic hornblende-schist.	Whitney's Rapids.	15	21	5 E.	Fine-grained; very compact; black; uniform in appearance.	*Orthoclase* the predominant feldspar; *oligoclase; hornblende*, very plenty, this and orthoclase being the chief constituents; numerous small grains of *augite; apatite* plenty; little *quartz; titanic* or *magnetic iron; hematite.*
881	469	Augitic hornblende-schist.	Edwards' and Clinton's mill.	N. W. 36	22	5 E.	Like 870.	Differs from 870 only in containing considerably more augite.
846	472	Augitic hornblende-schist.	Section at Grand Rapids. Station 11.	8	22	6 E.	Differs from the two preceding only in that the specimen shows a finely schistose structure.	Groundmass composed of *orthoclase, oligoclase* and *quartz*, all in some quantity; *hornblende* the most important constituent of the rock; *augite* in some quantity; *biotite; magnetite* or *titanic iron; apatite.*

TABULATION OF MICROSCOPIC OBSERVATIONS ON OLIVINE DIABASES OF GRAND RAPIDS.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
848	473	Olivine-diabase.	Grand Rapids.	8	22	6 E.	Fine-grained; of a close, even texture; black; uniform in appearance.	*Olivine*, in numerous patches, commonly with fresh cores, but many particles completely altered to *serpentine*, *magnetite* and *hematite;* numerous large crystals of *apatite*, both in feldspar and augite, though much more plentiful in the former; *labradorite*, much *magnetite*, in part only formed as a result of decomposition of olivine; *augite* in large areas, a single one often enclosing many individuals of the other ingredients; *hematite; biotite.*
874		Olivine-diabase.	Grand Rapids.	8	22	6 E.	Differs from 848 only in being finer grained.	Finer grained than the preceding; the olivine very fresh, the only alteration occurring in narrow bands along the fissures and outer surfaces. With these exceptions the rock is precisely like 848.
884		Olivine-diabase.	Centralia.	8	22	6 E.	Same as 874.	So like 848 that the section would not show they were from different specimens.
893		Olivine-diabase.	Grand Rapids.	8	22	6 E.	Very fine-grained; otherwise same as the preceding.	Crystals smaller than in any of the preceding numbers; otherwise in no way different from 874.

CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY No. II.

T. 24 N.



T. 23 N.

R. VII E. R. VIII E.

ROCKS OF THE VICINITY OF STEVENS POINT.

SKETCH MAP II.

The rock-exposures of this map are for the most part confined to the bed of the Wisconsin river, and the line of the Wisconsin Central Railroad west of the river. The rocks seen in these exposures[1] are plainly merely a continuation — with reversed (N. W.) dip — of the Grand Rapids gneisses, the anticlinal, as I have previously shown, lying not far from the great bend and the long southwestward stretch of the Wisconsin river in southern Portage and Wood counties. Between the Grand Rapids gneisses and those of the vicinity of Stevens Point, there are no essential differences. The latter tend to become rather more micaceous and more coarsely grained than the former; and to have the oligoclase a more prominent constituent, it being at times even the predominant feldspar. Hornblende is also rather more common in the sections of these gneisses than in those of the Grand Rapids rocks.[2]

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[1] Vol. II, p. 481.

[2] For further descriptions of the exposures of the Stevens Point region, see Vol. II, pp. 478–481, where the supposed mica-schist of Fig. 13 is in fact hornblende-schist.

TABULATION OF MICROSCOPIC OBSERVATIONS ON GNEISSES OF THE VICINITY OF STEVENS POINT.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
814		Biotite-gneiss.	"Yellow-Banks," Wisconsin river.	10	23	8 E.	Medium-grained; dark gray; compact. Light pink feldspar, quartz, and black mica, recognizable.	*Orthoclase*, predominant feldspar; *oligoclase; quartz*, chief constituent; *biotite*, abundant in small flakes; *chlorite; apatite; magnetite; hematite; limonite.*
778	481	Hornblende-biotite-gneiss.	Conant's Rapids.	N. E. 17	23	8 E.	Coarse-grained; dirty white and black mottled. Feldspar, quartz, shining flakes of mica, and black hornblende are recognizable.	*Orthoclase* and *oligoclase*, the former predominant; *quartz; biotite* and *hornblende* abundant, crowded together along the schistose planes; all of the above chief constituents occur in large individuals, many of each being from 1 mm. to 2 mm. across; little *apatite.*
779	479	Granitoid biotite-gneiss.	Conant's Rapids.	8	23	8 E.	Medium-grained; compact; massive; light gray, speckled with black. White porcelanous feldspar, pellucid quartz, shining flakes of mica, and a few grains of pyrite are recognizable.	*Orthoclase; microcline; oligoclase; quartz*, the largest constituent of the rock; *biotite;* few grains *hornblende;* numerous sharply outlined crystals of *apatite* visible with low power.
782	479	Chloritic biotite-gneiss.	Conant's Rapids.	S. E. 8	23	8 E.	Coarse-grained; very compact; bright pink to black. Red feldspar, translucent quartz, mica, and green chlorite are recognizable.	Little *orthoclase; oligoclase* and *quartz* compose the larger part of the rock; *biotite* abundant; the crystals of the above minerals are large, being often from 1 mm. to 2 mm. across; some *augite*, largely altered to *chlorite.*

783	479	Chloritic biotite-gneiss.	Conant's Rapids.	8	23	8 E.	Fine-grained; of an even texture; light-gray; quartz, feldspar, and mica, recognizable	*Orthoclase* and *oligoclase*, both much decomposed, the former predominant; *quartz*, composing about nine-tenths of the rock; *biotite; chlorite:* much *apatite* in large well-outlined crystals as inclusions in the quartz; brown stains of *limonite.*
780	479	Biotite-gneiss.	Conant's Rapids.	8	23	8 E.	Medium-grained; of a uniform compact texture; white to light pink. Dark colored translucent quartz and feldspar recognizable.	*Orthoclase,* the predominant feldspar; little *oligoclase; quartz;* rock composed almost wholly of the above minerals; very little *biotite; chlorite; apatite;* and *limonite.*
797	480	Augitic hornblende-biotite-gneiss.	Conant's Rapids.	S. W. 5	23	8 E.	Differs from 782 only in that, beside the minerals there seen, black crystals of hornblende are visible.	*Orthoclase* and *oligoclase,* the latter predominant; *quartz,* unusually full of cavities and containing little *apatite; biotite* and *hornblende,* quite plenty; *augite,* in some quantity, most individuals in part altered to *chlorite; limonite.* This rock is very like 782, the only differences being a slightly finer grain, and the presence of hornblende.
785	480	Hornblende-biotite-gneiss.	Stevens Point R. R. bridge.	S. W. 32	24	8 E.	Medium-grained; dark gray to black. Pink feldspar, translucent quartz, and mica in lustrous flakes are recognizable.	*Orthoclase* and *oligoclase,* the latter in larger quantity; *quartz; biotite* and *hornblende* abundant; *augite* in some quantity, many grains in part altered to chlorite; *chlorite,* besides occurring with a core of augite, exists in a few individuals where the change is complete; few small crystals of *apatite;* numerous rounded grains of *magnetite* or *titanic iron.*
786	481	Hornblende-biotite-gneiss.	R. R. bridge.	S. W. 32	24	8 E.	Coarse-grained; massive; white-pink-and-black-mottled. Quartz, feldspar, mica and hornblende, recognizable.	Coarser grained and the feldspar more decomposed than in 785; otherwise not different from it.

TABULATION OF MICROSCOPIC OBSERVATIONS ON GNEISSES OF THE VICINITY OF STEVENS POINT.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
787	481	Biotite-gneiss.	R. R. bridge.	S.W. 32	24	8 E.	Coarse-grained; mottled white, pink and black. Recognizable ingredients: feldspar, quartz and black mica.	*Orthoclose* and *microcline* in nearly equal quantities; little *oligoclase; biotite* abundant in large flakes; *magnetite; hematite.*
788	481	Biotite-gneiss.	Stevens Point.	S.W. 32	24	8 E.		*Orthoclase*; *microcline;* little *oligoclase; quartz;* much *biotite; chlorite;* large crystals of *apatite* both in the quartz and feldspar; little *magnetite.*
800	481	Biotite-gneiss.	First cut west of Stevens Point.				Medium-grained, even and compact in texture. Pink feldspar, translucent quartz, lustrous black biotite the recognizable ingredients.	Fresh *orthoclase* and *microcline; quartz; biotite* in numerous large flakes; *apatite.*
806	481	Biotite-gneiss.	Plover river.	S. E. 1	24	8 E.		*Orthoclase, microcline* and *oligoclase*, all somewhat decomposed, microcline predominant; *quartz* in large grains, containing many small crystals of *apatite; biotite* plenty; a few minute scales of *muscovite; ochre* stains.

TABULATIONS OF MICROSCOPIC OBSERVATIONS ON GRANITELLS OF VEINS IN THE STEVENS POINT GNEISSES.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
777	478	Granitell.	Conant's Rapids.	N. E. 17	23	8 E.	Very coarsely grained; uniform in texture. White and pink feldspar, and translucent dark quartz are recognizable.	Rock composed almost wholly of quartz and feldspar in nearly equal proportions, the latter mostly *orthoclase; some oligoclase; quartz* containing a little apatite; *biotite, augite, chlorite* and *magnetite* are each found in small quantity.
799½	480	Granitell.	Conant's Rapids.	N. W. 8	23	8 E.	Medium-grained; very compact; white to pink. Feldspar and quartz recognizable.	*Orthoclase; oligoclase; microcline; quartz* composing the chief part of the rock; a few small scattering grains of the following minerals: *biotite, chlorite, apatite, magnetite, limonite.*
798	480	Granitell.	Conant's Rapids.	S. W. 5	23	8 E.	Differs from 799½ only in showing a little biotite.	*Orthoclase; microcline;* the former predominant; *quartz;* very little *biotite, apatite, hematite* and *limonite.*
794	480	Granitell.	Conant's Rapids.	S. E. 6	23	8 E.	Very coarsely grained, some of the crystals of feldspar being an inch in length; compact. Pale pinkish feldspar, and pellucid quartz the recognizable ingredients.	*Orthoclase* and *oligoclase,* the former predominant, both considerably decomposed; *quartz* in large grains, some of them being 2 mm. across; others of the large grains of quartz as seen macroscopically are composed of numerous minute, rounded ones; very little *apatite, biotite* and *magnetite.*

TABULATION OF THE RESULTS OF A MISCROSCOPIC STUDY OF THE HORNBLENDE-SCHIST OF VICINITY OF STEVENS POINT.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
781	479	Augitic hornblende-schist.	Conant's Rapids.	S. E. 8	23	8 E.	Fine-grained; very compact; black; schistose. Quartz, feldspar, and lustrous hornblende the recognizable ingredients.	Groundmass composed of *plagioclase* and *quartz*, in about equal proportions; hornblende the most important constituent of the rock, most grains lying with their greater length in the schistose direction; few bunches of *augite* grains; *apatite;* little *magnetite.*

CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY No. III.

R.III E. Scale 1⅓ miles to 1 inch. R.IV E.

Numbers attached to exposures refer to specimens

ROCKS OF YELLOW RIVER.

SKETCH MAP III.

The upper part of Yellow river north of the line of the Green Bay & Minnesota Railroad is bedded on crystalline rocks for many miles. These rocks have been but very imperfectly examined; enough is known of them, however, to make it plain that gneiss and granite are the prevailing kinds, and that they are, in all probability, but the continuation westward of the gneisses of the region about Grand Rapids. The trend, however, is changed now to a northwesterly one, a direction which holds as far west as the valley of Black river and beyond. The interstratified bands of hornblende-schist characteristic of the Grand Rapids gneisses are present here also, and the same is true of the intersecting veins and masses of granitell. As points of difference between the Yellow river gneissic series and that of Grand Rapids, may be mentioned the presence in the former of intersecting masses of true quartz-porphyry, the absence so far as known of dikes of olivine-diabase, and the very large proportion upon Yellow river of granite without parallel arrangement to the ingredients.

So far as the thin sections examined are concerned, the Yellow river gneisses present no essential differences from those of Grand Rapids. Unaltered augite has not been observed in any of these sections, but in all probability it is represented by the chloritic ingredients. The interbedded hornblende-schists yield sections precisely like those of the Grand Rapids series.

The granites of Yellow river are chiefly mica granites, often of a pinkish or red color, and not unlike in general appearance the well known Scotch granite. The quartz-porphyry noticed intersecting gneisses up Yellow river presents the usual characters of such rocks. The structural features of the Yellow river rocks so far as made out, and the appearance of all exposures examined, have been previously described.[1]

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[1] Vol. II, pp. 490–492.

TABULATION OF RESULTS OF MICROSCOPIC STUDY OF THE GNEISSES OF YELLOW RIVER.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
973	491	Biotite-gneiss.	Yellow river.	N. ½ 14	23	3 E.	Medium-grained; compact; evenly schistose; pink-and-gray-mottled. Feldspar, quartz and greenish mica the recognizable ingredients.	*Orthoclase* and *oligoclase*, the former predominant, both much decomposed; *quartz* abundant; *biotite* in flakes which have a decided greenish tint; *chlorite; magnetic* or *titanic iron; hematite.*
974	492	Epidotic chlorite-gneiss.	Mouth of Rocky Run.	21	23	3 E.	Medium-grained; green-and-pink-mottled. Epidote and feldspar are recognizable. Running through the rock are large veins of pink colored substance, which differ from the mass of the rock in being chiefly composed of feldspar.	A highly altered rock. *Oligoclase*, and *orthoclase*, the former predominant, both much decomposed; *epidote* very abundant in large crystals and aggregations of small rounded ones scattered all through the section; *chlorite* plenty; *quartz; titanic iron* surrounded by its gray decomposition product.
977		Chloritic biotite-gneiss.	Woodworth's, Yellow river.	21	23	3 E.	Fine-grained; strongly schistose. Pink feldspar, quartz, green chlorite, and lustrous mica flakes are recognizable.	*Orthoclase; quartz* in grains, varying in size from medium to minute, composes the larger part of the rock; *chlorite* quite plenty in large irregular fibrous patches; little *biotite;* few grains *magnetite* and *hematite; limonite* stains.

967	491	Epidotic gneiss.	Hemlock creek.	S. E. 5	22	4 E.	Rather fine-grained; evenly textured; light pink. Feldspar and quartz recognizable.	*Orthoclase; microcline; oligoclase; quartz*, bearing *apatite; epidote* abundant; little *chlorite;* some *muscovite; magnetite* or *titanic iron*. This rock has the same constituents as 974, but it is not so highly altered, and contains much more quartz and less epidote.
969	491	Augitic hornblende-schist.	Yellow river, three-fourths of a mile north of Houston's mill.		22	3 E.	Fine-grained; massive; uniformly dark-gray. Mingled with the hornblende are a few small flesh-colored individuals.	A groundmass of *orthoclase, plagioclase* and *quartz;* the grains of the latter are very small; *hornblende* the largest constituent of the rock; *augite* very plenty in aggregates of rounded grains; *magnetite* or *titanic iron;* little *apatite*.
971	491	Augitic hornblende-schist.	Yellow river, three-fourths of a mile north of Houston's mill.		22	3 E.	Like 969.	*Hornblende* the most abundant constituent of the rock; *labradorite* the chief remaining one, much decomposed, but a few crystals fresh enough to give the banding in polarized light; *augite* as in 969. This rock is very like the preceding.

TABULATION OF RESULTS OF A MICROSCOPIC STUDY OF GRANITES OF YELLOW RIVER.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
980	492	Chloritic granite.	Yellow river.	3	23	3 E.	Very coarse-grained; feldspar from white to flesh-colored, the crystals large, some showing cleavage surfaces one-half inch in length; quartz grains large; green chlorite.	*Orthoclase* and *oligoclase*, both much obscured by decomposition; large grains of *quartz; chlorite*, rather sparse in green fibrous patches; *hematite; limonite; titanic iron* and gray decomposition product.
981	492	Biotite-granite.	Big Bull falls, Yellow river.	15	24	3 E.	Medium-grained; massive; uniform; pink; feldspar, pellucid quartz, dark green grains of mica, recognizable.	*Orthoclase; microcline; oligoclase; quartz;* all the above in coarse grains; *biotite* in flakes at intervals so much decomposed as to be scarcely recognizable; *hematite; titanic* or *magnetic iron.*
		Mucovite-granite.	Below Pitt's mill, Yellow river.	34	23	3 E.	Exceedingly coarse-grained; orthoclase in pale pink masses, some of them two inches through; quartz grains often three-fourths of an inch in diameter; large bunches of muscovite.	

RESULTS OF A MICROSCOPIC EXAMINATION OF QUARTZ-PORPHYRY OF YELLOW RIVER.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
970	491	Quartz-porphyry.	Yellow river, three-fourths of a mile north of Houston.		22	3 E.	Light gray, aphanitic, hard rock with conchoidal fracture; carrying in the matrix numerous grains of pellucid quartz, and many crystals of flesh-colored feldspar; scattering grains of pyrite are visible.	The porphyritic ingredients are *orthoclase*, *oligoclase*, and *quartz;* the feldspar crystals large, some being 2½ mm. across, well defined, but with the corners frequently rounded; they are somewhat decomposed, the oligoclase, however, showing distinct banding. The quartzes show the usual doubly terminated forms. The ground-mass shows nicely with a low power a spherulitic structure, being entirely made up of numbers of these radially fibrous masses about 35 mm. in diameter. When magnified 350 times, small areas act uniformly in the polarized light. These particles are, however, much decomposed, but are probably, for the most part, feldspar. Quartz also is present. There is in the section one aggregate of pleochroic *chlorite*, containing *titanic iron* and its gray decomposition product. Particles of *hematite* and *augite* are also recognizable.

ROCKS OF THE WISCONSIN RIVER VALLEY FROM JUNCTION CITY TO MOSINEE.

SKETCH MAP IV.

The rocks exposed in the low cuttings on the Wisconsin Central and Wisconsin Valley railroads in the vicinity of Junction City, and thence northward to the bridge across the Wisconsin river at Knowlton, are evidently but a continuation of the gneisses with interstratified hornblende-schist and granitell veins that are so largely exposed in the vicinity of Grand Rapids and Stevens Point.[1] From Knowlton north to Little Bull Falls,[2] although plainly the underlying rocks are near the surface, but few exposures were noted at the time of my examination.[3]

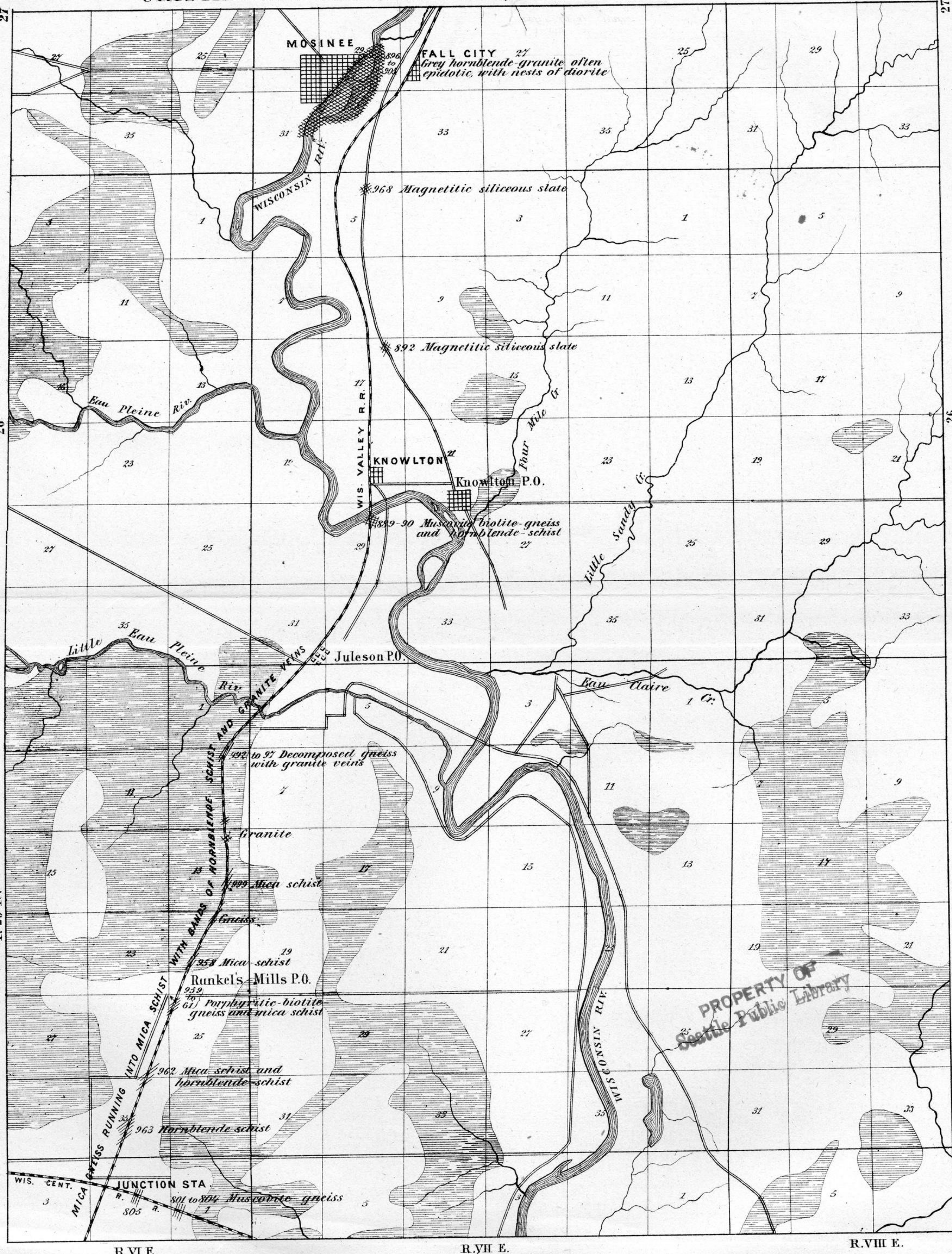
The few small exposures which were noticed in this distance are, however, of especial interest. They present a quartz-schist at times highly magnetitic, which is often so closely allied to the quartz-schists occurring in the vicinity of Marshall hill, north of Wausau, that both must be taken as belonging to the same formation. The general lithological characters of these schists are again so closely similar to those rocks of the Huronian of the whole Lake Superior region that little doubt can be entertained as to their Huronian age. The hornblende-granite of Little Bull Falls seems to limit these Huronian schists again on the north, so that we have here apparently the southwestern end of a narrow tongue of the great Huronian belt, which stretches from here northeasterly to and beyond the Menominee river.

So far as the dips and strikes of the rock beds shown in Sketch Map IV are concerned, it is to be said that the gneisses from Knowlton south trend northeasterly, with a dip which varies a few degrees upon either side of verticality; that the bedding of the quartz-schist between Knowlton and Mosinee was not satisfactorily made out on account of smallness of exposure; and that, while there are in the Little Bull Falls rocks many joints in places trending west of north and dipping upon either side of the vertical, so as to produce an apparent anticlinal structure, these joints are upon the whole too unreliable and abnormal to be accepted as indications of bedding.

Since the gneisses in the vicinity of Junction City and thence northward are merely the continuation of those of Grand Rapids and Stevens Point, it is only necessary to note here the one point in which they differ from the rocks of those places. There are included

[1] Vol. II, pp. 481–483. [2] Vol. II, pp. 483, 484. [3] 1874.

CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY No. IV



Scale $1\frac{1}{3}$ miles to 1 inch

here in them, certain bands which are peculiar for a porphyritic development, large feldspar and quartz particles being buried in a matrix-like mass, of which quartz and biotite are the principal constituents.

The siliceous schists lying between Knowlton and Mosinee being precisely like those of Marshall Hill need also no especial mention here.

The rocks of Little Bull Falls, however, deserve some further attention. The principal rock at this place[1] is hornblende-granite,[2] with a grain varying from quite coarse to rather fine, the coarser kinds presenting a white and black or green and black mottling, the finer kinds tending to uniform black or greenish black colors. Under the microscope, the thin section of this rock shows the feldspar commonly predominating, orthoclase and oligoclase presenting themselves in about equal proportions. Hornblende and quartz usually follow next; the hornblende is of the common green variety, the individuals generally presenting cores of augite. Accessory ingredients, several of which are present in the rock section, are biotite, apatite, magnetite, rutile — in needles in the quartz,— calcite and epidote; some sections show the last-named mineral in large proportion, the whole rock having undergone an epidotic decay.

Imbedded in the hornblende-granite just described are here and there to be seen irregular and limited bands and nests of a very fine-grained and compact black rock.[3] This rock proves in the thin section to be made up almost wholly of hornblende and labradorite, with which is mingled a little magnetite or titanic iron.

The black rock of a large dike, which may be seen cutting the hornblende-granite of Mosinee,[4] shows in the thin section what appears to be a very much altered diabase. Much altered minute plagioclases make up most of the section. Orthoclase, quartz, magnetic iron are also present in the groundmass, which is traversed by numerous reticulating bands of epidote and chlorite. The large porphyritic feldspars are orthoclase and oligoclase.

Numbers of large veins of white quartz cut the Mosinee granite. The thin section of the rock from one of these shows only large grains of clear quartz interlocked with one another into a solid mass, without the intervention of any other mineral. The only inclusion noticed in the quartz is oxide of iron in minute particles.

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[1] Vol. II., p. 483.

[2] Rather than syenite, which is the name given to them by Mr. C. E. Wright, Vol. II., p. 638.

[3] Vol. II, p. 484.

[4] Vol. II, p. 484.

TABULATION OF RESULTS OF MICROSCOPIC STUDY OF THE GNEISSES OF VICINITY OF JUNCTION CITY AND KNOWLTON.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
801	481	Muscovite-gneiss.	Wis. Cent. R. R. cut, one mile S. E. of Wis. Valley R. R. Portage county.	1	24	6 E.	Coarse-grained; very compact; white-yellow-and-black mottled. Feldspar, quartz and mica are recognizable.	*Oligoclase; orthoclase; quartz;* these minerals occur in well-defined medium-sized crystals, and also in very numerous small ones thrown together in confused patches; *muscovite* in numerous small scales, stained with iron, usually many collected together, all the scales having their greatest length in the same direction; little *augite; magnetic* or *titanic iron.*
804	481	Muscovite-gneiss.	Same place as 801.	1	24	6 E.	Coarse-grained; mottled white and pink. Feldspar, quartz, and mica, recognizable.	*Orthoclase* much decomposed and obscured by oxide of iron; minute brilliantly polarizing flakes of *kaolin* and *limonite* now occupy most of the space originally taken by the feldspar; *augite; muscovite* as in 801; *magnetic* or *titanic iron.* This rock is altered more than 801, otherwise it is much like it.
961	482 640	Augitic biotite-schist.	1140 rails south of railroad bridge at Knowlton, Portage county.	26	25	6 E.	Fine-grained; strongly schistose; black. Shining flakes of mica, and large cubic crystals of pyrite are recognizable.	The background of the rock is chiefly *quartz; orthoclase* is present; *biotite* composes the larger portion of the rock, most of the grains lying with their cleavage lines and greatest lengths parallel; *augite* quite plenty in aggregates of rounded grains; *titanic* or *magnetic iron* most often occurring in connection with or in the center of an augite aggregate; little *chlorite* and *calcite.*

959	482	Porphyritic biotite-gneiss.	Two and one-half miles north of Junction City, on W. V. R. R., Portage county.	26	25	6 E.	Fine-grained, with the exception of the porphyritic crystals of feldspar; white-and-black-mottled. Recognizable ingredients: feldspar in large rounded crystals, some of them half an inch in length; quartz; mica; a few large, black lustrous crystals, probably also mica.	*Orthoclase* in large, ill-defined crystals, much decomposed, and part replaced by secondary quartz, which is arranged about and through the feldspar; *quartz* the predominant mineral in medium-sized grains and in innumerable minute ones; *biotite* abundant, the flakes uniformly small; little *muscovite; titanic* or *magnetic iron;* one large fissured crystal of *titanite* 1.4 mm. long; a crystalline aggregate which probably represents an *andalusite* individual; *augite.*
960	482	Porphyritic biotite-gneiss.	Same place as 959.	26	25	6 E.	Like 959.	Differs from 959 only in containing no muscovite and in carrying *epidote.* Two large crystals of titanite, each somewhat larger than that of 959, are seen. These two rocks, 959 and 960, having large crystals of feldspar and quartz in a matrix-like mass of quartz and biotite, present a decidedly porphyritic appearance.
996		Augitic biotite-gneiss.	Cut on W. V. R. R., Portage county.	12	25	6 E.		*Orthoclase; microcline; quartz* as in 959; *biotite* very plenty; a good deal of *muscovite; augite* in numerous clustered grains; *chlorite; magnetic* or *titanic iron.*
889	483	Muscovite-biotite-augite-gneiss.	Cut on Wisconsin Valley Railroad at Knowlton.	29	26	7 E.	Medium-grained; evenly textured; white and black mottled. Feldspar, quartz, and mica, recognizable.	*Orthoclase* and *oligoclase,* the latter not plenty; *quartz; muscovite* in some quantity; less *biotite;* a good deal of *augite* in aggregates of rounded grains; very little *apatite;* one large crystal of *sphene.*

RESULTS OF A MICROSCOPIC STUDY OF THE HORNBLENDE-SCHISTS OF THE WISCONSIN VALLEY RAILROAD.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
963	482 640	Hornblende-schist.	1410 rails south of railroad bridge at Knowlton.	35	25	6 E.	Fine-grained; strongly schistose; black with light mottlings. Small lustrous grains of hornblende, and dirty white feldspar, recognizable.	*Orthoclase* and *quartz* form the groundmass, the latter in grains varying from those of minute size to quite large ones; hornblende is the chief ingredient.

TABULATION OF RESULTS OF A MICROSCOPIC STUDY OF HORNBLENDE-GRANITE OF LITTLE BULL FALLS.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
896	483	Hornblende-granite.	Little Bull Falls, Wisconsin river.	29	27	7 E.	Coarse-grained; very compact; mottled-white-and-black. Recognizable ingredients: large brilliant-black crystals of hornblende, white feldspar, transparent quartz.	
898	483	Hornblende-granite.	Little Bull Falls, Wisconsin river.	29	27	7 E.	Differs from 896 only in having quite numerous crystals of pyrite.	*Oligoclase* and *orthoclase* in about equal proportions; *hornblende* abundant in large crystals, some individuals containing cores of *augite; quartz* not very plenty; little *biotite; apatite; magnetic* or *titanic iron;* in the quartz numerous black needles of *rutile.*
903	484	Epidotic hornblende-granite.	Little Bull Falls, below the dam.	29	27	7 E.	Fine-grained; compact; black hornblende, veins of epidote, and a few patches of pyrite, are recognizable.	*Orthoclase, oligoclase,* and *quartz* are all found in some quantity; *hornblende* in irregular patches of varying size compose the larger part of the rock; *epidote* is scattered through the mass of the rock, beside which there are veins composed entirely of epidote; *magnetite* or *titanic iron;* few needles of *rutile* in the quartz; little *calcite.*
900	483	Hornblende-granite.	Little Bull Falls.	29	27	7 E.	A trifle finer grained than 896, otherwise precisely the same.	*Orthoclase; oligoclase; quartz* abundant; *hornblende;* a few large scales *biotite;* a few *augite* cores in the hornblende; *apatite* plenty; *magnetic* or *titanic iron; rutile* in quartz.

TABULATION OF RESULTS OF A MICROSCOPIC STUDY OF HORNBLENDE-GRANITE OF LITTLE BULL FALLS—Con.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
902	484	Hornblende-granite.	Little Bull Falls.	29	27	7 E.	Like 898.	Precisely like 898.
905	484	Epidotic granite.	Little Bull Falls.	29	27	7 E.	Fine-grained; evenly textured; uniform light green. Feldspar, quartz, epidote, are recognizable.	*Orthoclase*, *oligoclase*, *quartz*, in about equal proportions; *chlorite; epidote* in veins running in all directions through the section, and in numerous clustered grains, this mineral being present in larger quantity than any other; *magnetic* or *titanic iron;* little *apatite;* innumerable minute needles of *rutile* included in the quartz.

TABULATION OF RESULTS OF A MICROSCOPIC STUDY OF DIORITE OF LITTLE BULL FALLS.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
897	484 638	Diorite.	Little Bull Falls (in nests).	29	27	7 E.	Fine-grained; very compact; black. Hornblende, and feldspar, recognizable.	*Labradorite* and *hornblende* in nearly equal proportions compose almost the entire mass of the rock; the labradorite in general well preserved in crystals of quite uniform size, the average length being about 25 mm.; the hornblende is in indefinitely outlined patches from very small size to quite large; little *titanic* or *magnetic* iron.

TABULATION OF RESULTS OF A MICROSCOPIC STUDY OF ALTERED DIABASE (?) OF LITTLE BULL FALLS.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
899	484	Altered porphyritic diabase.	Little Bull Falls.	29	27	7 E.	Fine-grained; dark greenish black; brown weathering.	*Plagioclase* in minute grains, much decomposed, is the most important mineral; *orthoclase* and *quartz* are also found in some quantity; *titanic* or *magnetic iron* in numerous minute specks. These minerals are the only ones recognizable in the groundmass, running through which are numerous reticulating bands composed of *epidote* and *chlorite*. The many large porphyritic crystals are orthoclase and oligoclase.

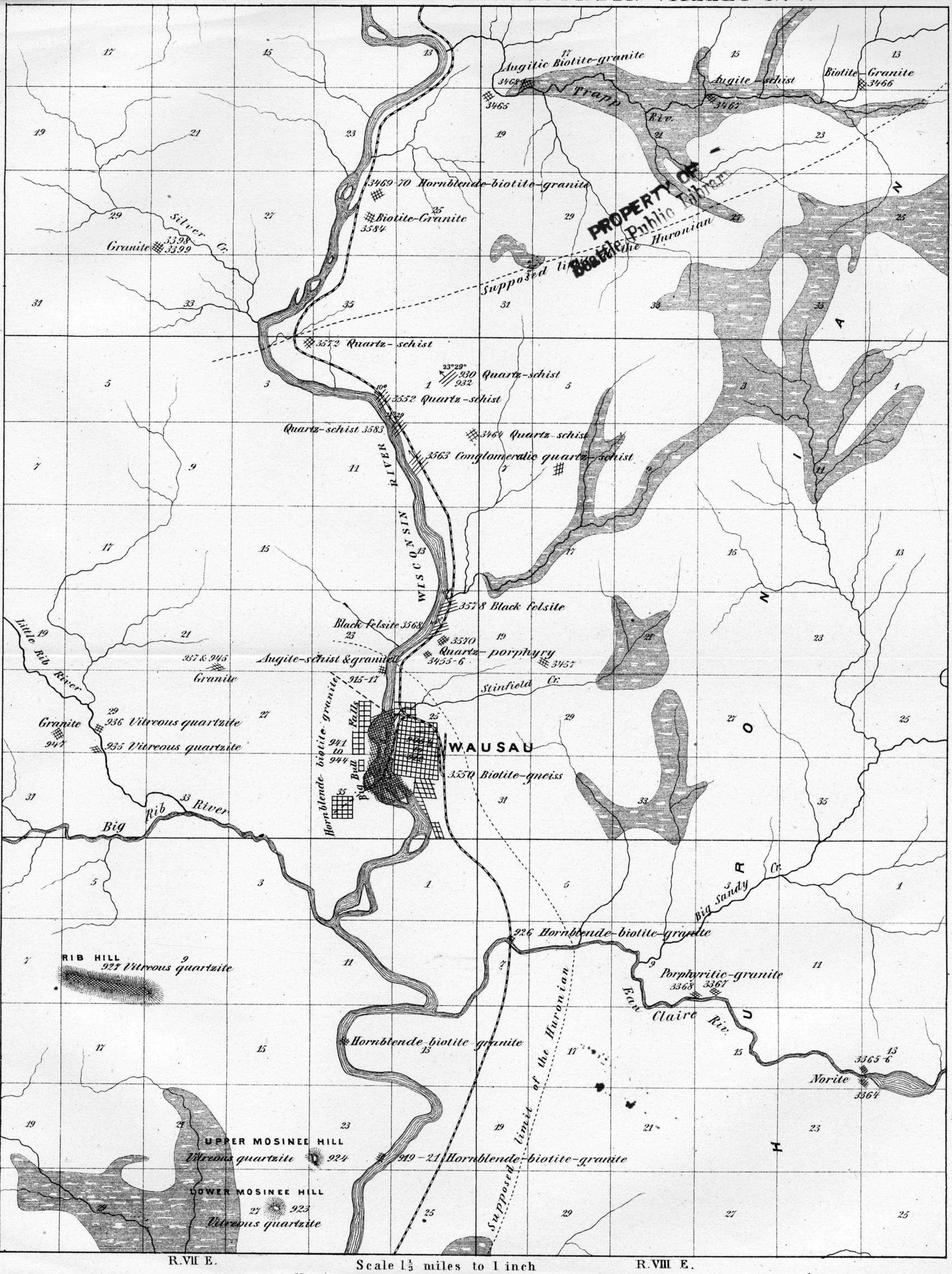
TABULATION OF RESULTS OF A MICROSCOPIC STUDY OF VEIN QUARTZ OF LITTLE BULL FALLS.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
901	484	Vein-quartz.	Little Bull Falls.	29	27	8 E.	Composed entirely of white translucent quartz.	Large grains of clear quartz the only mineral of account. These dovetail into each other, making a solid mass without the aid of any other mineral. Hence there is no trace of a clastic origin, and in this respect the rock is precisely similar to the quartzites of Rib and Mosinee hills. As inclusions there are present numerous minute specks of oxide of iron.

TABULATION OF RESULTS OF A MICROSCOPIC STUDY OF THE HURONIAN SCHISTS LYING BETWEEN KNOWLTON AND MOSINEE.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
892	483	Magnetic siliceous schist.	Two miles north of Knowlton.	29	26	7 E.	Aphanitic; very hard; conchoidal fracture; uniform dark greenish-gray.	Excessively fine, apparently fragmental, largely composed of kaolinized *feldspar; chlorite, magnetite*, and probably *quartz;* contained in this matrix are a few larger grains of quartz and feldspar, one of the latter being several mm. long.
968	483 640*a*	Magnetic siliceous schist.	Roadside five miles south of Mosinee.		26	7 E.	Precisely like 892.	Like 892. These rocks resemble the Marshall hill schists, but differ from them in containing a larger proportion of magnetite, in having a finer-grained matrix, and in containing but few fragments coarser than the matrix.

CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY No. V.



Scale $1\frac{1}{3}$ miles to 1 inch

Numbers attached to exposures refer to specimens

ROCKS OF THE WISCONSIN VALLEY IN THE VICINITY OF WAUSAU.

SKETCH MAP V.

The rocks of the district included within the area of this map are of a number of different kinds. They are described in the tables given below in the following order:

Granites.

1. *Hornblende-granite* of the immediate vicinity of Wausau.
2. *Granites* west and north from Wausau.

Porphyries.

3. *Quartziferous Porphyries*, east and north of Wausau.

Norites.

4. *Norites* of the Eau Claire river.

Schistose Rocks.

5. *Gneiss* of Wausau.
6. *Quartz-schists* of Marshall hill.
7. *Augite-schists* of Trapp river.

Quartzites.

8. *Quartzite* of Mosinee hill.
9. *Quartzite* of Rib hill.
10. *Quartzite* of Little Rib river.

The structural relations of these rocks are for the most part quite obscure, while at the same time they present a problem of considerable interest. In some of the schistose rocks here included we have plainly the southwest termination of the belt of Huronian schists which is so strongly developed and well known in the iron district of the Menominee river; but how far the associated rocks are Huronian or not is a much more difficult question, and one which cannot as yet be decided. For the present, therefore, we must content ourselves with recording what is known as to each of the several rocks here developed.

Granites. Full descriptions of the large exposures of coarse hornblende-granite in the vicinity of Wausau have already been given in Vol. II of this series, pages 486 to 488. Of these descriptions I have no modifications to make, unless the statements there given with regard to bedding might be taken to indicate a belief in the metamorphic origin of this granite. The jointing occurs as there stated, but is not now believed to indicate the original aqueous deposition of this rock, which is on the contrary regarded as of eruptive origin. The term syenite, used for the Wausau rock in Vol. II, was designed to represent the same mineral combination for which the term hornblende-granite is here applied, in accordance with the better and well established usage of the present day.

This granite is medium-grained to very coarse-grained, and massive, being commonly without any perceptible linear arrangement to the mineral ingredients. In all phases the feldspars, which are from yellowish gray to red in color, and at times as much as half an inch in length, are always the predominating ingredients. In subordinate quantity, but always recognizable, are crystals of black lustrous hornblende, sometimes reaching a fourth of an inch in length. Under the microscope, the main constituents of this granite are seen to be orthoclase, oligoclase and microcline. Along with these, hornblende, diallage, magnetic or titanic iron and quartz occur as principal constituents; and, as accessories, biotite, apatite, garnet and hematite. The two latter are comparatively rare, and occur always as inclusions of, or at least associated with, the diallage or amphibole. The following summary description of the microscopic characters of this granite, prepared after a study of a number of thin sections, is by Mr. Vanhise:

"These rocks are all very much alike in their chief characteristics. The feldspars, which are always a good deal decomposed, are in all cases the dominating constituents. The three species — orthoclase, oligoclase and microcline — are always present, the latter being usually the most abundant one. The colored cross-banding of the microcline, as seen in polarized light, presents various degrees of distinctness; the distinctness lessening with the increase in amount of decomposition, until finally only irregular bands of color, running in a single direction, are apparent. In this condition, in the ordinary light, the kaolinization is seen to have taken place chiefly in streaks, which are coincident in direction with the colored bands seen in the polarized light. Apatite is present in all the sections, though varying greatly both as to the size and number of crystals. It is a constant inclusion in the feldspars, and is also often to be seen in the quartz, diallage and hornblende. The quartz, except in two or three slices, is a subordinate ingredient. Both primary and secondary quartz appear to occur. Apparently primary are the large integral grains filling interstices between the other ingredients; but in some sections a portion of the quartz is arranged within the feldspar in such a way as to suggest its secondary nature, or at least its deposition after a certain amount of decomposition had affected the feldspars.

"The augitic ingredient in most cases is plainly diallage; all that does not show the characteristic cleavage of diallage is much decomposed. The diallage occurs both independently, and even quite without any associated hornblende in the slice (944), and also in the shape of cores to uralite or hornblende individuals. It appears probable that all the amphibole is an alteration product of the diallage. In support of this position are the following facts: The hornblende occurs both as greenish fibrous uralite (926), enveloping centers of diallage, and also in the shape of ordinary basaltic hornblende without included diallage, and with the characteristic color, cleavage, and dichroism. Again, the latter kind of hornblende occurs as a mere border about a diallage center, and from this condition in every stage of replacement up to the complete disappearance of the diallage.[1] Finally, both uralite and basaltic hornblende are found, not only with a single core of diallage to each crystal, but with several or many spots of the original mineral.

"Titanic or magnetic iron, biotite, garnet and hematite occur without any unusual characters. The order of crystallization of the several minerals appears to be as follows: apatite, feldspar, titanic or magnetic iron, biotite, diallage, hornblende (alteration of the diallage) and quartz. The only one of these minerals whose position is doubtful is the quartz, which may have preceded the diallage, in part at least. It is within the possibilities that the quartz is all of a secondary nature, in which case the original rock must have been an 'augite syenite.'"

This coarse granite, which is very strongly contrasted with any of the other granitoid rocks of this region, is found along the course of the Wisconsin river for a distance of upwards of five miles in a north and south line, and with a width from east to west of something over a mile. There can be little doubt that the several exposures within this area form part of one intrusive mass.

North and west from Wausau, within the area of Sketch Map IV, are a number of exposures of granite, for the most part quite unlike that just described. A peculiar, thin bedded, fine grained, feldspathic granite is described in Vol. II (p. 489) as forming the side of the ridge in the S. E. ¼ Sec. 21, T. 29, R. 7 E., and as occurring again near Single's mill, S. E. ¼ Sec. 30 of the same township. The thin section of this rock shows that in some respects it is nearly allied to Wausau granite, from which it differs, however, in lacking the hornblendic alteration of the augitic constituent. Orthoclase, oligoclase

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[1] See also G. W. Hawes' Lithology of New Hampshire.

and microcline are the principal constituents, the latter predominating. Other constituents are quartz; augite in some quantity; chlorite as decomposition product of the augite; abundant magnetite and ferrite.

A sixteen-inch vein of fine-grained granite is described in Vol. II (p. 488) as intersecting a dark gray schistose rock on the west bank of the Wisconsin river near the N. line of Sec. 26, T. 29, R. 7 E. The rock of this vein proves to be a biotite-granite, or granitell, the biotite being in very subordinate quantity. The constituents are oligoclase and orthoclase, the latter the predominant feldspar; quartz in large grains; and, as accessories, biotite, hematite, magnetite and epidote.

According to Mr. Clark, a fine-grained pinkish granite appears to prevail throughout Sec. 28, T. 30, R. 7 E., and, to judge from loose fragments, to extend northward from there well into Sec. 21. This rock is again a biotite-granite, with the biotite in very subordinate quantity. Oligoclase and orthoclase are the chief constituents; both are much decomposed, stained with oxide of iron, and often replaced by a secondary quartz, which is found in groups of radiating lines within the feldspars. Quartz also occurs in distinct roundish grains between the feldspars; biotite, chlorite and ferrite are accessories.

Large outcrops of a coarse-grained granite show on the east side of the Wisconsin river, over a considerable area in the N. E. ¼ Sec. 26, T. 30, R. 7 E. This is a rock in which pink feldspars and quartz, the latter in large proportion, are the only macroscopically recognizable ingredients. In the thin section, the feldspar is seen to include microcline and orthoclase; quartz occurs in very abundant large clear grains, while biotite and hornblende occur together in a very few large sized patches.

Along Trapp river, in the central part of T. 30, R. 8 E., Mr. Clark reports a number of granite exposures. The light-gray granite showing on the bank of the river in S. E. ¼ Sec. 18, T. 30, R. 8 E., is an augitic biotite-granite, in which are recognizable, macroscopically, a pinkish feldspar, a little quartz, and numerous small black mica flakes. Much decomposed orthoclase and oligioclase are seen in the thin section to be the principal constituents. The quartz is crowded into the spaces between the feldspars, and contains a little apatite. The mica is biotite. Chlorite and uralite are quite plenty among the minor ingredients, and now and then contain cores of augite, from the alteration of which mineral they have evidently been derived. Magnetite is also present. Scattered promiscuously through the body of this rock are angular fragments, sometimes a foot across, of a black hornblende-biotite-schist, which remain as proofs of the eruptive origin of the granite. A rock closely similar to the last described, but containing much more unaltered augite, is exposed upon the river bank about a mile further down the stream. The granite on Trapp river, near the corner 13-14, T. 30, R. 8 E., has not been examined under the microscope, but appears to resemble closely the other granites of the same stream. Mr. Clark reports that this granite occupies a large portion of T. 30, R. 8 E.

Porphyries. Felsitic porphyries form numerous exposures on the east side of the Wisconsin river in Secs. 24 and 25 of T. 29, R. 7 E., and in the adjoining Secs. 19 and 20 of T. 29, R. 8 E. Exposures of similar rocks occurs as far north as Sec. 8, T. 29, R. 7 E., and as far south as the vicinity of Kelley's lower mill on the Eau Claire river in Sec. 16, T. 28, R. 8 E. To judge from the numerous loose angular fragments scattered over the ground, this rock, which is readily decomposable and therefore not likely to make exposures, except upon an abrupt hill-side, underlies a large area in the western parts of T. 29, R. 8 E., and T. 28, R. 8 E., besides extending well to the southward of the Eau Claire river. No distinctly outlined belt of the porphyry, parallel to the common N. E. cleavage directions of the surrounding schists, is to be made out. The ledges all present a deep white or pinkish white weathering, which is also often carried well into the rocks along the lines of the numerous joints. In many cases there is also a brown iron stain, due to the oxidation of pyrite.

These porphyries present two types; the predominant one being a true quartziferous porphyry, with the usual blackish quartzes, and very abundant pink feldspars, imbedded in an aphanitic brownish gray or drab matrix. The other type is non-quartziferous, carries but few porphyritic feldspars, and has an excessively dense black matrix, with semi-conchoidal fracture. Both kinds decompose very readily, the decomposition being plainly assisted in much of the rock by the presence of pyrite. Throughout most of the area under which this rock evidently lies, although there is but little superficial drift material, it makes no outcrops, but has crumbled down into a clay soil with very abundant imbedded angular fragments of the porphyry. These angular fragments also clothe much of the ledges that are to be seen. This mode of weathering is one which is very characteristic of such felsitic rocks, and which is due to the setting up of decomposition along the planes of the numerous close joints which intersect the rock. These rocks present no appearance of bedding. Occasionally an irregular, wavering linear arrangement of the porphyritic feldspars, and of lighter colored spots in the matrix, is to be noted. Often, along with the general softening due to decomposition, there is present another decomposition-product in the shape of minute interlacing veins of greenish or brownish material, which in many cases is plainly epidotic.

These porphyries are microscopically similar to some of those of the Fox river region, of Marquette and Columbia counties, the first of the two types resembling closely the brownish-gray quartziferous porphyry of the town of Marcellon, Columbia county (Vol. II, p. 518); while the second type is close to the black porphyry of Observatory Hill in the southern part of Marquette county. The Wausau porphyries differ, however, from their more southern allies, in having for the most part a far less distinctly crystalline matrix. Compared with the porphyries which form so marked a feature of the Copper-Bearing Series of Lake Superior, these of Wausau differ macroscopically in lacking the red color which is so characteristic of those of the Lake Superior region; and microscopically in having a more distinctly crystalline matrix.

Under the microscope, the Wausau porphyries present a matrix from which isotrope material is for the most part completely absent; it being impossible, in fact, to assert its presence positively in any case. But while for the most part of a distinctly crystalline nature, a large proportion of the matrix in many slices is not resolvable into mineralogically recognizable particles; that is, is what Rosenbusch calls crypto-crystalline. With this, in greater or less proportion, is always some matter which is plainly composed of minute quartz and feldspar particles, to which are sometimes added particles of biotite. In nearly all sections this matrix has undergone a decomposition in the nature of kaolinization. In many, this decomposition has taken place in such a way as to emphasize a flowage texture in the original rock. In addition to containing more distinctly crystalline matter — as already indicated — than does the matrix of the Lake Superior porphyries, this matrix differs also in completely lacking the general red stain, due to diffused particles of iron oxide, and the coarser brown ferrites which are so completely characteristic of the Lake Superior rocks.

The porphyritic quartzes present all the usual characters of the quartzes of similar rocks from other regions, viz.: the doubly terminated (dihexahedral) crystalline outline; the club-shaped embayments and inclusions due to corrosion by the matrix; and dihexahedral inclusions of devitrified glass, in which respect these quartzes are identical with those of the Lake Superior region. The feldspars include both orthoclase and oligoclase. They are commonly rather irregular in outline, having apparently been eaten into by the matrix. In most sections, also, they are much clouded by decomposition. They are nearly always larger and more abundant than the quartzes. Most sections show a number of small, perfectly outlined sections of octahedral crystals of magnetite.

The minute veins, which, as above indicated, are often seen macro scopically, are also seen in many sections. They are at times made up largely of epidote, and again of a nearly opaque gray substance which behaves isotropically between the crossed nicols. Most of the veins have a central line composed of numerous brilliantly polarizing grains of water-deposited quartz.

In all respects these porphyries present the characters of eruptive rocks of the acid class. The nature of the matrix; the doubly terminated quartzes; the corrosion of the porphyritic quartzes and feldspar by the matrix; the existence of a fluidal structure, both macroscopically and microscopically visible; the presence of glass inclusions in the quartzes; the complete absence of anything like stratification — all point to the eruptive origin of these rocks. They are in fact the ancient equivalents of the modern rhyolites.

Norite. Unless the small black veins to be seen cutting the hornblende-granite of the vicinity of Wausau are of that nature, basic eruptive rocks have been observed at one place only within the area of Sketch Map V. Their existence further south, in the vicinity of Grand Rapids and Stevens Point, has already been noted, and other occurrences to the north of the area of this map still remain to be described.

The place referred to is at Kelly's upper mill on the Eau Claire river, S. W. ¼ Sec. 13, T. 28, R. 8 E.

Here are a number of low outcrops on the banks of the river, and again in the river-bed, forming the barrier rock of the dam. Irregular joints traverse the exposures, trending N. 30° E. and N. 40° W., and standing nearly perpendicularly. Macroscopically this rock presents a grain rather below the medium degree of coarseness, has a dark gray color, and appears to be made up of lustrous gray crystals of a diallage-like mineral. In the thin section, the principal constituent is found to present the appearance of diallage, but to be orthorhombic in crystallization; it is therefore hypersthene or enstatite, and is probably the former. The other constituents are labradorite, which is for the most part much altered, and titanic iron. Apatite, chlorite, and orthoclase are present in less quantity. According to Rosenbusch's nomenclature, this rock is a "norite," or gabbro with a "rhombic pyroxene."

Gneiss. Gneiss is reported by Mr. Clark as in place under the river alluvium at the city of Wausau, though nowhere observed at the surface, and not known elsewhere within the area of Map V. The several specimens forwarded by Mr. Clark present a rather fine-grained, light-gray, highly schistose, micaceous gneiss; in which quartz, feldspar, and black lustrous mica flakes are macroscopically visible. In the thin section, the feldspars — orthoclase and oligoclase — and biotite are seen to be the chief ingredients. Quartz is also abundant, however, occurring in the areas which are characteristic of gneisses, and charged with abundant needles and curving, hair-like lines of rutile, and also carrying a little apatite. Rather plenty particles of magnetite and a few round grains of augite are present as accessories. If this rock is actually in place as stated by Mr. Clark, it is worthy of note as limiting the distribution eastward of the coarse hornblende-granite which forms the bedrock of the Wisconsin river at Wausau.

Argillaceous quartz-schists. On the east side of the Wisconsin river, about four miles north of the city of Wausau, is an area of about three square miles, underneath which the rock is an argillaceous quartz-schist of a somewhat peculiar character. The area occupied by this rock appears to be a restricted one, being bounded upon the northwest by granite, while to the east and southeast the country rock is the quartziferous porphyry above described. Macroscopically, this rock presents a fine grain and dark gray color, having at times the appearance of a slaty quartzite with the characteristic sharp-edged fracture; while in other places there is a dense aphanitic texture, the rock presenting then much the appearance of the matrix of some of the porphyries above described. It is often very strongly banded with lighter and darker shades, which are plainly to be connected with the original deposition of the sediment of which the rock is composed. In some places a strongly conglomeritic appearance is presented, lighter gray fragments being buried in a darker gray groundmass. The natural exposures of this rock are very poor, though the district underlaid by it is very thickly strewn with angular fragments from its disintegration. On the line of the Wisconsin Valley Railroad, however, several deep cutting have exposed the rock on a large scale. In the cuttings the strike is from N. 35° to 85° E., and dip from 10° to 20° to the N. W.

Under the microscope, the Marshall Hill schists, although they have plainly passed through more or less alteration, are still recognizably of a fragmental origin. More or less rounded grains of quartz, with less abundant ones of orthoclase or oligoclase, are buried in an argillaceous matrix. The latter appears to be also of a fragmental nature, and to consist largely of kaolinized feldspathic material. Chlorite and epidote are often present as alteration products, while magnetite and ferrite are to be seen in many sections.

The Marshall Hill schists are strongly suggestive of some of the quartz-schists of the Marquette region, but are especially close to the argillaceous quartz-schists which form a large proportion of the so-called "Animikie" group of the north shore of Lake Superior.

Augite-schist. In the bank of Trapp river, in the N. E. ¼ of Sec. 21, T. 30, R. 8 E., near the section corner, is an outcrop five rods in length and three to six feet in height, of a dark gray schistose rock. In the thin section, this rock proves to be of a very peculiar character, inasmuch as while the principal constituent is augite in a fresh state, there is a large proportion of original quartz in the groundmass. The augite occurs both in irregularly outlined separate particles imbedded in the groundmass, and in larger crystals often including areas of the groundmass, which contains, besides quartz, numerous particles of orthoclase and triclinic feldspar.

Quartzites. The appearance in the field of the vitreous quartzites of the Mosinee and Rib Hill, and in the vicinity of Single's mill on the Little Rib river, south and west from Wausau, have already been described.[1] These quartzites are essentially pure vitreous transparent quartz, being composed of closely interlocked grains. They are quite without any trace of fragmental origin. The quartz grains, in all respects like the quartz of granite and gneiss, interlock with one another in such a manner as to render certain their original deposition where now found. The relations of these quartzites to the surrounding rocks were not satisfactorily determined. In one place only, near Single's mill, was any evidence of bedding perceptible. So far as the structure of the other masses is concerned, they might be merely great veins of quartz left standing by the decomposition and erosion of the surrounding rocks.

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[1] Vol. II, pp. 484–489.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE HORNBLENDE-GRANITES OF WAUSAU.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
907	487 633	Hornblende-granite.	Section at Big Bull Falls.	S. E. 26	29	7 E.	Medium-grained; of a uniform texture. Recognizable ingredients: pinkish feldspar, and black hornblende; these minerals give the rock a mottled appearance.	*Apatite* abundant; *orthoclase; microcline* and *oligoclase*, the microcline predominant, and much of it so decomposed as only to show irregular alternate strips of bright and dull colors in a single direction; *magnetic* or *titanic iron;* very little *biotite; hornblende* abundant; *quartz* in few large, clear grains, and in numerous small ones, some of the latter certainly being secondary.
908	487 638	Hornblende-biotite-granite.	Section at Big Bull Falls.	S. E. 26	29	7 E.	Medium-grained; massive; uniformly dark gray. Recognizable ingredients: feldspar, and hornblende.	*Apatite* in numerous large crystals, many of which are 0.12 mm. in length; *orthoclase, microcline* and *oligoclase*, all fresh; *magnetic* or *titanic iron; biotite* plenty; little *diallage* as cores of *hornblende;* much *hornblende; quartz* in numerous small rounded grains.
909	488	Hornblende-granite.	Big Bull Falls.	N. E. 35	29	7 E.	Coarse grained; of an even texture; chiefly composed of dirty yellowish-gray feldspar, in which the large lustrous crystals of hornblende stand out prominently.	Differs in no important respect from 910 and 941.
944		Hornblende-granite.	Wausau.	S. E. 26	29	7 E.	Like 908 in appearance and recognizable ingredients; differs from it only in having a yellowish tint, and in being finer grained.	This rock differs only from the typical hornblende rocks of the series in being much finer grained. *Apatite, feldspar, magnetic* or *titanic iron, diallage, hornblende* and *quartz* occur in the same way as before, both as to position and proportion. Particularly like 908.

910	487	Hornblende-granite.	Big Bull Falls.	N. E. 35	29	7 E.	Very coarse-grained; massive. Dirty drab colored feldspar predominant, some crystals being above half an inch long. There are also recognizable lustrous black hornblendes, many one-fourth inch in length.	Little *apatite* in the feldspar; *orthoclase, microcline*, and *oligoclase* in nearly equal proportions, all much decomposed and containing secondary quartz; *titanic* or *magnetic iron* in a few large grains, one 4 mm. long; very little *biotite; hornblende* abundant in large crystals, many crystals containing so much quartz as to appear in the ordinary light to be composed of many small ones, but cleavage and dichroism show the contrary; patches of intermingled quartz and hornblende grains are also foumd, in which the latter particles are independent crystals; *quartz*, sometimes in large grains, but mostly in small ones, occurring in interstices between the feldspar, and in crevices in the hornblende. Two or three greenish patches, which, though rounded at the corners, show a rectangular form; they are mineral aggregates, each perhaps representing an andalusite individual.
911	487	Hornblende-biotite-granite.	Section at Big Bull Falls.	S. E. 26	29	7 E.	The specimen varies from very coarse-grained to medium-grained; massive. Pale pink feldspar is predominant; from this background of feldspar the black lustrous crystals of hornblende stand out prominently.	Very little *apatite; orthoclase, microcline*, and *oligoclase*, quite fresh in some places, in others decomposed and including secondary quartz; *magnetic* or *titanic iron;* little *biotite; hornblende*, very abundant, containing in some cases cores of diallage; *quartz*, plenty, occurring in medium-sized grains, and in small ones included in the hornblende.
912	487	Hornblende-biotite-granite.	Big Bull Falls.	S. E. 26	29	7 E.	Resembles in every particular the finer portions of 911.	*Apatite* in crystals varying from above 0.25 mm. in length and 0.04 mm. in breadth, to those so small as only to be visible with a high power; *orthoclase; microcline; oligoclase; titanic iron; biotite*, sparse; *hornblende*, in some crystals containing cores of *diallage*; *quartz*, not plenty, in part at least secondary.

TABULATION OF RESULTS OF A MICROSCOPIC STUDY OF THE HORNBLENDE-GRANITES OF WAUSAU — Con.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
941	487	Hornblende-biotite-granite.	Big Bull Falls.	N. E. 35	29	7 E.	Like 910; it has not, however, any of the very large crystals of feldspar which are seen in 910.	The description of 910 will answer for this specimen, except that biotite is much more abundant in 941, and the hornblende, besides having the inclusions of 910, has also large blood-red pieces of hematite and often cores of diallage.
943	488	Hornblende-granite.	Big Bull Falls.	N. E. 35	29	7 E.	The feldspar is much finer grained than in any of the preceding, of a light brownish yellow tint. The quartz is so plenty as to be visible with the magnifier. The hornblende is arranged in parallel planes, giving the rock a strong schistose appearance.	This rock contains the coarse grains of feldspar which characterize the other rocks of the series, but the greater part of it is composed of much finer grains of intermingled quartz and feldspar. *Apatite; feldspars* of the same species as heretofore; *magnetic* or *titanic iron;* little *biotite; hornblende*, in large crystals as in 910 and 941, a single crystal often including so much quartz as to appear broken into many pieces; biotite, garnet and magnetic iron included in the hornblende; *quartz*, much more abundant than in any of the preceding rocks of the series.
942		Hornblende-biotite-granite.	Wausau.	N. E. 35	29	7 E.	Coarse grained uniformly greenish grey. Differs from the other Wausau rocks in the prominent position assumed by the quartz, and in the disappearance of the large lustrous crystals of hornblende.	*Apatite* very plenty in the feldspar, not present or sparse in the quartz; *feldspars* as heretofore; *magnetic* or *titanic iron; biotite, diallage*, and *hornblende* less abundant than in any of the preceding; *quartz* very plenty; in this respect like 943; *hematite; chlorite.*

926	486	Hornblende-granite.	Haseltine's mill.	7	28	8 E.	Like the coarse part of 911.	*Apatite* crystals few and small; *feldspars* as before, both as to species and inclusions; *magnetic* or *titanic iron;* little *biotite; diallage* as cores of uralite, and in unaltered grains; *uralite,* plenty and each crystal containing a core of diallage; *hornblende; quartz* very sparse, that present being certainly in part secondary; *garnet,* in a few crystals included in the diallage and uralite.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF GRANITES FROM NORTH AND WEST OF WAUSAU.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
937		**Augitic granite.**		S. E. 21	29	7 E.	Rather fine-grained; somewhat friable; mottled brownish yellow. Recognizable ingredients: feldspar, quartz, and minute greenish-black particles of chlorite.	*Orthoclase, oligoclase* and *microcline*, the latter predominant, all much decomposed; *quartz; augite*, in some quantity, and as a decomposition product; *chlorite; magnetite*, abundant; *ferrite*. This rock seems to be merely a peculiar phase of the Wausau granite.
916	489	Biotite-granite or granitell.	West bank of Wisconsin river.	N. E. 26	29	7 E.	Fine-grained; compact; light pink. Shows feldspar and quartz, and scattered through these a few dark flakes.	*Oligoclase* and *orthoclase*, the latter predominant; *quartz*, in large grains; small quantities of *biotite, hematite, magnetic* or *titanic iron*, and *epidote*.
3469		Hornblende-biotite-granite.	Hill near Wisconsin river.	N. E. 26	30	7 E.	Coarse-grained; pink feldspar is the chief constituent; quartz in large pellucid grains is prominent; a few greenish black flakes of mica and hornblende are scattered through the rock.	*Microcline; orthoclase; quartz* in large, clear grains, making up a large proportion of the rock; *biotite* and *hornblende* occurring in large patches together.

3584		Biotite-granite.	Wisconsin river.	Near cent. 26	30	7 E.	Differs from 3469 only in having the feldspar of a little lighter tint.	*Microcline; orthoclase; oligoclase; quartz*, as in 3469, unusually full of cavities, both vapor-filled and liquid-filled, many of the latter containing bubbles; *biotite;* a little *hematite* and *magnetite.* This rock probably contains hornblende also, although the small section shows none.
3465		Augitic biotite-granite.	Trapp river.	N. W. 19	30	8 E.	Medium-grained; easily crumbled. White to pink feldspar, clear quartz, and black grains of mica, are easily recognizable.	*Orthoclase* and *oligoclase*, in large clouded grains, containing bright shining grains of a decomposition product (kaolin); *quartz; biotite* plenty in large crystals; *augite* in large unaltered crystals, and also in many small grains, surrounded by chlorite as a decomposition product; *uralite* in small quantity; *titanic* or *magnetic iron.*
3468		Augitic biotite-granite.	Trapp river.	S. E. 18	30	8 E.	Medium-grained; compact. Light pink feldspar, a little quartz, and black lusterless mica flakes are visible.	*Orthoclase* and *oligoclase* — much decomposed, the crystals often showing no bright colors under the crossed nicols; *quartz*, not plenty, crowded into the spaces between the feldspar crystals, and containing but little *apatite; biotite*, plenty.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF PORPHYRIES OF VICINITY OF WAUSAU.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Microscopic descriptions of the thin sections.
3452	Felsitic porphyry.	Near Wausau.	N. E. 24	29	7 E.	Consists of a light drab, aphanitic groundmass, which is mottled by numerous indistinct and illy defined lighter feldspar crystals of varying size Parallel dark lines running through the specimen give it a schistose appearance.	The porphyritic ingredients include numerous rounded grains of orthoclase differing much in size, and considerably decomposed, although many show in polarized light bright colors; also a few large crystals of oligoclase. The kaolinized condition of the matrix much obscures its original nature. It is excessively fine, and consists of a light gray granular mass. With a high power some minute areas act nearly uniformly with respect to polarized light, indicating that the matrix in part at least is composed of minute crystalline individuals, the larger part, however, being cryptocrystalline. The dark lines visible macroscopically resolve themselves into veins containing quartz usually as a middle line along with some epidote and a grayish, largely opaque, isotrope substance, the latter being the predominant one.

3455	Quartz-porphyry.	Near Wausau.	S. W. 24	29	7 E.	Aphanitic; hard, showing a rough fracture. Dark translucent grains of quartz, and light pink feldspar crystals are abundantly scattered through a dark pinkish-drab matrix. The pink porphyritic feldspars are more abundant and larger than the quartzes. In the arrangement of the feldspars and the lighter colored streaks in the matrix, there is often to be seen a tendency to linear directions.	The porphyritic quartz is in large clear grains, some of them showing a rhomboidal form due to a vertical section, or nearly so, through a rhombohedron or hexagonal pyramid. A few apatite inclusions are seen in the quartz, as also many cavities which frequently contain bubbles. Often the fine felsitic matrix cuts deep bays into the quartz individuals, within which apparently isolated areas of the matrix are also found, but these areas were probably connected with the matrix by necks perpendicular to the plane of the section. If this were the case the above appearance would be given. Porphyritic oligoclase and orthoclase are plenty. Both are eaten by the matrix, considerably decomposed, and include secondary quartz. The matrix of this rock is greatly decomposed and its nature thereby is a good deal obscured. It appears to consist, however, for the most part of cryptocrystalline matter, along with some microfelsitic and a good proportion of microcrystalline matter, the latter in the shape of particles of feldspar and quartz, the feldspars, indeed, appearing to grade upwards in size to the large porphyritic ones. The whole matrix has undergone a decomposition akin to kaolinization, and in some cases the decomposition has been carried on in irregular linear directions, which possibly results from a flowage texture in the unaltered rock.
3456	Quartz-porphyry.	Near Wausau.	S.W. 24	29	7 E.	Differs from 3453 only in having lighter colored porphyritic feldspars.	Very much like 3455. The groundmass, however, composes a larger portion of the rock than in 3455; also, besides the regular porphyritic quartzes, there are considerable areas which are aggregates of many small quartz individuals, averaging about 0.07 mm. in breadth. Otherwise this rock is the same as 3455.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF PORPHYRIES OF VICINITY OF WAUSAU—Con.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Microscopic descriptions of the thin sections.
3457	Quartz-porphyry.	Near Wausau.	S.W. 20	29	7 E.	The matrix is of the same appearance as 3455 and 3456. But porphyritic crystals of feldspar have the same dark drab color as the matrix, and are difficult to distinguish from it.	Like 3455; the appearance presented by the porphyritic ingredients is precisely the same. The only difference in the matrix is that it is present in greater proportion and shows in many places a distinct flowage texture.
3570	Quartz-porphyry.		Near center, 24	29	7 E.	Exactly like 3455.	The only thing which distinguishes this section from that of 3455 is the fact that some of the quartz areas, instead of being composed of a single grain, are made of several grains, fitting each other perfectly and entirely filling up the space. These areas look the same as the quartz areas of a granite. This rock is much less decomposed than the preceding, and it is plainly to be seen that its matrix includes a large proportion of micro-felsitic matter. The feldspars are also relatively fresh. The quartz aggregates of the foregoing description are not prominent characteristics and are in the nature of fillings of geodic cavities.
3579	Quartz-porphyry.		Near center, 24.	29	7 E.	In no way different from 3570.	In regard to having areas made up of particles of quartz, it is intermediate between 3456 and 3570, the granules not being so numerous and minute as in 3456, nor so few and large as in 3570; otherwise it is the same as 3570.

3568	Black felsite.	Wisconsin Valley Railroad, Station 65.	N. W. 24	29	7 E.	Very hard, black, aphanitic matrix, with a smooth semi-conchoidal fracture. Specks of pyrite and small indefinitely outlined crystals of feldspar are scattered through the matrix. The porphyritic ingredients are much smaller and rarer than in any of the preceding.	The porphyritic crystals of feldspar are oligoclase and orthoclase, very small and sparse, the former in greater abundance. No quartz is seen. The matrix, which is excessively fine, is composed of an intimate mixture of micro-crystalline and crypto-crystalline matter, the former consisting of biotite, feldspar, and quartz. A portion of the feldspar is triclinic. The biotite shows its characteristic optical properties plainly with high power. Some of the quartz grains are considerably larger than the average particles of the matrix. Brilliantly polarizing specks of kaolin as a decomposition product of the feldspar are scattered thickly through the rock. Square magnetic crystals at intervals.
3462	Quartz-porphyry.	Near Wausau.	S. E. 8	29	8 E.	Numerous small crystals of quartz and feldspar in a light to dark gray aphantic matrix; matrix very hard, with a conchoidal fracture, and cut by fine veins.	The porphyritic ingredients are quartz and orthoclase, the former more plenty; the feldspars are a good deal decomposed. The quartz often includes portions of the matrix. The fine veins seen macroscopically cut directly through the section and are seen to be composed of numerous grains of epidote. The porphyritic crystals are clearly defined. The matrix shows no distinctly unindividualized material, although crypto-crystalline matter is present. It is composed largely of minute particles of feldspar, which is considerably kaolinized. Quartz is present, also brown particles which are probably biotite and ferrite.
3368	Quartz-porphyry or granitic porphyry.	Kelley's lower mill.	S. W. 10	28	8 E.	Medium to fine-grained; even texture; mottled pale pink and gray.	Large illy defined decomposed porphyritic crystals of feldspar are mixed in a confused matrix, coarser than usual. This matrix is composed of feldspar, quartz, magnetite, and biotite, all confusedly mingled together. Chlorite and a few large crystals of apatite are seen.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF NORITES FROM THE LOWER EAU CLAIRE RIVER.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
3366	Norite.	Kelly's upper mill.		28	8 E.	Dark-gray; medium-grained; made up chiefly of lustrous hypersthene crystals	*Plagioclase*, and *hypersthene* or *enstatite* are the predominant minerals. Large, clear hexagonal crystals of *apatite*, beside small needle-like crystals, are present. The feldspar is *labradorite* and largely decomposed, but in some places showing the twin lamillation distinctly. There are a few small grains of *orthoclase*. *Titanic iron* is seen in numerous large patches. *Hypersthene* or *enstatite* (probably the former) is the chief constituent of the rock; its cleavage in one direction is very distinct. Another faint cleavage nearly at right angles to this is shown by lines of brown inclusions. Chlorite is present as a decomposition product of the hypersthene and perhaps of the plagioclase also.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF ARGILLACEOUS QUARTZ-SCHISTS OF MARSHALL HILL.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
930	Argillaceous quartz-schist.	Jenny road.	N. line 12	29	7 E.	Aphanitic; of a subconchoidal fracture; closely banded light and dark gray; argillaceous odor when breathed upon; quartzite-like.	Fragmental. Fine grains of quartz and feldspar, the former predominant, occur plentifully scattered through a dense matrix. The feldspar is in part oligoclase and part orthoclase. The above constituents are all in disconnected, rounded to subangular grains, presenting no sharp angles, and thus clearly showing the fragmental origin of the rock. The matrix is excessively fine, seems to be of a fragmental character, and appears to be decomposed feldspathic material. Throughout it are seen many brightly polarizing flakes of kaolin, much chlorite and some magnetite and ferrite.
932	Argillaceous quartz-schist.	Marshall hill.	S.W. 1	29	7 E.	Like 930.	One-half of the section precisely like 930, the other being somewhat finer grained and containing a large preponderance of matrix. This rock and 930 are evidently the same.
3552	Argillaceous quartz-schist.	Wisconsin Valley railroad, station 24.	S. E. 2	29	7 E.	A trifle coarser-grained than 932, otherwise different from it in no way.	Like 930.
3583	Argillaceous quartz-schist.	Wisconsin Valley railroad, station 207.		29	7 E.	Like 3552.	Like 930.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF ARGILLACEOUS QUARTZ-SCHISTS OF MARSHALL HILL — Con.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3563	Argillaceous quartz-schist.	Wisconsin Valley Railroad cut.	N.W. 24	29	7 E.	The finer part of the rock is precisely like 3552 and 3583. But, buried in this fine, gray, matrix-like material are many sub-angular to angular, conglomeritic fragments of sizes varying from those so small as to be indistinguishable, to those which are an inch or more across. The fragments are lighter colored than the matrix, otherwise appear the same. This specimen shows to the naked eye the fragmental character of these rocks, which in the cases of 930, 932, 3552 and 3583 can only be perceived by the aid of the microscope.	The thin section of this rock is seen to be chiefly made up of the fine, decomposed, argillaceous matrix already noted as characterizing the foregoing rocks. Distinctly recognizable fragments of quartz and feldspar occur in clusters through the section, but are not so uniformly distributed as in the case of 930, and are, for the most part, much more minute. The angular fragments which are so noticeable macroscopically are still distinctly perceptible in the thin section, but appear to differ from the body of the rock only in their lighter color.

3572	Argillaceous quartz-schist.					Fine-grained; of an even texture; gray; stained with greenish epidote; fracture sub-conchoidal.	Very like the Marshall Hill rocks. Presents something of a porphyritic appearance, but the particles of quartz and feldspar, in part oligoclase,— which, larger than in 930, are plentifully scattered through the matrix,— are uniformly rounded and worn, showing the clastic origin of the rock. The matrix is the same essentially as 930; perhaps carrying more magnetite and less chlorite. Differs from 930 in containing quite numerous good-sized particles of epidote which is secondary to the matrix.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF AUGITE-SCHIST FROM TRAP RIVER.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constitution as determined by the microscope.
3467	Augite-schist.					Very fine-grained; schistose; light to dark gray; in places dark gray obscurely banded with layers of a lighter gray.	Fully two-thirds of the rock are composed of unaltered augite, a greenish alteration being only rarely perceptible. The augite occurs in part in irregularly outlined, small particles, but also in relatively large-sized areas. The wholly colorless groundmass is made up of very minute, wholly colorless, particles of quartz, along with which is a smaller proportion of feldspar, a portion of which is banded. The matrix is intermixed with the small augite particles, and also included in the larger augites which occasionally show the cleavage of diallage. Magnetite occurs somewhat abundantly in small, irregularly outlined particles.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF QUARTZITES OF VICINITY OF WAUSAU.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Microscopic descriptions.
927	485	Quartzite.	Rib Hill.	9	28	7 E.	Massive, translucent, glassy quartz is the only mineral visible.	Almost pure quartz. Usually the grains are of very large size, some of them reaching 7½ mm. in greatest breadth, and interlocking after the manner of the quartz of gneiss and granite. The only other minerals present are a little oxide of iron, mostly magnetite, and a few minute flakes of muscovite. As to cavities this quartz is as common in granite, and from the position of the grains was evidently crystallized in place.
935	489	Quartzite.	Single's mill.	S. E. 29	29	7 E.	Same as 927, except in this a little oxide of iron can be seen.	Differs from 927 only in having a little more muscovite and oxide of iron.
923	484	Quartzite.	Lower Mosinee Hill.	27	29	7 E.		Only different from the above in containing, included in the quartz, numerous black needles of rutile, and in containing more ferrite and a little chlorite.
936	489	Quartzite.	Single's mill.	S. W. 29	29	7 E.	Like 927. Crystalline rock. The only minerals distinguishable are shining flakes of mica and grains of quartz.	As in all the preceding quartzites the grains of quartz fit perfectly along their irregular lines of junction. They are of about the same size as in 927 and freer from other minerals and inclusions than either of the preceding. Iron oxide appears to be the only impurity present. In none of these rocks is there any trace of a clastic origin. *Chlorite* and *uralite* quite plenty; *titanic* or *magnetic iron; apatite* present also in the feldspars. Hornblende-biotite-schist.

ROCKS OF THE UPPER EAU CLAIRE RIVER.

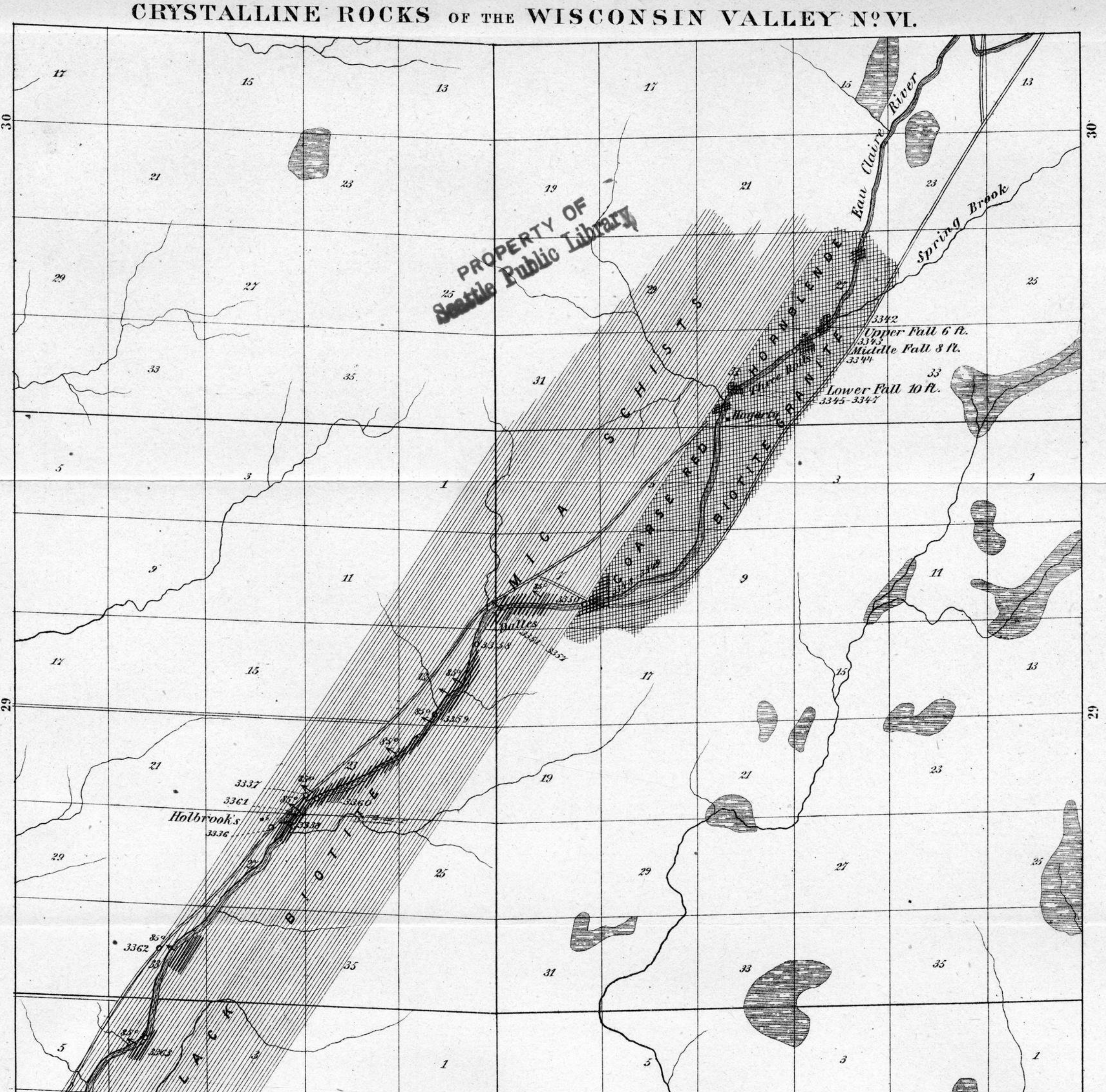
SKETCH MAP VI.

The field observations along the Eau Claire river were made wholly by Mr. A. C. Clark, who found no exposure on or in the vicinity of the river above Sec. 27, T. 30, R. 10 E.

Below this point the exposures are nearly continuous for some ten miles along the downward course of the stream. Only two rock belts, however, are crossed in this distance. The easternmost of these is composed of an exceedingly coarse-grained, pinkish granite, in which all of the ingredients, including pinkish feldspars, quartz, biotite, and hornblende, are easily recognizable macroscopically. Compared with the Wausau granites, this is for the most part of a much coarser grain, much more highly quartzose, and carries more mica and less hornblende. This granite is quite structureless.

The westernmost of the two belts of the Eau Claire river is composed of mica-schist, dipping constantly to the northwest, at a very high angle (80° to 90°), and trending 35° E. of N. The total width of the belt at right angles to the strike is as much as one and one-half miles, and the total rock thickness can not be less than 7,000 feet. Macroscopically, the rock of this belt is usually very fine-grained to aphanitic, and of a dark gray color, the dark gray being often banded by a lighter gray in a direction parallel to the schistose structure. Only rarely are any of the ingredients recognizable macroscopically. The thin sections show under the microscope a mica-schist in all respects like that which prevails so largely in the Huronian of the Marquette and Menomonie regions of Michigan, and the Penokee region of Wisconsin. There is the usual quartz-feldspar groundmass, which is only rarely so fine as to prevent the recognition of its mineral character. The feldspar is chiefly orthoclase, although a little oligoclase is recognizable. The principal mica is biotite, but with it, in most sections, some muscovite is associated. More rarely particles of hornblende and augite are met with, while apatite, magnetic iron, and ferrite, are frequent accessories.

CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY No. VI.



Scale 1⅓ miles to 1 inch
Numbers attached to exposures refer to specimens

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE GRANITES OF EAU CLAIRE RIVER.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3340	Hornblende-biotite-granite.	Little Rapids of the Eau Claire river.	N. E. 27	30	10 E.	Very coarse-grained; the recognizable ingredients are: pink feldspar which shows cleavage pieces over three-fourths of an inch long; quartz in large clear grains; and mica and hornblende in crystals of corresponding size.	Feldspar crystals are very large. *Oligoclase*, *microcline*, and *orthoclase* all are present, the latter in the largest quantity; *quartz* in large clear grains, bearing as inclusions very long slim needles of *rutile; hornblende* and *biotite* both occur plentifully in large crystals; little *titanic* or *magnetic iron; apatite.*
3343	Biotite-granite.	Three Rolls, Eau Claire river.	N. E. 33	30	10 E.	Same as above, except that only here and there a minute grain of biotite or hornblende is visible.	*Feldspars* same as in 3340; *quartz* also same, only more abundant; little *biotite* and *hornblende;* no *apatite.*
3345	Biotite-granite.	Lower Fall, Three Rolls, Eau Claire river.	S. E. 33	30	10 E.	Fine-grained, compact granite. Pink feldspar, pellucid quartz, and shining black grains are visible.	*Feldspars* of the usual three kinds, *orthoclase* the chief one; *quartz* very plenty, having as inclusions few small *apatite* individuals, and pierced in every direction by innumerable dark, long slender needles of *rutile*, the latter only visible with a high power; *biotite* very abundant; *titanic* or *magnetic iron.*
3346	Granite.	Lower Fall, Three Rolls, Eau Claire river.	S. E. 33	30	10 E.	Red, slightly friable rock. Feldspar and quartz are recognizable.	*Microcline* and *orthoclase* in nearly equal proportions, much stained with oxide of iron; *quartz* in part secondary, having as inclusions few small crystals of *apatite; titanic* or *magnetic iron; hematite.*

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE GRANITES OF EAU CLAIRE RIVER — Con.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
3348	Hornblende-biotite-granite.	Eau Claire river.	33	30	10 E.	Differs from 3340 only in being a trifle coarser-grained and having a more pinkish tint to the feldspar.	Differs from 3340 only in the rutile needles being much more plenty.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE MICA SCHISTS OF EAU CLAIRE RIVER.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
933	Muscovite-biotite-schist.	Eau Claire river.	34	29	7 E.	Uniform light gray, finely schistose rock, with a somewhat lustrous appearance, and greasy feel.	*Quartz* and probably *feldspar*, constituting the groundmass in excessively fine grains, averaging not above .02 mm. in breadth; *biotite*, the second mineral in quantity, in flakes with their basal planes mostly parallel to the schistose ones; a little *muscovite; magnetic* or *titanic iron; limonite.* Besides the finely crystalline mass of the rock there are present quite a number of large, apparently porphyritic, crystals of *quartz; orthoclase* and *oligoclase.*
3337	Biotite-schist.	Near Holbrook's, in the river beds.	S. E. 22	29	9 E.	Drab, compact, lustrous, aphanitic schist.	Groundmass *quartz* and *feldspar* finer than in 933; *biotite* in numberless exceedingly minute flakes; a little *muscovite; ferrite.*
3352	Biotite-schist.	Dells on Eau Claire river.	S.W. 7	29	10 E.	From gray to reddish in color; as to grain and schistose characters same as preceding ones of the series.	*Quartz* and probably *feldspar* constitute the groundmass; *biotite* as in 993; considerable *magnetic* or *titanic iron; apatite; chlorite.* Porphyritic crystals of feldspar and quartz. This rock as to fineness and general appearance closely resembles 933.
3354	Hornblende-biotite schist.	Dells on Eau Claire river.	S.W. 7	29	10 E.	Fine-grained, though coarser grained than any of the preceding, the black mica and white grains of quartz and feldspar being distinguishable.	Much coarser grained than any of the preceding. The groundmass is *quartz, orthoclase*, and a little *oligoclase*, the grains varying from quite small to medium size, the mean being about 12 mm.; *biotite* very abundant as heretofore; considerable *hornblende;* a few grains of *augite* and *muscovite; magnetic* or *titanic iron; apatite.*

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE MICA SCHISTS OF EAU CLAIRE RIVER—Con.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3356	Muscovite-biotite-schist.	Dells on Eau Claire river.	S. W. 7	29	10 E.	Mica and white quartz and feldspar visible, the rock being more or less banded from alternate layers of mica and the other minerals.	Groundmass again *quartz* and *orthoclase* in grains averaging about .07 mm. across; *biotite* as usual, muscovite most plenty of any so far observed in the series; *augite; magnetic* or *titanic iron.*
3358	Biotite-schist.	Dells on Eau Claire river.	N. W. 13	29	9 E.	Same as 3356.	Groundmass as heretofore. The crystals are however not so well defined, but appear to average about the same size as 3356. *Biotite* is more plenty than in any of the preceding, a very large proportion of the rock is made of that mineral; *magnetic* or *titanic iron.*
3360	Biotite-schist.	Eau Claire river.	S. W. 23	29	9 E.	Fine-grained, black layers alternating with white ones; layers about one-fourth of an inch thick.	*Quartz, feldspar*—a portion at least being *plagioclase*—*biotite* and *magnetic* or *titanic iron* compose this rock. Differs from the preceding only in having a finer grain and containing much magnetic iron.

3361	Biotite-schist.	Eau Claire river.	S. E. 20	29	9 E.	Has a more chloritic look and is decomposed more than any of the preceding rocks of this series.	Groundmass for most part very fine and obscure, but in a few places the particles are large and clear; in these places the minerals are *quartz* and *orthoclase*, the former being predominant. The gray obscurity of the larger part of the section is due to the decomposition of orthoclase; this is shown by the fact that considerable areas of the substance, so far as it polarizes at all, give the same colors. *Biotite* and *magnetic* or *titanic* iron as before. This rock is the coarsest grained one of the series, but it is so much decomposed as to show macroscopically now but few traces of its original condition.
3363	Chloritic biotite-schist.	Eau Claire river.	Cen. 33	29	9 E.	Lighter colored, otherwise of much the same appearance as 3354.	Very fine groundmass, like 933. *Biotite* and *magnetic* or *titanic* iron; the biotite occurs in minute flakes and in those of considerable size. Included in the fine matrix are many large porphyritic crystals of *orthoclase; chlorite* in some quantity; *hornblende.*

ROCKS OF RIB RIVER VALLEY ABOVE MARATHON CITY.

SKETCH MAP VII.

The locations of exposures within the area of this sketch map are for the most part from the notes of Mr. A. C. Clark; only one or two references to this district having been made in Vol. II.

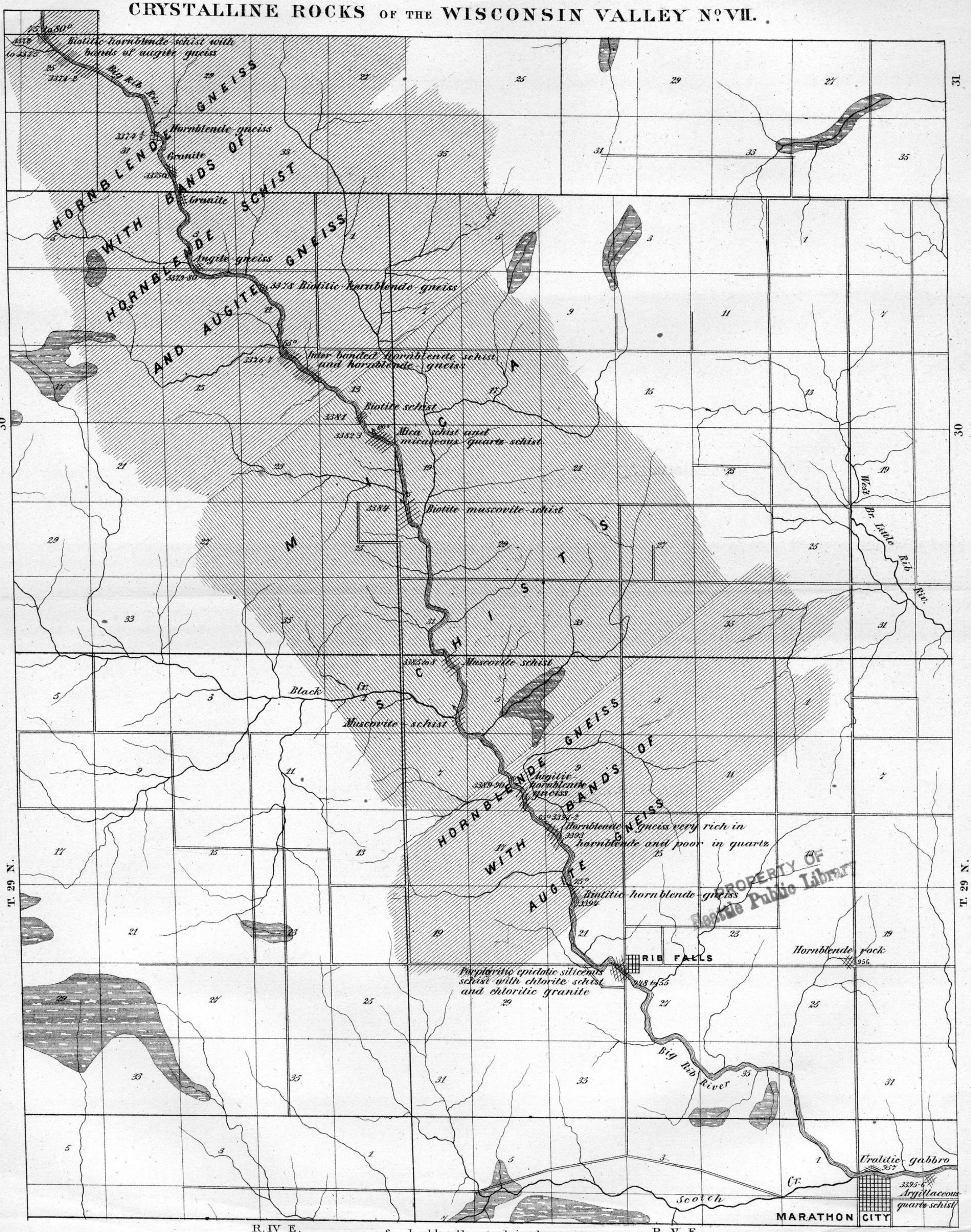
Above Pine river falls the rock seen in Rib river as far as T. 31, beyond which exposures were not discovered, are coarse-grained, light-colored, hornblendic gneisses, alternating with fine-grained, dark-colored schistose beds, and here and there intersected by veins of granitell. The layers trend northeast and southwest with a high dip, which is, so far as observed, constantly to the north. The gneisses are for the most part hornblendic, but black mica is often present, while many of them are augitic, the hornblende either being quite absent or present in subordinate quantity only. So intimate is the association here of augite and hornblende, that little room for doubt can remain as to the uralitic origin of the latter mineral in all of these gneisses, including even those in which no augite remnants are visible.

The schists interbedded with these gneisses are for the most part hornblendic, being simply finer-grained phases of the prevailing hornblendic gneisses. Mica is a constituent in all cases. Less common schistose bands are without hornblende, being true mica schists, with the mica either biotite or muscovite. Augite in subordinate quantity is present in these mica schists.

In the N. W. ¼ of Sec. 16, T. —, R. 5 W., are several structureless outcrops of a coarse-grained greeenish rock which would formerly have been called a typical hornblende rock. In the thin section this rock is found to be much altered, all the recognizable feldspars being triclinic; while hornblende is the chief constituent, and the quartz very subordinate and apparantly secondary, the proper name under the accepted nomenclature appears to be diorite. The occurrence of cores of augite, and even of strongly marked diallage within many of the hornblende individuals, suggests that here again, as in so many of the previously described rocks, the hornblende is merely a paramorphic product of the augite. If this is a correct conclusion, the rock is to be classed with the uralitic gabbros.

From Rib river falls down stream to the east line of the map, the exposures seen on Rib river are unlike those met with further up the stream. The exposures at Rib river falls have already been roughly

CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY No. VII.



Scale 1⅓ miles to 1 inch

described in Vol. II (p. 489). The place is a puzzling one, and as to the structural relations of the rocks here exposed I have nothing now to add. Further experience with the rocks of this region teaches me, however, to doubt the connection with true bedding of the parallel planes whose directions are recorded in Vol. II. Microscopically, also, the Rib river falls rocks are puzzling. A better understanding of them can only be reached by tracing them into less altered forms. As full descriptions of the sections of these rocks as it is possible to make are given in the following tables. Nothing can be gained by a recapitulation of their characters in this place.

Still further down stream the rocks seem to be a westward continuation of the Huronian schists of the vicinity of Wausau, along with intersecting masses of gabbro.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE HORNBLENDIC AND AUGITIC GNEISSES AND SCHISTS OF RIB RIVER.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3371	Hornblende-biotite-schist.	Rib river rapids.	S. E. 25	31	3 E.	Fine-grained, schistose black rock, the color being due to hornblende; quartz is visible in grains of medium size.	*Quartz*, *orthoclase* and *oligoclase*, constituting the groundmass, all occurring in uniform, well preserved grains, averaging about .4 mm. in breadth; green or yellow *hornblende*, the most abundant mineral in the rock, grains very large, many of them above 1.5 mm. in greatest length; *biotite*, in some quantity; *apatite*, in the usual crystals penetrating the quartz, feldspar and hornblende; brown stains of *limonite*.
3374½	Hornblende-gneiss.	Rib river.	Cen. 31	31	4 E.	Mottled black and white rock; medium-grained; schistose; white quartz and feldspar, and black lustrous hornblende are distinguishable.	*Orthoclase* and *labradorite*, the latter very plenty (in this respect this rock is peculiar, being the first gneiss in which I have observed labradorite); *quartz* as usual; *hornblende*, very abundant in large grains; a little *biotite; apatite; magnetic* or *titanic iron; limonite.*
3378	Hornblende-biotite-gneiss.	Rib river.	N.W. 11	30	4 E.	Coarse-grained gneiss; white quartz and feldspar, and black hornblende recognizable; hardly distinguishable from 3376.	*Orthoclase*, *oligoclase* and *quartz*, in nearly equal proportions, the crystals of each varying from medium size to large; *hornblende* and *biotite*, in large quantity; *apatite; magnetite* or *titanic iron.*

3376	Hornblende-biotite-gneiss.	Rib river.	N. E. 14	30	4 E.	Coarse-grained; otherwise not different from 3374½.	*Plagioclase* and *orthoclase*, in large crystals; *quartz*, as usual; *hornblende*, as in 3374½ and 3371, abundant; *apatite*, unusually abundant, in stout blunt crystals, as well as the usual slender ones, in both the quartz and feldspar; *biotite;* little *augite*.
3377	Hornblende-biotite-schist.	Rib river.	N. E. 14	30	4 E.	Differing from 3371 only in being finer grained.	This rock is very like 3371, the only differences being the presence of a greater proportion of magnetic or titanic iron — these minerals being abundant — and of apatite, and the finer grain.
3389	Augitic hornblende-gneiss.	Rib river.	S. E. 8	29	5 E.	Light colored, mottled, coarse-grained rock. White quartz and feldspar are recognizable, also greenish grains of some mineral, which give the rock a tinge of that color.	*Orthoclase* and some *oligoclase*, both much decomposed, in large grains, some of them 3 mm. in length; *quartz*, plenty, also in large grains; *hornblende*, the next mineral in importance, mostly if not wholly a result of alteration of augite, that mineral being found in cores in most of the hornblende crystals; *augite*, in some quantity. This rock contains relatively much less hornblende and augite than the previously described hornblendic rocks.
3373	Chloritic augite-gneiss.	Rib river rapids.	N. E. 25	31	3 E.	Light gray; fine-grained; schistose; quartz in small grains is predominant. Greenish black flakes of an undeterminable mineral are recognizable.	*Quartz*, in small grains constituting the larger portion of the rock; *orthoclase* and *plagioclase*, in some quantity; *augite*, and its decomposition product *chlorite*, in numerous grains and patches, the augite often as a core of the chlorite; little *biotite*.
3374	Chloritic augite-gneiss.	Rib river rapids.	N.W. 25	31	3 E.	Differs from 3373 only in being of a flesh red color.	This rock is much like the preceding. *Orthoclase* is more prominent, and more decomposed; *microcline; augite* and *chlorite* as in 3373, but more plenty; very little *biotite;* stains of *oxide* of *iron*.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE HORNBLENDIC AND AUGITIC GNEISSES AND SCHISTS OF RIB RIVER — Con.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
3379	Augite-gneiss.	Rib river.	S. W. 3	30	4 E.	Massive, schistose rock, has a light gray groundmass with black crystals scattered through it.	*Orthoclase* and *oligoclase*, not very plenty; *quartz*, composing perhaps half of the rock; *augite*, very prominent, being next to the quartz in quantity, occurring in medium sized rounded or irregular grains; *chlorite* and *uralite* as decomposition product of the augite; *hornblende*; *apatite*; numerous small rounded grains of *titanite*, and some which show the regular forms of that mineral.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE MICA SCHISTS OF RIB RIVER.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3381	Biotite-schist.	Rib river.	S.W. 13	30	4 E.	Light gray, fine-grained, schistose rock; white quartz and dark shining small flakes of mica are recognizable.	*Quartz* with a little *orthoclase* and *oligoclase*, in minute grains, constituting the groundmass; *biotite*, very plenty, most of the scales with their basal plane parallel to the schistose plane; *apatite; magnetic* or *titanic iron.*
3383	Micaceous quartz-schist.	Rib river.	N. E. 24	30	4 E.	Very fine-grained, light gray rock. The particles of quartz are so small as to be indistinguishable. Scales of mica give the rock, when split parallel to the schistose plane, a lustrous appearance.	*Quartz*, very greatly predominant in small grains which show nothing of the rounded appearance of those of sandstones. Many minute crystals of *apatite*, included in the quartz; *biotite*, prominent; *muscovite* in small blades and scales; little *iron oxide*.
3384	Mica-schist.	Rib river.	N.W. 30	30	5 E.	Dark, gray-white-and-black-mottled rock of medium grain. Decomposes in an uneven manner, showing that one mineral decomposes more easily than the others. Effervesces in acids.	Groundmass consists of *quartz* and *calcite*, the former for most part in minute grains, the calcite in large quantity; *biotite* is the prominent mica; *muscovite* is plenty. The flakes of mica lie mostly parallel to the schistose plane. A little *augite*, some *magnetite* or *titanic iron*, and *apatite*, are also present.
3388	Magnetitic muscovite-schist.	Rib river.	N. E. 6	29	5 E.	Fine-grained, compact, finely schistose, lustrous rock, of a steel gray color, varying in places to a flesh red.	The very fine-grained groundmass appears to be made up of *quartz* and *feldspar*. *Muscovite* and *magnetite* are both abundant, and the individuals are arranged along lines parallel to the schistose direction. *Augite* is present in rounded grains.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF DIORITES OR URALITIC GABBROS OF RIB RIVER.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3391	Diorite.	Rib river.	N. W. 16	29	5 E.	Composed chiefly of dark green lustrous hornblende and coarse crystals of much decomposed feldspar.	*Feldspar*, in large crystals, much decomposed; some certainly and all probably plagioclase; *kaolin* and scales of *chlorite*, as decomposition products of the feldspar; *hornblende*, the predominant mineral, of a green fibrous variety, and containing *garnets*, *titanic iron*, and often cores of *augite; epidote*, in fissures running across the section. The hornblende individuals, when they contain cores of augite, are less strongly dichroic, in fact answer to the description of uralite. A little secondary *quartz*, perhaps secondary, and *apatite* are present.
3392	Diorite.	Rib river.	N. W. 16	29	5 E.	Finer grained than the preceding, and the feldspar apparently fresh; otherwise like 3391.	*Labradorite*, quite fresh in places, though a portion is much decomposed, containing *rutile* and *apatite; hornblende*, chiefly or wholly of the variety *uralite*, most of the crystals containing one or several large patches of diallage as cores, and still retaining the characteristic fibrous structure of that mineral. Other pieces of amphibole, however, are true hornblende, showing regular cleavage, etc. But since the hornblende is found in all stages of growth, from the time it was diallage, it is probable that all the hornblende was formed by the alteration of diallage. *Magnetic* or *titanic iron* and a little *quartz*, probably secondary, are recognizable.

3394	Diorite.	Rib river.	N. W. 21	29	5 E.	In general appearance much like the two preceding, but has a larger proportion of feldspar than either, and as to coarseness of grain lies between 3391 and 3392.	*Hornblende*, as in 3392, although a larger proportion contains no diallage cores; *diallage* and *augite*, as in 3392; *quartz*, plentiful in large grains, containing no inclusions; *apatite* and *rutile;* *titanic iron*, with its gray decomposition product; *titanite*, in a few irregular crystals; *oligoclase* and *orthoclase*, in about equal proportions; a few large grains of *biotite*.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE ROCKS OF LOWER RIB RIVER.

No. of Specimen.	Page, Vol. II.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions	Constituents as determined by the microscope.
948	489	Chloritic siliceous schist.	Rib Falls.	N. E. 28	29	5 E.	Very fine-grained; compact with rough conchoidal fracture.	The groundmass of this rock is composed chiefly of minute quartz and feldspar fragments, and has a strong appearance of fragmental origin. Thickly scattered through the groundmass are minute greenish particles of chlorite, and some perhaps of hornblende. There are also present good sized crystals of orthoclase and oligoclase, always much clouded. The orthoclase crystals carry bright greenish epidote, which ingredient is also present in the groundmass to some extent, in fine particles. Quartz seams and nests appear in one part of the section.
950			Rib Falls.	N. E. 28	29	5 E.	Light gray to dark green; mottled; large crystals of white feldspar compose a large portion of the rock; these are buried in a matrix, giving the rock a porphyritic appearance.	Numerous very large dull crystals of orthoclase and oligoclase are imbedded in a groundmass composed chiefly of small particles of quartz with some orthoclase and triclinic feldspar. As seen in polarized light the appearance of this matrix often suggests a fragmental origin. There are also present biotite, chlorite, hornblende, magnetite, and brown oxide of iron; these five minerals being arranged in clusters in such a manner as to suggest their secondary origin from some original large sized porphyritic ingredients.
952		Epidotic biotite-granite.	Rib Falls.	N. E. 28	29	5 E.	Medium-grained; compact. Light pinkish gray feldspar, quartz and dark green mica are visible.	*Orthoclase* and *oligoclase*, predominant; much *quartz; biotite* plenty; *chlorite*, clustered so as to suggest alteration from some other mineral; *apatite; magnetic* or *titanic iron;* little *epidote*.

953		Calcitic chlorite-schist.	Rib Falls.	N. E. 28	29	5 E.	Aphanitic; foliated; finely lamellar; soft greasy feel; dark green color; contains pyrite.	Very fine grained; composed largely of fine fibrous *chlorite* and very small grains *calcite; quartz*, *magnetite* and *ferrite* are present.
954		Epidotic siliceous schist.	Rib Falls.	N. E. 28	29	5 E.	Larger part like 953. Intrusive masses of light pink granitic material.	Much *epidote*, *quartz*, and considerable *chlorite* are scattered through a very fine matrix which seems to be largely composed of kaolin; *calcite* and *ferrite*.
955		Epidotic hornblende-schist.	Rib Falls.	N. E. 28	29	5 E.	Fine-grained; massive; uniform texture and color; black.	*Hornblende* is the chief constituent, in irregular pieces with ragged outlines varying from large size to minute. The larger part of the remainder of the rock is of *feldspar*, in part certainly *plagioclase*, but so much decomposed as to make it impossible to say whether orthoclase is present or not; little *quartz; epidote* in fissures cutting through the section.
957		Hornblendic gabbro.	Marathon city.	1	28	5 E.	Medium-grained; compact; uniform dark gray; large black lustrous crystals of hornblende stand out prominently in the finer mass of the rock.	*Diallage*, in rounded crystals, the most important constituent; *oligoclase;* few large crystals of *hornblende* with cores of diallage; little *magnetic* or *titanic iron*.
3395		Argillaceous quartz-schist.	Rib river.	S.W. 5	29	6 E.		This rock in its general appearance and clastic character resembles closely the Marshall hill rocks. The fragmental particles are more numerous, smaller, and vary from large ones through every grade down to the excessively fine matrix. In the Marshall hill rocks these crystals are largely quartz; in this, orthoclase feldspar is much predominant. Oligoclase and quartz occur. The matrix appears to be precisely the same, kaolin and chlorite probably preponderating, magnetite and ferrite present. Besides the small feldspar fragments, there are seen two or three very large porphyritic crystals of orthoclase, one of them being a Carlsbad twin.

ROCKS OF THE WISCONSIN RIVER VALLEY FROM PINE RIVER TO GRANDFATHER BULL FALLS.

SKETCH MAP VIII.

The principal rocks of the area of this map are hornblende gneiss and schist, with interstratified beds of augite-gneiss and schist, and mica-schist; the whole group being plainly but the northeasterly extension of the similar rocks of the Upper Rib river, Sketch Map VII. Associated with these gneisses, and probably intersecting them, are belts of gabbro and peridotite. In the extreme northwestern corner of this area, at Grandfather Bull Falls, granite is exposed in a belt of considerable width; but no specimens are at hand to represent the rock.

As with the hornblende schists and gneisses of Rib river, so also with their continuations in the area now under discussion, the hornblende is in all cases merely a paramorphic product of the augite and diallage, many thin sections in fact being without hornblende. As to other ingredients these gneisses are like those of Rib river and do not need any further general description.

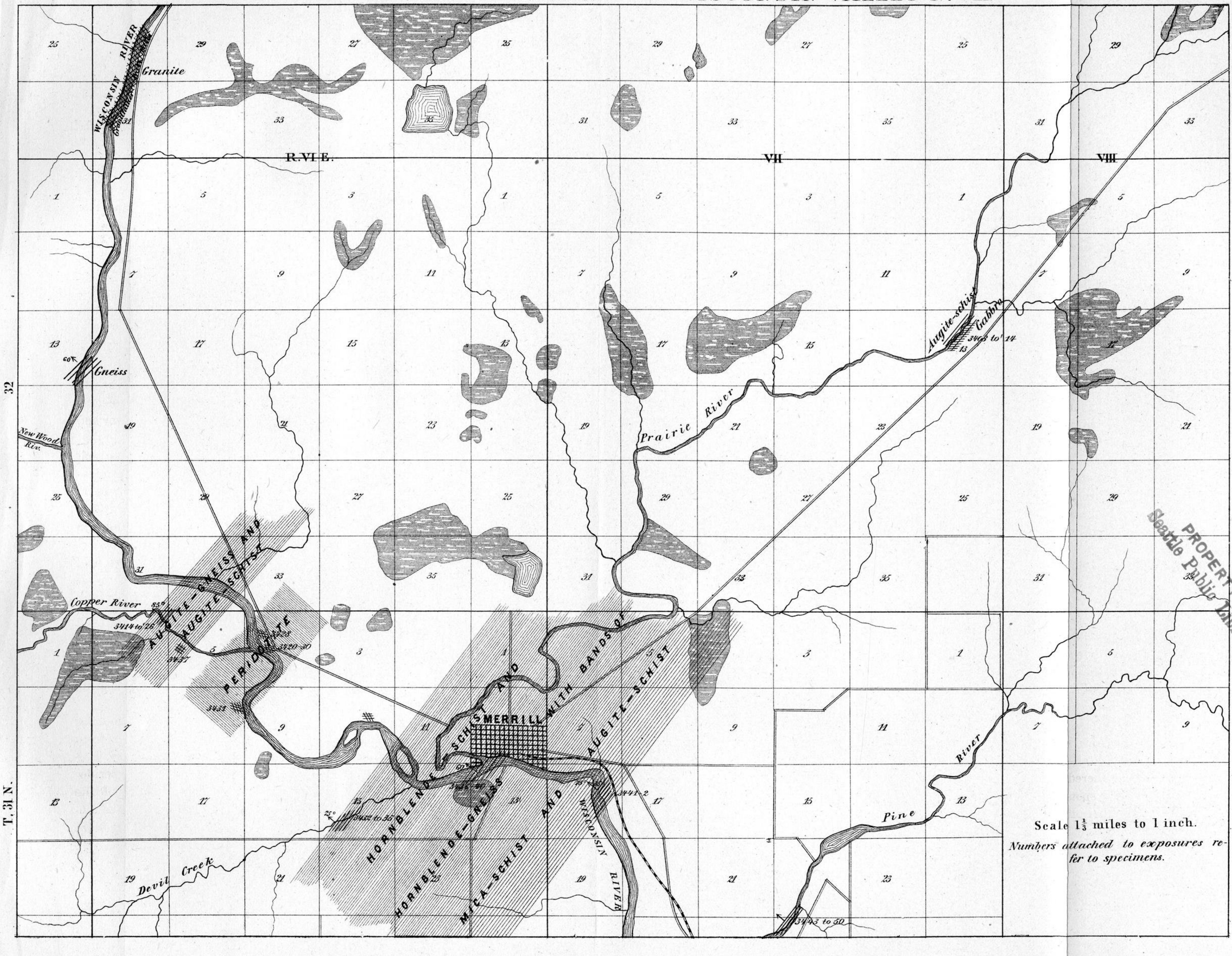
From the descriptions in the following tables it will be seen that these gneisses carry mica as a constant ingredient, and that the mica-schists interstratified with them are plainly only peculiar phases in which the mica predominates over the augite and hornblende. One, or both, of the latter minerals is commonly to be seen in the thin sections of these mica-schists.

Along the rapids of Prairie river, for a distance of about one-fourth mile, in the N. E. ¼ of Sec. 3, T. 32, R. 7 E., a belt of uralitic gabbro may be seen in contact with an augitic gneiss. This gabbro is of a dark gray color, and a medium grain. The triclinic feldspar and altered diallage are both distinguishable by the naked eye.

In the thin section, labradorite and diallage, in nearly equal proportions, are seen to make up almost the whole of the rock, the last named mineral being more or less altered to uralite. Apatite, titaniferous magnetite, chlorite and biotite are the accessories.

A black, rough-textured, often greenish-stained, greasy looking rock, which makes large exposures along the Wisconsin river from Rocky Island in the N. W. ¼ of Sec. 4, T. 31, R. 6 E., to the N. E. ¼ of Sec. 8 of the same township, proves to be a highly altered peridotite. Sections of the freshest portions show a few spots of the original chrysolite, but even in these cases the larger part of the section is made of serpentine. The other recognizable ingredients are

CRYSTALLINE ROCKS OF THE WISCONSIN VALLEY No. VIII.



enstatite or hypersthene, and magnetite, along with hematite and ochre as decomposition products. Some sections show no trace of the original olivine.

The peculiar gray and greenish gray schists of Pine river in Sec. 22, T. 31, R. 7 E., in the southern part of the area embraced in Sketch Map VIII, are quite unlike the other rocks of this area. Their nature is somewhat obscure, but they seem to be of a fragmental origin, and upon the whole appear to be somewhat allied to the argillaceous quartz-schists of Marshall Hill.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE HORNBLENDIC AND AUGITIC GNEISSES AND SCHISTS OF THE WISCONSIN VALLEY IN THE VICINITY OF MERRILL.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3410	Biotite-augite-gneiss.	Rapids on Prairie river.	S. E. 13	32	7 E.	Fine-grained; light-gray; compact. White feldspar, translucent quartz and black grains of mica and augite are recognizable.	*Orthoclase* and *oligoclase; quartz*, very plenty, containing apatite; *biotite* and *augite*, in some quantity; *chlorite*, often surrounding the augite as a decomposition product; a little *muscovite*.
3412	Biotite-augite-gneiss.		13	32	7 E.	Same as 3410.	*Orthoclase* and *oligoclase*, as in 3410; *microcline; quartz*, less than in the above; *biotite*, very abundant; *muscovite; augite*, as in 3410, though less in quantity; *chlorite; apatite*, very plenty, both in the feldspar and quartz.
3404	Augitic biotite-muscovite-granite.	Rapids on Prairie river.	Cen. 13	32	7 E.	Differs from the preceding in that the feldspar is bright pink instead of white, giving the rock a much redder color; otherwise the same.	*Feldspars*, as in 3410 and 3412, but more clouded by decomposition and stained with oxide of iron; *quartz, biotite* and *apatite*, same as before; less *augite; muscovite*, in some quantity.
3415	Augite-biotite-gneiss.	Copper river.	N. E. 6	31	6 E.	Fine-grained; brick red. White quartz, red feldspar and brownish flakes of mica are recognizable.	*Microcline; orthoclase; oligoclase; quartz; biotite; muscovite*, in very small quantity; *augite*, in few small grains; *magnetite; limonite;* a little *apatite*.

3417	Augite-biotite-gneiss.	Copper river.	N. E. 6	31	6 E.	Rather coarse-grained; mottled. Dirty white crystals of feldspar, quartz and black shining scales are visible.	*Orthoclase; oligoclase; microcline; quartz*, containing apatite; *biotite; augite*, all through the section in innumerable small round grains; *magnetite* or *titanic iron*.
3422	Hornblende-schist.	Copper river.	N. E. 6	31	6 E.	Finely schistose, black, massive rock of uniform color and appearance.	*Hornblende*, largely predominant, the crystals lying in all directions, but most of them parallel to the schistose planes; *quartz*, next in abundance to the hornblende, in minute, round grains; *magnetite* or *titanic iron*, prominent in numerous irregular black patches; *hematite*, in a few red scales.
3424	Augitic schist.	Copper river.	N. E. 6	31	6 E.	Compact; fine-grained; schistose. Feldspar in reddish white grains, quartz, and mica in small flakes are recognizable.	*Orthoclase; oligoclase; microcline; quartz; augite*, in numerous clusters of particles, also in many isolated small rounded grains; *uralite; muscovite*, in a few minute flakes; *apatite; limonite; titanic iron*, with its gray decomposition product.
3427	Augitic biotite-schist.	Copper river.	N. W. 5	31	6 E.	Fine-grained; strongly schistose; of a uniform glistening black color.	*Augite* and *biotite*, in nearly equal proportions are the chief constituents of the rock. The augite occurs in small rounded grains scattered very uniformly. *Quartz, plagioclase*, and *orthoclase* are the most important remaining minerals; *magnetite* is present.
3434	Hornblende-biotite-schist.	Devil's creek.	S. W. 15	31	6 E.	Medium-grained. White feldspar, translucent quartz, and an abundance of black mica scales are apparent to the unaided eye.	*Quartz* and *feldspar* constitute the groundmass. Most of the quartz occurs in small irregular grains packed between the hornblende individuals. The feldspar, which is labradorite in part at least, occurs in large areas entirely free from quartz. The hornblende is much decomposed. Its crystals for the most part lie with their longer dimensions parallel to the schistose direction, and are very plenty. A little *augite* is included in the feldspar areas. *Biotite*, in abundance; a little *magnetite* is present.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE HORNBLENDIC AND AUGITIC GNEISSES AND SCHISTS OF THE WISCONSIN VALLEY IN THE VICINITY OF MERRILL—Con.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3432	Hornblende-biotite-schist.	Devil's creek	S. W. 15	31	6 E.	Fine-grained, black, uniform schistose rock. Here and there white feldspars are visible.	*Quartz* and *orthoclase* constitute the groundmass, the former preponderant. The grains of each are small and of uniform size. *Hornblende* is very abundant, occurring as in 3434; *biotite* is plenty; *augite* occurs in small rounded grains at intervals; *apatite* occurs as usual. This and the preceding rock very much alike.
3436	Augitic hornblende-biotite-gneiss.	Wisconsin river.	N. E. 14	31	6 E.	Coarse-grained. Large black crystals of hornblende, white quartz, gray feldspars, and shining grains of mica are apparent to the unaided eye.	*Oligoclase* and *orthoclase*, plenty; *quartz*, in small quantity; *hornblende* and *biotite*, abundant, the two minerals usually packed together and cutting each other in all directions, biotite being later than the hornblende, as one crystal of the former often includes several of the latter; *augite*, in numerous tabular crystals, and as cores of hornblende individuals; *apatite; oxide of iron*.
3439	Chloritic diallage-gneiss.	Wisconsin river.	S. W. 12	31	6 E.	Fine-grained; compact. White feldspars, translucent quartz, and numerous greenish-black flakes of mica are apparent to the unaided eye.	*Oligoclase* and *orthoclase*, in large crystals, composing a large proportion of the rock; *quartz* prominent in large grains; *diallage*, in numerous small individuals; *chlorite*, as decomposition product of the diallage, quite plenty; *magnetite* or *titanic iron*.

3440	Hornblende-diallage-granite.	Wisconsin river.	S.W. 12	31	6 E.	Medium-grained white quartz and feldspar, and black hornblende, in nearly equal proportion, are apparent to the unaided eye.	A portion of the feldspars — *orthoclase* and *oligoclase* — are in large crystals, some of them being 1.7 mm. in length. Other crystals are small and confusedly mingled together with the quartz. The *quartz* occurs in small grains. The large crystals of feldspar mingled with the mass of rock, which is composed of small particles of quartz and feldspar, give it a somewhat porphyritic appearance. *Hornblende* is very abundant, this mineral composing a considerable portion of the rock. The individuals vary from a very small size to those which measure more than 3.5 mm. in length. A portion of the hornblende at least is an alteration product of diallage; for often one end of a crystal is diallage and the other hornblende. The *diallage* also occurs separately in some quantity. *Biotite* is present in a few grains, as is also the usual *magnetite* or *titanic iron*.
3441	Chloritic diallage-gneiss.	Wisconsin river.	N. E. 18	31	6 E.	Coarser grained than 3439. The quartz and feldspar in many places are stained with iron oxide; otherwise the rock is much the same as 343.	This rock is in every way intermediate between 3439 and 3440. The feldspar and quartz have something of the same peculiar appearance shown in 3440; yet it is not so marked, these minerals having more of the characters ordinary in gneisses, as shown in 3439. Again, the diallage, which in these rocks appears to be the mineral from which the chlorite and hornblende were formed, is more altered than in 3439, yet not so much as in 3440. In this rock it is, as in 3439, the most important mineral of the three, yet there is a good deal of chlorite, and some uralite. Uralite is not present in 3439, and is very prominent in 3440. Chlorite is not present in 3449, and prominent in 3441. A little biotite, some magnetite or titanic iron, and limonite stains are observable.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE MICA-SCHISTS OF THE VICINITY OF MERRILL.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3425	Augitic mica-schist.	Copper river.	N. E. N. E. 6	31	6 E.	Black; fine-grained; schistose mica in shining flakes, most of them parallel to the schistose planes, is the only mineral recognizable.	*Biotite*, composing nearly the whole of the rock, many scales showing strong dichroism, but the greater part cut parallel to the basal plane; *muscovite*, present in some quantity; *augite*, in the usual clusters of rounded grains; *magnetite*, associated with the augite; *quartz* and *orthoclase*, in a few grains.
3437	Quartzose biotite-schist.	Wisconsin river.	S. W. 12	31	6 E.	Light gray; finely schistose. White quartz, and mica in lustrous flakes are recognizable.	*Quartz*, constituting the groundmass in small irregular grains averaging only about .08 mm. in breadth; *biotite*, the second mineral in quantity, the flakes mostly parallel to the schistose planes; *augite* and *hornblende*, present in small quantity; *plagioclase*, in a few small crystals; *hematite*.
3436	Mica-schists.	Wisconsin river.	S. W. 12	31	6 E.	Fine-grained; gray; much like 3437, the only difference being that the mica is more prominent and the quartz less so.	*Quartz*, as the groundmass, in grains somewhat larger than 3437; *plagioclase*, in small quantity mingled with the quartz; *biotite*, the principal mica, the greater portion of the flakes having their bases parallel to the schistose plane; *muscovite*, in some quantity; *magnetite; apatite*.
3442	Chloritic mica-schist.					Fine-grained; soft; strongly schistose. Mica in blackish gray shining flakes, quartz, and feldspar are recognizable.	*Quartz* and *orthoclase*, composing the groundmass, the former largely predominant; *biotite* and *muscovite*, both very plenty, together forming perhaps half of the rock; *chlorite*, quite abundant; *magnetite; epidote; apatite*.

RESULTS OF A MICROSCOPIC STUDY OF THE SCHISTS OF PINE RIVER.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic description.	Constituents as determined by the microscope.
3443 to 3450		Pine river.				The color varies from a dark, lustrous, greenish gray to yellowish drab. They all give a strong odor of clay. The matrix is aphanitic. In it is seen fragments of quartz and feldspar, and in some specimens clusters and veins of quartz grains.	The nature of these rocks is somewhat difficult to make out, but they appear to be of a fragmental origin, and have been much altered since the original deposition of the particles of which they are composed. The groundmass is excessively fine, is of a tint varying from greenish to yellowish, and seems to be largely composed of argillaceous matter, with which is mingled much chlorite, ferrite, considerable magetite and apparently serpentine. Cutting the matrix are quite numerous minute veins of quartz, which are evidently secondary. Packed in nests and scattered through the matrix are very many quite large broken or rounded fragments of feldspar and quartz. The former is much predominant and is chiefly orthoclase, although plagioclase is present. These feldspars are usually quite fresh, but are often replaced in part by secondary quartz.

TABULATION OF THE RESULTS OF A MICROSCOPIC STUDY OF THE GABBROS OF PRAIRIE RIVER, AND PERIDOTITE OF THE UPPER WISCONSIN.

No. of Specimen.	Name.	Place.	Section.	Town.	Range.	Macroscopic descriptions.	Constituents as determined by the microscope.
3405	Altered gabbro.	Rapids on Prairie river.	13	32	7 E.	Medium grained; dark gray. Plagioclase and diallage are both distinctly visible.	Rock almost entirely composed of labradorite and diallage in nearly equal proportions. *Apatite*, in short, stout crystals; *labradorite*, but little decomposed; *diallage*, finely fibrous, altered in part to uralite and chlorite, in some crystals the change to *uralite* being complete; *titaniferous magnetite*, with its gray decomposition product; *biotite*, in some quantity.
3407	Altered gabbro.	Rapids on Prairie river.	Cen. 13	32	7 E.	Same as preceding.	Much like the above; the alteration has, however, taken place to a much greater extent. *Apatite; labradorite; diallage*, largely altered to uralite, the change in some cases being complete, while in others there remains a core of diallage; *biotite*, present in considerable quantity; *magnetic* or *titanic iron*, probably as a product of the alteration of the diallage.

3428	Peridotite.	Rocky island, Wisconsin river.	4	31	6 E.	Black; rough textured, greasy rock, showing in some places large brightly shining cleavage surfaces.	*Olivine*, in a few remnants which with crossed nicols still give bright colors; *enstatite* or *hypersthene*, abundant, somewhat altered, but still retaining all the optical properties, polarizing, however, less brilliantly than the unaltered mineral; *serpentine*, as a decomposition product of the olivine, and much of it pseudomorphous with it, now the chief constituent of the rock; *magnetite*, in very numerous patches of varying size all through the section; some *hematite* and *limonite*. Much of the three last named minerals, perhaps most of them, are products of the decay of the olivine. A few scattering individuals much decomposed which are apparently *plagioclase*.
3429	Peridotite.	Wisconsin river.	S. E. N. E. 4	31	6 E.	Same as 3428.	Same as 3428, the decomposition perhaps carried a little further.
3430	Peridotite.	Wisconsin river.	N. E. 4	31	6 E.	Same as 3428.	Same as 3428.
3430a	Peridotite.	Wisconsin river.	N. E. 4	31	6 E.	Light green, no cleavage surfaces, otherwise as above.	Evidently of the same nature as 3428, but the olivine is completely altered to serpentine, etc., while the enstatite no longer retains its optical properties. Other minerals as above.

SUMMARY OF RESULTS.

With regard to the broader structural and genetic relations of the rocks described in the foregoing pages, a study of so restricted an area as the one here covered cannot be expected to afford any satisfactory conclusions. Such conclusions can only be looked for when the whole extent of the crystalline schists of the northwestern states and the adjoining part of Canada shall have been submitted to a comprehensive and exhaustive investigation. In these paragraphs, then, it is designed simply to sum up in a convenient form for future reference the observations detailed in the preceding pages.

Setting aside for a moment the peculiar quartz-schists and quartzites met with in the immediate vicinity of Wausau, the crystalline rocks of the Wisconsin valley may be described as a great series of schistose gneisses. Alternating with these are finer grained and more highly lamellar schists, which are plainly only phases of the prevailing gneiss. Intersecting the gneiss at long intervals are dikes of dark colored basic material — olivine-diabase, norite, gabbro, peridotite, and alteration forms of those rocks,— while structureless masses and areas of granite occur, often plainly, and always presumably, of an intrusive nature. In some cases we have instead of the granite a typically developed quartziferous porphyry.

In trend, these prevailing gneisses and associated schists range from N. 35 E. in the extreme northeastern part of the area examined, to N. 65 E. midway in its width, and to north of west at the extreme southwest; the whole series thus swinging around more and more to the westward as it is followed along the strike from the northeast. The beds stand nearly always at a very high angle, on either side of the vertical, from which they rarely depart more than 40°.

Beginning at the southernmost exposures of crystalline rocks in the Wisconsin valley, and proceeding northward, we cross first a belt some five and twenty miles in width occupied chiefly by mica gneisses of a light gray, pinkish gray, or mottled coloring, and very rarely with a general greenish hue. These gneisses are all augite-bearing, and the same is true of the interbedded hornblende schists. Quartz-porphyry and black olivine-diabase are met with at rare intervals in intrusive masses. Intersecting granite and granitell appear much more commonly.

Next north of this belt is another some ten miles in width, in which the nature of the underlying rocks has been only imperfectly determined. At Little Bull falls are structureless masses of a dark greenish, or white-and-black-mottled hornblende granite; while further to the east and northeast, on the Eau Claire river, coarse grained red granite, and fine-grained dark, colored mica schists in immense thickness, are the underlying rocks.

Still further to the north is an area, some twelve miles in width, in which the different kinds of rocks present a very irregular and no longer distinctly belt-like distribution. Of these rocks the argillaceous quartz-schists of Marshall hill seem certainly to belong with the so-called Huronian schists which stretch down into this district from their well known occurrence on the Menominee river. Possibly, also, the quartzites of the lower part of the Little Rib river and of the Rib and Mosinee hills belong to the same formation, but this is much more doubtful; the appearance of these quartzites suggesting strongly their vein origin. The coarse red granite of the immediate vicinity of Wausau seems to be a limited mass of eruptive origin, and the same appears to be true of the granites which lie to the west and north of Wausau, and also of the quartziferous porphyry which occupies so large an area to the east of that place. The gabbro in the vicinity of Marathon city on the Big Rib river, and the norite of the lower Eau Claire are plainly eruptive.

Although it is regarded as certain that some of the rocks in the vicinity of Wausau belong with the Huronian, the limits of the Huronian in this region can only be guessed at. Indeed, the whole subject of the relations of the Huronian and Laurentian formations of the northwestern states is one still veiled in so much uncertainty that it is not possible to assert positively that all of the schistose rocks of the Upper Wisconsin valley should not be included within the Huronian. Judging from purely lithological data, I have surmised that the limit of the Huronian in this region may be somewhere near the position of the dotted line upon the accompanying plate; but that the limit is as thus indicated can be regarded as nothing more than an intelligent guess.

The northern limit of the last belt crossed in our northward journey is near a line running through Rib river falls and Marshall hill on the Wisconsin. Beyond this line to the northward the country is again everywhere occupied, so far as the northern limit of the area examined, by gneisses with interbedded schists and intrusive gabbro, peridotite, and granite. The gneisses of this belt differ, however, from those further to the southward in being prevailingly hornblendic instead of micaceous, in carrying less quartz, and in their general tendency to a greenish hue. They are also more highly augitic, some of the layers being in fact augite gneisses, without either the hornblende or mica. The same is true also of the associated dark colored schists, which are otherwise in no important respect different from those imbedded with the more southern mica gneisses.

Besides establishing the mineralogical nature and relations of the various constituents of the several phases of rock presented in this region, Mr. Vanhise's microscopic work has brought out some very important facts with regard to the existence of augite in the crystalline schists and of the relations to it of the hornblende of these rocks. It has long been known that hornblende occurs as a paramorphic product from augite, this product being known as uralite. Since the application of the microscope to the study of rocks, the occurrence of uralitic forms of hornblende has been shown to be not uncommon among basic eruptive rocks. Hawes first showed that the so-called "basaltic" hornblende, whose sections are characteristically of a deep brown color and very highly dichroic, also occurs as a rock constituent with cores of augite. Later I myself found the same thing among some hornblende gabbros of the Lake Superior country.

Mr. Vanhise's study shows now that augite, so far from being a stranger to such rocks as gneiss and granite, is nearly as common a constituent, so far at least as this region is concerned, as hornblende or mica, and that all of the hornblende of the rocks of this region is but altered augite. My own examinations of many hundred sections of the eruptive rocks of the Copper-Bearing Series of Lake Superior have convinced me that in those rocks also there is no hornblende that is not secondary; and while I am not at all prepared to say that there is no such thing as original hornblende, in the older crystalline rocks, I am sure that there is far less of it than has heretofore been supposed. Many diorites are thus but uralitic or altered diabases and gabbros; while many syenites, hornblende granites, hornblende gneisses, and hornblende schists are also but altered augitic rocks. The existence of this wide-spread alteration, and of another equally important one which I have elsewhere shown to obtain widely in the rocks of the Lake Superior region, namely, the substitution of secondary quartz for primary feldspars, make it very evident to me that any one attempting to solve the problem of the origin of the crystalline schists must give much attention to the matter of internal alterations and replacements.

PART VIII.

SUPERFICIAL GEOLOGY

OF THE

UPPER WISCONSIN VALLEY.

BASED MAINLY ON THE

OBSERVATIONS OF A. C. CLARK.

EDITED BY T. C. CHAMBERLIN.

SUPERFICIAL GEOLOGY OF THE UPPER WISCONSIN VALLEY.

BASED ON THE NOTES OF A. C. CLARK. EDITED BY T. C. CHAMBERLIN.

The facts relating to the superficial geology of the valley of the Upper Wisconsin river (Marathon and Lincoln counties), will appear in their clearest and most interesting form, if they are sketched with reference to the agencies which produced them. The whole region lies within the territory covered by the ancient ice-sheet of the first glacial epoch, but only partially within that overspread during the second glacial epoch. The limit of the glacial advance skirts Marathon county on the east, following essentially the watershed between the Wisconsin and Wolf rivers to town 33, when it curves westerly across the southern portion of Lincoln county through the tiers of townships numbered 33 and 34 N., to the watershed between the Wisconsin and Chippewa rivers in Taylor county. Thus nearly all of Marathon, and the southern portion of Lincoln county, lie within the region covered by the earlier glaciation, but not by the later.

Valley Flood Deposits. When, however, the ice of the second epoch occupied the territory north of the limit above sketched, its melting gave rise to large quantities of water, which issued from its margin in innumerable streams that flooded the adjacent land, and, gathering into great streams, flowed down the principal valleys, bearing sand and gravel derived from the glacial drift. The deposits so formed, while they lie within the territory of the older glaciation, were really formed during the later epoch, and through the agency of its glacial floods. These constitute the deposits that occupy the valleys of the Wisconsin and its main tributaries — the Plover, the Eau Claire, the Pine and the Prairie rivers on the east, and the Big Rib and the Wood rivers on the west. They also constitute the level areas of sand and gravel which border the rough morainic region that marks the limit of the second glacier. The sandy plains immediately adjacent to the Wisconsin river are striking examples of this deposit. The fact that it is strictly a valley deposit of washed material, derived from the north, and not in any proper sense a representative of the superficial deposits and soil of the region in general, has been overlooked by thousands of transient visitors, whose entrance and exit were confined to the valley, and who have therefore borne away an impression of sandiness and sterility altogether untruthful as applied to the region in general.

Earlier Glacial Deposits. As we pass up from the level deposits that adjoin the river, into the uplands, a rolling surface, covered with drift composed of clay, sand, gravel and bowlders, variously intermixed and arranged, is encountered. Among the bowlders those of granite and gneiss greatly predominate. With these are associated various metamorphic schists, diabases, gabbros, porphyries, and other representatives of igneous rocks, together with occasional erratics from the Lake Superior sandstones. The granitic bowlders are mainly of the class underlying the region, and were undoubtedly locally derived in the main. Some, however, have as unquestionably been transported from distant regions, lying to the northward. The same may be remarked of the metamorphic schists and of the igneous rocks. In the distribution of these bowlders belts seem to be quite clearly discernible, having a northeast-southwest trend, which is essentially that of the underlying formations, and probably also that of ice-movement in such localities, though this has not been determined by observation of striæ.

The gravel is of essentially the same character as the bowlders, but seems to contain less of local and of soft rock, and relatively more of that of distant origin. The sand and clay are merely the finer products of the glacial grinding, and of the decomposition of the drift constituents. The original rock being of the classes above indicated, it is not strange that a relatively small amount of calcareous matter is found in the soils and clays. Of the numerous tests made by Mr. Clark in the field, none gave evidence of a notable calcareous ingredient. Notwithstanding this, however, the decomposition of the lime-bearing feldspars and other silicates furnishes a slow and constant supply of lime, competent to support a healthy and vigorous vegetation.

A modified portion of the clay, near Wausau, is used for the manufacture of an excellent brick.

Morainic Accumulations. The limit of the extension of the ice-sheet of the second glacial epoch is marked by a thick accumulation of drift, heaped up in an irregular pell-mell fashion, giving a rough, ridged surface, characterized by irregular hills and depressions of the peculiar type which has been fully described in other parts of the report, under the head of the Kettle Moraine. To these descriptions the reader desiring ampler information of the special contour, structure and method of formation is referred. By reference to them it will be observed that that portion of the Kettle Moraine which marks the western border of the ancient Green Bay glacier, runs northward from the point where it crosses the great bend of the Wisconsin river, following (or perhaps rather constituting) the watershed between the Wisconsin and Fox and Wolf rivers across the southeastern corner of Marathon county to town 33. Here it turns quite abruptly to the westward, or perhaps it is to be regarded as meeting a portion of the moraine coming from the westward, which curves in a low arc across the Wisconsin valley, crossing the river in town 34, and crossing the western watershed into the Chippewa valley, in towns 32 and 33, ranges 1 and 2 east. Full details relating to the course and character of this moraine in this great forest region have not been worked out, but wherever seen it has been found to possess essentially the same characteristics that pertain to the formation where it has been more critically studied.

By a glance at any good map of the region, it will be observed that many small lakes lie along the course and to the northward of the moraine, while to the southward, in the area of the older drift, lakes are almost wholly absent. These lakes lie in the depressions formed by the irregular heaping up of the drift. The strange and irregular forms of many of them reveal in themselves this irregularity. A portion of them occupy depressions in the marginal moraine itself, in which case the basin is usually deep, and bounded by sharp slopes. Another portion occupy broader and less abrupt depressions in the great sheet of drift (the *till* or *ground moraine* of the glacier) that spreads over the region north of the terminal moraine. Still another class occupy depressions in comparatively level areas of modified drift — usually sand and gravel plains.

Bowlder Clay or Till of the Second Glacial Epoch. As already implied, the region north of the terminal moraine is occupied by a broad, irregular sheet of commingled drift, spread out by the ice-sheet; in other words its ground moraine. This, on its southern margin, graduates into the morainic accumulations, which really constitute its edge. The distinction between the wide-spread sheet of till, and that peculiar corrugation of it which forms the marginal moraine, nowhere very sharp, is here, judging from the observations that have been made, more than usually undefined. When we consider that this area lies in the fork between the paths of the Chippewa and Green

Bay glaciers, and near the summit of the Archæan highlands, something of unusual complexity is not strange.

The Kettle range, instead of consisting of a single morainic ridge usually embraces a group of moraines, sometimes considerably separated from each other. These give additional complexity to the marginal portion of the later glacial drift, and hence add to the confusion of the drift accumulation.

In central and northern Lincoln county, there are considerable areas occupied by high drift hills with rounded tops, some of them having a circular form resembling an old-fashioned bee-hive in contour and proportions. Others are elongated, having an elliptical base while others are extended into ridges. Between them are deep valleys, usually dry, and manifestly formed by the irregularities of the drift accumulation, and not by post-glacial erosion. In depressions associated with these valleys lie many of the beautiful lakes of the region. There are other quite extensive areas whose general surfaces are level, but upon which have been impressed, as it were, basins — some with gently sloping, and others with abrupt margins,— in which lie lakelets of clear water. The surface portions of these plains are usually formed of assorted and stratified drift. Below this there is, without doubt, the original unassorted and unstratified glacial material, though this is not a matter of observation. These level tracts were doubtless formed, in the main, by glacial floods and lakes, produced during the melting and retreat of the ice.

It appears, therefore, that the surface features of this region north of the moraine, including the most of Lincoln county, are due almost exclusively to the special way in which the drift was deposited; while that portion south of the moraine, including nearly all of Marathon county, except the valley plains, has a surface whose features are mainly due to the contour of the underlying rock, over which the drift spreads as a thin blanket, only slightly modifying the rock topography and not greatly masking it. The rock contour was in the main due, probably, to pre-glacial erosion, modified somewhat by the rasping of the glacier of the first epoch.

Peculiarities of Drainage. An exceptionally small portion of the rainfall of the lake region flows away on the surface. There are large areas over which there are no running streams, even at the time when spring floods run rampant elsewhere. The waters collect in the numerous lakes and perhaps still more numerous small marshes that represent extinct lakes, and is there held and prevented from immediately flowing away. Many of the lakes have neither visible inlet nor outlet. The question of their supply and drainage has frequently been raised. The fact that their waters are usually exceptionally clear and spring-like in character deserves consideration. We entertain the opinion that if the truth were fully known it would be found to be diverse in different cases. In some instances the supply of the lakes is simply the drainage of the adjacent surfaces, increased, in some cases, by springs around their margins; and their discharge is through the atmosphere by evaporation — that great outlet of all lakes, which is too often unreckoned in the study of drainage phenomena. That there is no open communication between adjacent lakes is demonstrated in some instances by the difference of level of their surfaces. But in other instances there seem to be good reasons for believing that there are underground channels of communication through the porous material of the drift, and that through these both ingress and egress of waters take place, and communication is at length had with the streams of the region. The most of these lakes are abundantly supplied with a variety of fish. This fact harmonizes with the hypothesis of an underground communication, sufficiently open to permit the fry of fish to make the passage, though the simple fact that the lakes are supplied with fish admits of other explanation.

SOILS.

As previously remarked, the valley drift is largely composed of sand and gravel, giving a light soil, and is, in some portions, quite sterile. The plains that lie along the margin of the Kettle Moraine, and were formed by the escaping glacial waters, are of less uniform character. In some instances they were mainly formed of gravel derived from the crystalline rocks, which, on decomposition, gives a loam of rather light, but yet excellent character. In other instances, they are composed quite largely of sand, and have a low degree of fertility, while in other cases, almost every ingredient was washed away except purely silicious sand, and the resulting soil is extremely poor. This is the character of some of the "barrens." Some of the so-called "barrens," however, of this and other regions of Northern Wisconsin, are not due so much to extreme sterility of soil, as to successive fires which have destroyed not only the growing vegetation, but also the vegetable mold, which would otherwise preserve the moisture, and enhance the fertility.

Of a similar character are the soils covering the plains in the region of later glaciation, north of the Kettle Moraine. Nearly all that have been observed are sandy in varying degrees, and covered with a light soil.

The soils covering the older drift which occupies the larger part of Marathon county, are, for the most part, clayey or sandy loams. The majority of these soils are of good quality, as may be learned not only by an inspection of the soils themselves, but also from the heavy forests of hardwood and conifers which they support. The more sandy portions are not usually so silicious as to be very poor, nor the more clayey portions so argillaceous as to be objectionably cold and stiff. They are, as indicated, loams, verging on the one hand toward clayey, and on the other toward sandy soil. In some localities, bowlders are so abundant as to render the soil difficult of cultivation without considerable labor expended in their removal, which at this early stage of development is scarcely justified, but which will in time be done profitably, and will give an excellent soil.

The morainic area and that north of it occupied by unmodified drift varies considerably in the character of soil presented. Sandy loams prevail more largely than other varieties. These grade from those so silicious as to be quite poor into those light loams which are most desirable in this northern latitude. Clayey loams occupy some areas, but cannot be regarded as a prevalent soil. On the whole, while there is much poor soil in the region, there is also very much that is excellent, and, as before indicated, the common impression gained by transient visitors of the region, who see little but the sandy tracts of the river plains, is very far from being correct in regard to the real fertility of the region, and its agricultural possibilities, when its wealth of forest shall have been consumed.

The general distribution of these soils may be seen by consulting the soil map of the atlas.

NATIVE VEGETATION.

What has been remarked of the surface deposits and the soils of the region leaves little to be said to the reader, schooled in the adaptation of vegetation to natural conditions, concerning the character of the forests that occupy this region. The more sandy tracts are occupied by the Red, or, as it is usually termed, Norway Pine *(Pinus resinosus)*, and by Black or Scrub Pine *(Pinus Banksiana)*. The better class of sandy soils bear White Pine *(Pinus strobus)*, together with White Birch *(Betula papyracea)*, and Poplar *(Populus tremuloides)* in the drier situations, while in the moister there mingle with these Hemlock *(Abies Canadensis)*, Yellow Birch *(Betula excelsa)*, Elm *(Ulmus Americana)*, occasionally Basswood *(Tilia Americana)*, and a variety of others.

On the loamy and clayey soils are heavy growths of hardwood and Hemlock, with occasional Pine. Among the hardwoods, the Maples *(Acer rubrum* and *A. saccharinum)* predominate, with which are associated Elms, Oaks *(Quercus rubra)*, Yellow Birch, Grand-toothed Poplar *(Populus grandidentatus)*, the Balsam Fir *(Abies balsamea)*, and others.

Swamps and semi-paludal situations are occupied by White Cedar or Arbor Vitæ *(Thuja occidentalis)*, Tamarack *(Larix Americana)* and Black Spruce *(Abies nigra)*. Many of the marshes are occupied by the Cranberry.

PART IX.

GEODETIC SURVEY.

A brief sketch of the geodetic work done in the state since 1874, under the auspices of the United States Coast and Geodetic Survey, together with a short outline of the principles and methods pursued in the triangulation, accompanied by two maps, one showing the triangulation executed and proposed, and the other the difference between the positions of the trigonometrical stations as given by ordinary surveys and the same in their true position on the spheroid.

BY PROF. JOHN E. DAVIES,

Of the University of Wisconsin, Chief of the Geodetic Survey in Wisconsin.

[Published by authority of the Superintendent of the United States Coast and Geodetic Survey.]

GEODETIC SURVEY.

Prof. T. C. Chamberlin, State Geologist:

SIR — Although the triangulation work in Wisconsin is far from completion, I forward, at your request, a brief synopsis of the work already done. It may add to the interest of this report to state wherein the methods adopted differ from those used in ordinary surveying, and I therefore add a brief resume of the methods of the United States Coast and Geodetic Survey, adopted in the triangulation of Wisconsin.

(1) In all such trigonometrical surveys account is taken of the curvature of the earth; and, indeed, the computed amount of this curvature, since it leads to a ratio of the area of the spherical triangle included by three distances, to the area of the whole earth, serves, in a measure, to give the error of observation of the angles measured at the apices of the triangle; *because the area of a spherical triangle is the same fraction of half the surface of the sphere that the excess of the sum of the three angles of the triangle over two right angles is of four right angles.* This sphericity becomes first apparent when the lines which form the triangle sides are from four to five miles in length.

(2) Such surveys as the triangulation of a large district, are always preceded by a careful reconnoissance of the entire country to be covered with triangles. The object of this is to select the most advantageous points for the apices of the triangles, so that these triangles may be of the shape most conducive to accuracy of measurement, and have proper lengths of sides, which are made as long as the character of the country will allow. Due attention must also be paid to a proper system of cross lines to afford checks to the estimated lengths of lines. After the stations have been selected, signals are erected upon them, of such size and height as best correspond to the distances and positions from whence they are to be seen. This requires very careful consideration of all the conditions involved. Sometimes the erection of a signal of 50, 60 or 75 feet in height, the pole being of heavy timber 8 or 10 inches square, is the only alternative to cutting

long lines in various directions through heavy timber. In such cases, when these stations come to be occupied for the measurement of angles, the signals have to be taken down, and scaffolds, with tripods of about equal height from which to observe, substituted for them. In every case, the scaffold on which the observer stands is disconnected entirely from the tripod on which the instrument stands. The tripod is made of heavy timber, in order to be as firm as possible. In this manner no jar is communicated to the instruments by any motion of the observer as he moves around upon the scaffold, nor by any ordinary jarring of the ground about the scaffold. In spite of their great weight these heavy structures are, owing to the severe storms and their generally exposed positions, often blown down during the progress of the work, occasioning great inconvenience and extra labor. That at Mt. Pleasant, Green county, was blown down three times, twice the same season; the timbers were wrenched off in spite of the heaviest anchoring with green oak posts, four feet in the ground. During the season of 1881, the large tripod at Gratiot's Grove, in La Fayette county, was partly occupied *at night* on account of the length of lines to the surrounding stations and the prevailing haze during the day time. Lamps with parabolic reflectors were sighted upon for signals. One of these was 30 miles distant on a low hill in Iowa, across the Mississippi river from the observing station. The angles obtained were apparently as good as those observed by daylight.

(3) Of course the estimation of the lengths of the various triangle sides requires that the length of some *one* triangle side should be measured with great accuracy, after which the mere measurement of angles will suffice. As the sides of the *main* triangles are far too large to be measured directly, they are connected by a system of gradually decreasing triangles to a line, selected on as level ground as possible, called a *base-line*, the length of which is ascertained by actual measurement with all possible precision. At some favorable place, far distant from the starting base, another base-line is measured with equal accuracy as the first, and its measured length compared with its length as computed through the triangulation. The two lengths measured and computed should agree to a very small difference.

The latter base-line is called a *base of verification*. Only the starting base-line has thus far been measured in Wisconsin. This line is located on the sandy plane bordering the Wisconsin river near the village of Spring Green in Sauk county. Its length is about 468 kilometres or 2.91 statute miles. Its termini are marked by massive blocks of Joliet limestone, properly engraved, and placed over substantial masonry six feet square, sunk six feet into the ground. This masonry surrounds at the bottom a hard fourteen-inch cube of limestone, in which is sunk a six-inch round bolt of *solid copper.* A cross mark on this bolt indicates the real terminus of the line. The importance of these monuments and marks would seem to call for some action on the part of the state to preserve them permanently from injury and defacement. I recommend this subject to your consideration, and suggest that you bring the matter in proper shape before the legislature or other proper authorities.

(4) The Spring Green base-line was measured by means of two four-metre standard steel rods terminating in agates. The contact was regulated by spring slides; the inclination of the rods measured by sectors attached to the wooden boxes in which the steel bars were imbedded; and the temperature was measured by thermometers, whose bulbs were in contact with the steel rods, and protected from the direct rays of the sun by proper covers. The temperature was read and recorded for each rod as it was laid down; so also the inclination of the rod. This made a total of over 4,000 readings for temperature, and 4,000 readings for inclination, as the entire line contained a little over 1,169 bars, and was throughout measured three times over, and parts of the line four times. Each rod, inclosed in its wooden box [the whole called a "*base-bar*"], was supported in position by two wooden trestles which had to be very firmly placed and leveled before the base-bars were laid upon them. Two men handled the bars, two the trestles, one watched very carefully the contact of the agate plates, one read and recorded the temperatures and readings of the inclination sector, and one kept in the rear or far ahead with a telescope and transit carefully leveled to see that the bars were kept in line. This he was enabled to do by small black wands standing upright upon the ends of the base-bars, which were carefully kept upon the exact direction of the base-line previously staked out. One man with a good horse team kept up with the party in case of sudden rains or accident. On stopping the measurement for any cause, the position of the agate edge of the last bar was transferred to a cross mark on a copper tack placed in a firmly driven six by six block of wood, well sunk into the ground. This was done by placing the transit, carefully leveled, at fifty or one hundred feet to one side of the line, and bringing the vertical thread of the transit tangent to the agate edge at the end of the measuring bar, and cutting at the same time the cross mark on the copper tack. The rods used in the measurement had their coefficients of expansion by heat well determined, and their precise length at a standard temperature,

both before leaving Washington and after their return thither, was ascertained by very careful comparisons with standard bars in the United States Coast Survey Office. Concerning the finally computed measure of the Spring Green base-line, and the accuracy of the measurement, Mr. C. A. Schott, Chief of the Computing Division of the United States Coast Survey, remarks: "It appears plainly [after a discussion of the measurements by the method of least squares] that the error arising from uncertainty in length of the measuring rods is the *principal* one, that due to the measurements proper being very small, in the present case only $4.456 \sqrt{3}$ ($= \pm 7.72$[1]) millimetres, or $\frac{1}{606002}$ of the length for a *single* measure." * * * "We therefore have for the resulting length of the Spring Green Base of Wisconsin, the value 4678.6725 metres ± 0.0178 metres, and its logarithm 3.6701226 ± 17." [Report to the Assistant in Charge of the Coast Survey Office, March 7, 1879.— See the detailed report at the close of this article.]

(5) Having a correct value of the base-line, the length of all the other triangle sides are dependent upon the accuracy of the measures of angles around the apices of the triangles. Every possible care is taken to get these angles correct. They are measured with the telescope *direct* and *reverse* to eliminate collimation; partly in the morning and partly in the afternoon to avoid one-sided illumination of the signals; and on different days to ensure an average condition of the atmosphere. In all, a *minimum* of 72 separate measurements of each angle are made. In some cases on the Wisconsin survey these separate measurements of one angle have amounted in all to between 300 and 400 measures. It is doubtful, however, whether with instruments of moderate power, such as the 12-inch Gambey Repeating Theodolite for Horizontal Angles, and the 10-inch Vertical Circle for Zenith Distances used in the triangulation of Wisconsin, there is any gain in these excessive measures, as, beyond a certain limit, certain small errors are probably merely *repeated* and not *eliminated*. On reaching each triangulation station the signal is carefully observed with a transit for any leaning or want of proper centering, and due allowance made in case there is any. As the most careful measurements of all the angles around a station will not make them equal 360° precisely, nor tally perfectly among themselves, it is necessary to adjust them so as to get the *most probable* relative values for all the angles measured around a station. This is done by the method of least squares, which, although not required of observers by the

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[1] There are about twenty-five millimetres in an inch.

office at Washington, has been uniformly done on the triangulation of Wisconsin. An example of this adjustment will be given at the end of next section. After the angles are adjusted in this manner around a station, it is still necessary to adjust them so that any given triangle side shall have the same length when reached by different routes. This is called the *adjustment of figure.* It can for a given triangulation only be made complete when two base-lines are measured — a starting base and a base of verification — as the ratio of these two measured lines enters into the adjustment. Partial adjustments, however, can be made as the work progresses. An example of this is also added.

(6) In estimating the lengths of triangle sides the rules of plane trigonometry are used — the actually measured *spherical* angles being reduced to corresponding *plane* ones by proper distribution of the error and subtraction of the *spherical excess.* This latter is computed as follows:

Let a, b=triangle sides (approximately known).
C=Angle included between these sides.
A=Equatorial radius of the earth=6,377,397.16 metres.
B=Polar radius of the earth=6,356,078.96 metres.
e=the eccentricity$=\sqrt{1-\frac{B^2}{A^2}}$; $e^2=0.006674372$.
L=mean latitude of the three apices of the triangle.
ε=spherical excess.

$$\varepsilon=\frac{a\,b\ Sin\ C\ (1 \times e^2\ Cos\ 2\ L)}{2\ A^2\ Sin\ 1''}$$

An example of the computation of the spherical excess in one of the average triangles of the Wisconsin survey is here given; also the computation of a set of triangle sides.

Computation of the spherical excess in the triangle { Platte Mds., Highland, Harker.

a=Line Platte Mound—Highland	log. 4.57439
b=Line Platte Mound—Harker	log. 4.48742
C Sine	log. 9.73082
m	log. 1.40432
Spherical excess=1″.57	0.19695

m here denotes the factor $\frac{(1+e^2\ Cos^2\ L)}{2\ A^2\ Sin\ 1''}$

Before giving the computation of a set of triangle sides, an example each will be given, first of the *adjustment of angles around a station*, and second an *adjustment of figure.*

The following adjustment, selected on account of its simplicity, will serve as an example of the manner in which field adjustments of angles around a station have been made on the Wisconsin survey, preparatory to passing on to the computation of triangle sides, which is in turn preceded by an adjustment of the angles of the diagram constituting the particular quadrilateral or other figure, the lines of which are about to be computed.

TRIANGULATION STATION, POINT JUDAS, NEAR WISCONSIN RIVER,

Occupied for Measurement of Angles in July, 1878.

ADJUSTMENT OF ANGLES AROUND STATION.

(FIELD COMPUTATION.)

Names of stations.	Angles observed. °	′	″	Weight.	Correct'ns.	Seconds corrected.
Quarry and Blue Mounds	28	41	48.1	7	+.1	48.2
Wyoming and Quarry	70	17	19.4	10	—.3	19.1
Wyoming and Blue Mounds	41	35	30.9	7	.0	30.9
Highland and Wyoming	53	57	27.6	10	—.3	27.3
Highland and Quarry	124	14	46.8	9	—.4	46.4
Quarry and Highland	235	45	14.4	9	—.8	13.6

CONDITION EQUATIONS.

I .... $0=-1.2-v_5-v_6$

II .... $0=-.2+v_5-v_2-v_4$

III .... $0=+.4-v_1+v_2-v_3$

EQUATIONS OF CORRELATIVES.

	Corrections.	$\frac{72}{p}$	v.	K_1	K_2	K_3
0=	—.1	10	1	......	......	—1
0=	—.3	7	2	......	—1	+1
0=	.0	10	3	......	......	—1
0=	—.3	7	4	......	—1	....
0=	—.4	8	5	—1	+1	....
0=	—.8	8	6	—1	......	....

NORMAL EQUATIONS.

	Constants.	K_1	K_2	K_3	Values.	Residuals.
0=	—1.2	1.6	—8	......	0.097	0.000
0=	— .2	—8	......	—7	0.045	0.052
0=	+ .4	......	—7	27	—0.004	0.023

Resulting Horizontal Angles.

	°	′	″
Quarry	00	00	00.0
Blue Mounds	28	41	48.2
Wyoming	70	17	19.4
Highland	124	14	46.8

Adjustment by the method of least squares of the angles entering into the figure Blue Mound, Highland, Wyoming, Platte Mound, Harker; the latter station being situated within the figure.

The adjustment is followed by the computation of the triangle sides for the same figure. [For the figure see the maps with sketches of triangulation accompanying this report.]

1°. Formation of the Equations of Condition.

(8). 1. 9. 10.

		Angles.	Logarithms.	Diff's for one second.
		° ′ ″		
8. 10. 9	$-\frac{8}{1}+\frac{10}{1}$	46 30 22.18	9.86060.65	+0.20
8. 1. 10	....	32 33 04.00	9.73082.41	+0.33
1. 9. 8	$-\frac{1}{9}$	73 33 22.90	9.98186.33	+0.06
			9.57329.39	
		° ′ ″		
10. 9. 8	$-\frac{1}{10}$	104 41 56.73	9.98554.85	−0.06
1. 10. 8	....	92 35 42.57	9.99955.43	−0.01
8. 1. 9	$-\frac{8}{1}+\frac{9}{1}$	22 47 40.30	9.58819.05	+0.51
			9.57329.33 Diff= +0.06	

(10). 1. 2. 9.

		Angles.	Logarithms.	Diff's for one second.
		° ′ ″		
2. 9. 10	$-\frac{9}{1}+\frac{10}{1}$	76 12 28.53	9.98729.40	+0.05
9. 1. 10	....	29 45 23.70	9.22907 42	+1.22
1. 2. 10	$-\frac{1}{2}$	22 13 52.82	9.57789.05	+0.52
			8.79425.87	
		° ′ ″		
10. 2. 9	$+\frac{1}{9}$	21 21 06.58	9.56121.34	+0.54
10. 9. 1	....	31 08 33.83	9.71363.48	+0.35
10. 1. 2	$-\frac{10}{1}+\frac{2}{1}$	19 18 36.80	9.51941.16	+0.60
			8.79425.98 Diff= −0.11	

2°. Equations of Condition.

I...... $0=-3.83-(\frac{8}{1})+(\frac{9}{1})-(\frac{1}{9})+(\frac{1}{8})$ } Angle equations.
II...... $0=-1.77-(\frac{9}{1})+(\frac{10}{1})-(\frac{1}{10})+(\frac{1}{9})$ } Angle equations.
III...... $0=-2.07-(\frac{10}{1})+(\frac{2}{1})-(\frac{1}{2})+(\frac{1}{10})$ } Angle equations.
IV...... $0=+0.06+.33\,(\frac{10}{1})-.50\,(\frac{9}{1})+.17\,(\frac{8}{1})-.06\,(\frac{1}{9})+.01\,(\frac{1}{10})$ } Side equations.
V...... $0=-0.11+1.82\,(\frac{10}{1})-1.22\,(\frac{9}{1})-.60\,(\frac{2}{1})-.52\,(\frac{1}{2})-.35\,(\frac{1}{9})$ } Side equations.

3°. Table of Correlatives.

v	a	b	c	d	e	Corr.
$(\frac{1}{2})$	......	......	−1	....	−0.52	−0.52
$(\frac{1}{8})$	+1	......	......	....	....	−1.61
$(\frac{1}{9})$	−1	+1	......	−0.06	−0.35	−1.33
$(\frac{1}{10})$	......	−1	+1	+0.01	....	+0.46
$(\frac{2}{1})$	......	......	+1	....	−0.60	+1.05
$(\frac{8}{1})$	−1	......	....	+0.17	....	−0.96
$(\frac{9}{1})$	+1	−1	......	−0.50	−1.22	−0.06
$(\frac{10}{1})$	......	+1	−1	+0.33	+1.82	−0.04

4°. Normal Equations.

	Constants.	a	b	c	d	e	Values.	Residuals.
I	0=−3.83	+ 4	− 2	......	−0.61	−0.87	+1.606	0.0000
II	0=+1.77	− 2	+ 4	− 2	+0.76	+2.69	+0.3388	+0.0003
III	0=−2.07	......	− 2	+ 4	−0.32	−1.90	+0.7650	0.0000
IV	0=+0.06	−0.61	+ 76	−0.32	+0.3915	+1.2316	+3.8274	+0.0002
V	0=+0.11	−0.87	+2.69	−1.90	+1.2316	+5.5487	−0.4802	0.0000

The values of a, b, c, d, e, derived from the normal equations substituted, with the proper coefficients, in the table of correlatives, will be found to give the numbers found in the column of corrections of that table. These corrections applied to their respective directions will give the finally corrected directions as shown by the following table, from which the resulting angles are obtained for computation of the triangle sides. With these latter angles the figure will be found to close, and the various cross lines will pass through their proper converging points.

Table of Observed and Corrected Directions for the Figure Harker, Blue Mound, Platte Mound, Highland and Wyoming.

Blue Mounds — 12 in. Gambey, No. 32, 1775-1876.

Stations observed on.	Directions.			Corrections.	Seconds corrected.
	°	′	″	″	″
Platte Mound	187	19	21.2	....	......
Harker	209	33	13.7	+0.32	14.02
Wyoming	230	54	21.0	−0.40	20.60

Platte Mound — 12 in. Gambey, No. 32, 1878-79.

	°	′	″	″	″
Highland	0	00	00.0	....	......
Wyoming	22	47	40.3	....	......
Harker	32	33	04.0	....	......
Blue Mounds	51	51	40.8	....	......

Highland — 12 in. Gambey, No. 32, 1879.

	°	′	″	″	″
Blue Mounds	35	54	09.64	−0.33	09.31
Wyoming	36	29	12.01	−0.36	11.65
Harker	65	16	52.20	+0.92	53.12
Platte Mound	120	08	06.06	....	......

Harker — 12 in. Gambey, No. 32, 1878.

	°	′	″	″	″
Platte Mound	0	00	00.0	....	......
Highland	92	35	42.82	−0.25	42.57
Wyoming	139	06	04.87	−0.12	04.75
Blue Mounds	221	32	29.93	+0.37	30.30

Wyoming — 12 in. Gambey, No. 32, 1878.

	°	′	″	″	″
Blue Mounds	0	00	00.00	−1.61	58.39
Harker	76	12	27.06	−0.14	26.92
Platte Mound	107	21	00.75	....	......
Highland	180	54	23 61	+0.04	23.65

COMPUTATION OF TRIANGLE SIDES.

For the figure — Harker, Blue Mounds, Platte Mound, Highland, Wyoming.

Denomination.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Plane angles and distances. ″	Logarithms.
Highland–Blue Mounds								4.6290558
Wyoming	179	05	36 36	−1 66	34.73	0.00	34.73	1.8005242
Highland	0	35	02.37	−0.02	02.35	0 01	02.34	8.0082703
Blue Mounds	0	19	22.94		22.94	0.01	22.93	7.7511261
Wyoming–Blue Mounds								4.4378503
Wyoming–Highland								4.1807053
Wyoming–Blue Mounds								4.4378503
Harker	82	26	25.06	+0.50	25.56	0.23	25.33	0.0037912
Wyoming	76	12	27.06	+1.47	28.53	0.22	28.31	9.9872939
Blue Mounds	21	21	07.30	−0.72	06.58	0.22	06.36	9 5612122
Harker–Blue Mounds								4.4289354
Harker-Wyoming								4.0028537
Highland–Wyoming								4.1807064
Harker	46	30	22.05	+0.13	22.18	0.12	22.06	0.1393937
Highland	28	47	40.19	+1.27	41.46	0.12	41.34	9.6827535
Wyoming	104	41	56.55	+0.18	56.73	0 13	56.60	9.9855486
Harker–Wyoming								4.0028536
Harker-Highland								4.3056487
Highland–Blue Mounds								4.6290558
Harker	128	56	47.11	+0.62	47.73	0.36	47.37	0.1091693
Highland	22	22	42.56	+1.25	43.81	0.35	43.46	3.6907102
Blue Mounds	21	40	29.52		29.52	0.35	29.17	9.5674235
Harker-Blue Mounds								4.4289353
Harker–Highland								4.3056486
Highland–Blue Mounds								4.6290558
Platte Mound	51	51	40.80	+2.01	42.81	1.34	41.47	0 1042900
Highland	84	13	56 75	+1.61	58.36	1.35	57.01	9.9977960
Blue Mounds	43	54	22.34	+0.52	22.86	1.34	21.52	9.8410320
Platte Mound–Blue Mounds								4.7311418
Platte Mound–Highland								4.5743778
Wyoming–Blue Mounds								4.4378503
Platte Mound	29	04	00.50	+1.12	01.62	0.86	00.76	0.3135155
Wyoming	107	21	2.36	−1.32	01.04	0.86	00.18	9.9797763
Blue Mounds	43	34	59.40	+0.52	59.92	0.86	59.06	9.8384747
Platte Mound–Blue Mounds								4.7311421
Platte Mound–Wyoming								4.5898405

COMPUTATION OF TRIANGLE SIDES.

For the figure — Harker, Blue Mounds, Platte Mound, Highland, Wyoming — Con.

Denomination.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Plane angles and distances.	Logarithms.
	°	′	″		″	″	″	
Harker-Blue Mounds........								4.4289354
Platte Mound..............	19	18	36.80	+1.09	37.89	0.46	37.43	0.4805845
Harker....................	138	27	29.70	+0.46	30.16	0.47	29 69	9.8216220
Blue Mound	22	13	52.80	+0.52	53.34	0.46	52.88	9.5778908
Platte Mound-Blue Mounds..								4.7311419
Platte Mound-Harker.......								4.4874107
Wyoming-Harker............								4.0028537
Platte Mound..............	9	45	23.70	+0.02	23.72	0.17	23.55	0.7709276
Wyoming	31	08	33.83	−1.33	32.50	0.17	32.33	9.7136296
Harker	139	06	04.75	−0.46	04.29	0.17	04.12	9.8160594
Platte Mound-Harker								4.4874109
Platte Mound-Wyoming.....								4.5898407
Highland-Wyoming.........								4.1807064
Platte Mound..............	22	47	40.30	+0.90	41.20	0.48	40.72	0.4118074
Highland..................	83	38	54.41	+1.60	56.01	0.48	55.53	9.9973263
Wyoming	73	33	22.90	+1.33	24.23	0.48	23.75	9.9818638
Platte Mound-Wyoming.....								4.5898401
Platte Mound-Highland								4.5743776
Highland-Harker								4.3056487
Platte Mound..............	32	33	04.00	+0.92	04.92	0.52	04.40	0.2691746
Highland..................	54	51	12.94	+1.61	14.55	0.53	14.02	9.9125869
Harker....................	92	35	42.57	−0.46	42.11	0.53	41.58	9.9995544
Platte Mound-Harker								4.4874102
Platte Mound-Highland								4.5743777

The close coincidence of the logarithms of the sides as computed from different bases (for example, the line Harker — Blue Mounds) will be noticed. This coincidence could only occur as an accident, had not the errors been distributed in the manner pointed out by the Theory of Probability. Indeed, the final adjustment can only be made when *all* the angles of the whole triangulation are measured, and a second base line (or base of verification) has been accurately measured.

When this is done, the whole system of small errors affecting the measurements of angles, together with those entering into the measurements of both base-lines, are so distributed as to render the sum of the squares of the residuals a minimum, which is the principle of least squares.

Of course, it is supposed that the errors alluded to are not *mistakes*, but merely those minute irregularities in measurement inherent even in the most refined observations or experiments of a thoroughly skilled observer, and generally dependent upon varying conditions, entirely beyond personal control, such as the state of the atmosphere, degree of illumination of the signal, more or less one-sidedness of this illumination on different days, etc.

The final adjustment of a large triangulation is a work of immense labor, and that of Wisconsin, when completed, will be no exception to the rule. Even now, the partial adjustments in some cases, lead to the necessity for solving seventeen simultaneous equations, containing seventeen unknown quantities. In the reduction by least squares of the Spanish triangulation, it has been necessary to satisfy simultaneously more than seven hundred equations of condition; while the triangulation of India is so extensive as to preclude the possibility of managing it as one whole — there being an aggregate of 955 equations of condition, besides the additional ones for the closing of circuits. In the triangulation of Great Britain, "the network covering the kingdom was divided into a number of blocks, each presenting a not unmanageable number of equations. The number of blocks is 21; in 9 blocks there are over 50 equations, and in one case the number is 77. The calculations — all in duplicate — were computed in two and one-half years, an average of eight computers being employed."

Before undergoing such great labor in computation, it will readily be supposed that no precautions to secure accuracy in the measurements are omitted or overlooked.

In case a signal pole is found leaning, even by so much as a fraction of an inch, the direction of this leaning as well as its amount is ascertained, and the consequent corrections calculated for all the angles measured upon it, while in this inclined position. So also in case frost, or wind, or other causes have slightly shifted the top of a tripod from the vertical, or if by accident it is eccentrically placed, careful and oftentimes laborious reductions are made of the actually measured angles so as to reduce them to what would be the true measure when taken from the real station as marked by an iron bolt in the rock below. Several instances of this have already occurred in the triangulation of Wisconsin. Some provision ought to be made to more carefully guard these latter marks from injury or removal, or permanent obliteration, as they constitute the real triangulation stations, and are supposed to be immovable.

(7) In order that the *direction* of the lines on the surface of the sphere may be known, observations for *azimuth*, i. e., for the angle between a triangle side and the *true* meridian, are taken as often as time or a peculiarly advantageous position will allow. This is done by observations on a close circumpolar star — either the *Pole Star*, λ or δ *Ursae Minoris*, or 51 *Cephei*, according to circumstances, being most commonly used. A mark is set up at a distance of a couple of miles, and illuminated by night. The telescope is directed alternately at the star and mark, and the astronomical time, and the reading of the azimuth circle of the Horizontal Theodolite, are carefully noted. The time, of course, must be independently determined with all the accuracy possible by observations with a sextant or transit. In case of a sextant being used the method of equal altitudes is adopted.

For the triangulation in Wisconsin, Azimuths were taken at East Base and Quarry Bluff in 1876.[1] The observations were made with the 12-inch Horizontal Circle and the Coast Survey Siderial Chronometer Fletcher 1508. The resulting Azimuth of the line *Quarry — Big Hollow* was 102° 28′ 04.″06, and of *East Base — Stewart Bluff* 245° 47′ 21.″8. New Azimuths will be measured from time to time as opportunity permits.

The following Azimuths were determined at Shervill Mound, Iowa, in 1880:

EXAMPLE OF THE COMPUTATION OF AN ASTRONOMICAL AZIMUTH OF A DIRECTION IN THE TRIANGULATION OF WISCONSIN.

From Observations taken at Sherrill's Mound △'n Station in October, 1880.

Deduced Corrections and Rates for Siderial Chron'r (Fletcher, 1508) for *Apparent Noon* of the days on which observations were taken on *Polaris for Azimuth.* Also the corrections and hourly rates for *twenty hours* of *chronometer time* on the same dates.

Date.	Corrections.		Rate.	Date.	Chron. Time.			Correction.		Hourly Rate.
Noon.	m	s	s		h	m	s	m	s	s
Oct. 4..	+14	32.40	+4.24	Oct. 4..	20	00	00	+14	33.69	0.1767
Oct. 6..	+14	41.47	4.30	Oct. 6..	20	00	00	14	42.76	0 1792
Oct. 12..	+15	9.59	4.41	Oct. 12..	20	00	00	15	10.84	0.1838
Oct. 14..	+15	18.29	3.75	Oct. 14..	20	00	00	15	19.34	0.1563
Oct. 20..	+15	54.20	+6.26	Oct. 20..	20	00	00	+15	55.84	0.2608

[1] Likewise at Gratiot's Grove, Wis., and at Sherrill's Mound, Iowa, in 1880.

From Observations taken at Sherrill's Mound △'n Station in October, 1880 — continued.

Chronometer (Fletcher Siderial, 1508). Times of the Means[1] of each set with the Chronometer corrections for the same, to reduce them to Siderial Time.

Set	Chronometer Times.			△T		Siderial Time		
				1880. Oct. 4th.				
	h	m	s	m	s	h	m	s
1	20	14	24.1	+14	33.7	20	28	57.8
2		32	58.2	+14	33.8		47	32.0
				Oct. 6th.				
1	19	56	34.7	+14	42.7	20	11	17.4
2	20	05	58.1	+14	42.8		20	40.9
3		14	40.1	+14	42.8		29	22.9
4		23	07.8	+14	42.8		37	50.6
5		30	28.4	+14	42.8		45	11.2
6		39	29.3	+14	42.9		54	12.2
7		56	59.7	+14	42.9	21	11	42.6
8	21	04	32.3	+14	43.0		19	15.3
9		11	05.0	+14	43.0		25	48.0
10		19	01.2	+14	43.0		33	44.2
				Oct. 12th.				
1	20	17	16.3	+15	10.9	20	32	27.2
2		28	16.9		10.9		43	27.8
3		34	35.7		10.9		49	46.6

Set	Chronometer Times.			△T		Siderial Time.		
				Oct. 12th.				
	h	m	s	m	s	h	m	s
4	20	42	20.9	+15	11.0	20	57	31.9
5	21	18	52.3		11.1	21	34	03.4
6	21	26	00.6		11.1	21	41	11.7
				Oct. 14th.				
1	20	31	52.9	+15	19.4	20	47	12.3
2		42	54.2		19.4		58	13.6
3		53	44.3		19.5	21	09	03.8
4	21	19	03.4		19.5		34	22.9
				Oct. 20th.				
1	20	49	51.3	+15	56.1	21	05	47.4
2		59	55.7		56.1		15	51.8
3	21	20	24.1		56.2		36	20.3
4		29	14.6		56.2		45	10.8
5		35	00.0		56.3		50	56.3
6		41	13.2		56.3		57	09.5
7		47	34.8		56.3	22	03	31.1
8		54	17.4		56.3		10	13.7

Apparent Places of Polaris.

Date.	α			δ			$\cos\varphi \tan\delta$
	h	m	s	°	′	″	
Oct. 4	1	16	1.59	88	40	28.24	31.81056
Oct. 6			2.21			28.94	31.81523
Oct. 12			3.25			31.34	31.83124
Oct. 14			3.23			32.14	31.83659
Oct. 20			3.58			34.26	31.85075

[1] See Field Record Book, where the means are worked out for each set.

Sherrill Mound, Dubuque County, Iowa, 1880.

HOUR ANGLES OF POLARIS AT THE MIDDLE TIMES OF OBSERVATION FOR EACH SET FOR AZIMUTH.

Date.	No. of Set per Set.	Total No.	Siderial Time. t			α (Polaris.)			(α−t) Hour Angle of Polaris.		
1880.			h	m	s	h	m	s	h	m	s
October 4	1	1	20	28	57.8	1	16	01.6	4	47	03.8
October 4	2	2		47	32.0	1	16	01.6	4	28	29.6
October 6	1	3		11	17.4	1	16	02.21	5	04	44.8
October 6	2	4		20	40.9	1	16	02 21	4	55	21.3
October 6	3	5		29	22.9	1	16	02.21	4	46	39.3
October 6	4	6		37	50.6	1	16	02.21	4	38	39.6
October 6	5	7		45	11.2	1	16	02.21	4	30	51.0
October 6	6	8		54	12.2	1	16	02.21	4	21	50.0
October 6	7	9	21	11	42.6	1	16	02.21	4	04	19.6
October 6	8	10		19	15.3	1	16	02.21	3	56	46.9
October 6	9	11		25	48.0	1	16	02.21	3	50	14.2
October 6	10	12		33	44.2	1	16	02.21	3	42	18.0
October 12	1	13	20	32	27.2	1	16	3.25	4	43	36.1
October 12	2	14		43	27.8	1	16	3.25		32	35.5
October 12	3	15		49	46.6	1	16	3.25		26	16.7
October 12	4	16		57	31.9	1	16	3.25	4	18	31.4
October 12	5	17	21	34	03.4	1	16	3.25	3	41	59.9
October 12	6	18		41	11.7	1	16	3.25		34	51.6
October 14	1	19	20	47	12.3	1	16	3.23	4	28	50.9
October 14	2	20		58	13.6	1	16	3.23	4	17	49.6
October 14	3	21	21	09	03.8	1	16	3.23	4	06	59.4
October 14	4	22		34	22.9	1	16	3.23	3	41	40.3
October 20	1	23	21	05	47.4	1	16	3.58	4	10	16.2
October 20	2	24		15	51.8	1	16	3.58	4	00	11.8
October 20	3	25		36	20.3	1	16	3.58	3	39	43.3
October 20	4	26		45	10.8	1	16	3.58	3	30	52.8
October 20	5	27		50	56.3	1	16	3.58	3	25	37.3
October 20	6	28		57	09.5	1	16	3.58	3	18	54.1
October 20	7	29	22	03	31.1	1	16	3.58	3	12	32.5
October 20	8	30		10	13.7	1	16	3.58	3	05	49.9

Sherrill Mound, Dubuque County, Iowa, 1880 — continued.

LOGARITHMS OF THE HOUR ANGLE FUNCTIONS. HOUR ANGLES REDUCED TO ARC.

τ.			τ.			Sine τ.	Cos τ.	Tang A.	A.
Oct. 4th.			°	′	″	Logarithms.	Logarithms.	Logarithms.	1° 43′. ″
4	47	3.8	71	45	57.0	9.9776256	9.49541	8.4779560	17.989
4	28	29.6	67	7	24.0	9.9644218	9.58967	8.4654582	22.265
Oct. 6th.									
5	4	44.8	76	11	12.0	9.9872544	9.37796	8.4868313	25.868
4	55	21.3	73	50	19.5	9.9824893	9.44458	8.4824339	22.180
	46	39.3	71	39	49.5	9.9773699	9.49775	8.4776515	13.641
	38	11.6	69	32	54.0	9.9717244	9.54234	8.4723301	58.260
	30	51.0	67	42	45.0	9.9662790	9.57893	8.4671626	45.933
	21	50.0	65	27	30.0	9.9588788	9.61842	8.4600989	8.447
4	4	19.6	61	4	54.0	9 9421618	9.68445	8.4440182	32.333
3	56	46 9	59	11	43.5	9.9339522	9.70936	8.4360754	48.500
	50	14.2	57	33	33.0	9.9263146	9.72951	8.4286649	13.321
3	42	18.0	55	34	30.0	9.9163839	9.75230	8.4190044	11.652
Oct. 12th.									
4	43	36.1	70	54	1.5	9.9754094	9.51483	8.4755885	44.307
	32	35.5	68	8	52.5	9.9676172	9.57079	8.4682151	60.594
	26	16.7	66	34	10.5	9.9626268	9.59948	8.4634613	54.653
4	18	31.4	64	37	51.0	9.9559599	9.63190	8.4570817	27.287
3	41	59.9	55	29	58.5	9.9159915	9.75313	8.4184010	4.141
3	34	51.6	53	42	54.0	9.9063799	3.77218	8.4090269	8.796
Oct. 14th.									
4	28	50.9	67	12	43.5	9.9647049	9.5880713	8.4653698	21.040
	17	49.6	64	27	24.0	9.9553314	9.6346723	8.4564050	18.094
4	6	59.4	61	44	51.0	9.9449118	9.6751898	8.4463786	3.558
3	41	40.3	55	25	4.5	9.9155655	9.7540319	8.4179121	58.064
Oct. 20th.									
4	10	16.2	62	34	3.0	9.9481949	9.6634213	8.4493487	43.089
4	00	11.8	60	2	57.0	*	*	*	*
3	39	43.3	54	55	9.5	9.9129948	9.7593436	8.4152113	24.614
	30	52.8	52	43	12.0	9.9007411	9.7822653	8.4032485	58.924
	25	7.3	51	16	49.5	9.8922153	9.7962338	8.3949080	19.693
	18	54.1	49	43	31.5	9.8824990	9.8105359	8.3853877	28.728
	12	32.5	48	8	7.5	9.8719955	9.8243682	8.3750800	31.293
3	5	49.9	46	27	28.5	9.8602593	9.8381481	8.3635453	23.138

* Rejected. Errors made in recording.

Sherrill Mound, Dubuque County, Iowa, 1880 — continued.

DEDUCTION OF FINAL AZIMUTH AT SHERRILL MOUND, FROM SEPARATE MEANS.

Date.	Azimuth of Star.			Corrections.		Angle.			Azimuth mark.			Δ	Δ²
	°	'	"			°	'	"	°	'	"		
1880.													
Oct. 4.	181	43	17.98	−1.34	+5.20	−349	42	3.75	192	01	18.09	0.43	0.185
Oct. 4.	181	40	22.27	.95	+5.20	10	20	48.75			15.27	2.39	5.712
Oct. 6.		45	25.87	.37	+5.20	−349	44	16.50			14.20	3.46	11.972
Oct. 6.		44	22.18	.27	+5.20	10	16	50.63			17.74	0.08	0.006
Oct. 6.		43	13.64	.26	+5.20	−349	41	57.38			21.20	3.54	12.532
Oct. 6.		41	58.26	.22	+5.20	10	19	16.13			19.37	1.71	2.924
Oct. 6.		40	45.93	.16	+5.20	−349	39	27.75		*		*	*
Oct. 6.		3	98.45	.22	+5.20	10	22	6.75			20.18	2.52	6.350
Oct. 6.		35	32.33	.21	−5.20	−349	34	8.25			18.67	1.01	1.020
Oct. 6.		33	48.50	.14	−5.20	10	27	36.75			19.21	2.25	5.063
Oct. 6.		32	13.32	.17	−5.20	−349	30	47.25			20.70	3.04	9.242
Oct. 6.		30	11.65	.13	−5.20	10	31	9.38			15.70	1.96	3.842
Oct. 12.		42	44.31	.19	−5.20	−349	41	16.13		*		*	*
Oct. 12.		41	00.59	.14	−5.20	10	20	19.50			14.75	2.91	8.468
Oct. 12.		39	54.65	.18	+5.20	−349	38	39.00			20.67	3.01	9.060
Oct. 12.		38	27.29	.17	+5.20	10	22	45.00			17.32	0.34	0.116
Oct. 12.		30	04.14	.12	+5.20	−349	28	52.50			16.72	0.94	0.884
Oct. 12.		2	88.80	.15	+5.20	10	33	4.88			18.73	1.07	1.145
Oct. 14.		40	21.04	.20	−5.20	−349	38	58.88			16.76	0.90	8.10
Oct. 14.		38	18.09	.26	−5.20	10	23	02.63			15.26	2.40	5.760
Oct. 14.		36	03.56	.25	−5.20	−349	34	35.25		*		*	*
Oct. 14.		29	58.06	.18	−5.20	10	31	25.13			17.81	0.15	0.023
Oct. 20.		36	43.09	.21	−5.20	−349	35	16.88			20.80	3.14	9.860
Oct. 20.		29	24.62	.15	−5.20			1.50			17.77	0.11	0.012
Oct. 20.		26	58.92	.10	−5.20			24.38			18.00	0.34	0.116
Oct. 20.		25	19.69	.11	−5.20			58.50			15.88	1.78	3.168
Oct. 20.		23	28.73	.13	−5.20			49.88		*		*	*
Oct. 20.		21	31.29	.13	+5.20			20.63			15.73	1.93	3.725
Oct. 20.	181	19	23.14	−.12	+5.20			46 13			14.35	3.31	10.956

Mean 192° 1′ 17.″66 .... 112.951

$\Sigma \Delta^2$=112.951.

Final Azimuth.... 192° 1′ 17″.66 + .31 = 192° 1′ 17″.97 ± .30. Probable error of 0″.3

* Rejected by Peirce's criterion.

(8) Latitudes and Longitudes are determined for the principal stations astronomically, and all others are computed from them. In fact the computations of the triangle sides are followed by what are technically termed the L. M. Z. computations, viz.: the computations for Latitude, Longitude and Azimuth, that of some starting point being known. Azimuths of lines are reckoned in Geodesy from the South point round by West and North through 360 degrees, and the forward and back Azimuths are different on account of the gradual convergence of the meridians towards the poles. That is to say, if two stations, A and B, say 20 miles apart, are respectively northeast and southwest, then the angle measured at the point A from the south point westward to the line AB will not be exactly 180° less than the angle measured at B westward and around to the same line BA (as it would be were the north and south lines at A and B, respectively, parallel lines). As a mere example of this form of computation I append the following copy of the computation of the Azimuth of the line Mt. Pleasant and Union. It will be seen that whereas the azimuth of this line as measured at Mt. Pleasant is 244° 55′ 13″.71, the azimuth of the same line at Union is not exactly 180° less than this, but is on the contrary 65° 07′ 02″.21, the distance between the two stations being 26195.3 metres.

L. M. Z. 1ry △n.

EXAMPLE OF THE COMPUTATION OF THE GEODETIC AZIMUTH OF THE LINE UNION (IN ROCK COUNTY) TO MT. PLEASANT (IN GREEN COUNTY); THE POSITION OF MT. PLEASANT BEING KNOWN.

		°	′	″
Z	Mount Pleasant to Fitchburg	188	47	27.45
∠	Fitchburg and Union	+56	07	46.26
Z	Mt. Pleasant to Union	244	55	13.71
dZ	....	......	+11	48.50
180°	....	......	......	......
Z′	Union to Mt. Pleasant	65	07	02.21

NOTE.—Z denotes a forward azimuth; Z′ a back azimuth; ∠ an angle.

	°	′	″			°	′	″
L	42	41	30.246	Mt. Pleasant	M	89	29	45.737
dL	......	+5	58.515	26195.3 Met's	dM	......	−17	23.922
L′	42	47	28.761	Union	M′	89	12	21.815

NOTE.— L is the given latitude; M the given longitude; L′ and M′ the required ones.

K	4.4182232	K^2	8.83645	....	....	h	2.5561
Cos Z	9.6272386	Sin^2 Z	9.91399	$(\delta L)^2$	5.1122	K^2 sin^2 Z	8.7504
B	8.5106448	C	1.36921	D	2.3917	E	6.1617
h	2.5561066	....	0.11965	....	7.5039	....	7.4682
1st term	−359.838	3d term.	+0.003	....	....	....	......
2d term	+1.317	4th term.	−0.003	....	....	....	......
....	−358.838	....	....	....	....	....	......
3d & 4th t	+0.006	....	....	A′	8.5090472	Arg.	......
−dL	−358.515	dM	3.018668	K	4.4182232	K	− 2
......	42′ 44° 29.5″	Sin λ	9.831673	Sin Z	9.9569941	dMu	+19
½dL	....	Cos ½d L, ar.co	0.000000	Cos L′ ar.co	0.1344029	....	......
....	....	....	2.850341	....	3.0186681	Corr.	+ 7
....	....	−d Z	″ −708.5	dM	″ −1043.922	....	......

NOTE.—K is the distance of the two stations; A B C D E are quantities depending on the figure of the earth.

POSITION OF UNION △'N STATION AS DETERMINED FROM THE OTHER EXTREMITY OF THE LINE FITCHBURG — MT. PLEASANT, THE POSITION OF FITCHBURG BEING KNOWN.

		°	′	″
Z.............	Fitchburgh to Mt. Pleasant...........	8	49	55.74
∠.............	Mt. Pleasant and Union	−50	48	11.58
Z.............	Fitchburg to Union	318	01	44.16
d Z...........	....	....	+9	22.00
180°...........	....	....	....	....
Z′.............	Union to Fitchburg...................	138	11	06.16

	°	′	″			°	′	″
L.....	42	58	45.769	Fitchburg....	M	89	26	07.637
d L....	......	−11	17.017	28065.10 Met's	dM	......	−13	45.816
L′....	42	47	28.752	Union.......	M′	89	12	21.821

K......	4.4481665	K²	8.89633	....	....	h	2.8301
Cos Z...	9.8712708	Sin² Z	9.65053	(δL)²	5.6601	K² sin² Z	8.5469
B......	8.5106237	C	1.37344	D	2.3921	E	6.1680
h.......	2.8300610	....	9.92031	....	8.0522	....	7.5450
1st term.	+676.178	3d term.	″ +0.011	....	....	....	.....
2d term.	0.832	4th term.	+0.004	....	....	....	.....
	+677.010	....	....	....	....	....	.....
3d &4th t	+ .007	....	....	A′	8.5090472	Arg.	.....
−d L...	+677.017	d M	2.916883	K	4.4481665	K	−14
λ.......	42° 53′ 07.3	Sin λ	9.832850	Sin Z	9.8252671	dMu	+11
½d L...	....	Cos ½d L ar.co	0.000001	Cos L′ ar.co	0.1344029	....	− 3
....	....	....	2.749734	....	2.9168834	Corr.	.....
....	....	−d Z	−562.″00	d M	−825.″816	....	.....

The two results for Latitude and Longitude of *Union* will be seen to be almost exactly the same, as estimated from two points which are 32335.6 metres apart.

(9) During those times of the day when the atmosphere is most steady, measurements are made for differences of heights of the trigonometrical stations. These are determined by zenith distances, measured with a 10-inch *Vertical Circle* (separate from the Horizontal Theodolite), and carefully corrected for level, height of poles and telescope above the ground, and computed generally by the formula:

$$h-h'=\frac{K \text{ Sin } \frac{1}{2}(Z'-Z)}{\text{Cos}\frac{1}{2}(Z'-Z+C)}$$

where

C=angle subtended at center of the earth by the distance *K* between the stations.
R=radius of curvature of the arc joining the stations.
h, h'=heights of stations above sea level.
Z Z'=measured and corrected zenith distances respectively.

$$C=\frac{K}{R \text{ Sin } 1''}$$

The following example of the computation of the difference of height between Blue Mound and Platte Mound may not be uninteresting:

Log. K=4.73115.
Z'=90° 17′ 51.5″ zenith distance observed at Blue Mound on Platte Mound.
Z =90° 06′ 57.6″ zenith distance observed at Platte Mound on Blue Mound.
Middle latitude, 42° 54′.
Angle, 56° 57′.

			′	″		
Log. K.	4.73115	Z′−Z	10	53.9	Log. K.	4.73115
Table	8.50958	½(Z′−Z)	5	26.95	Sin.	7.20005
		½(Z′−Z+C)	19	57.25	Ar. Co. Cos.	0.00001
Log. C	3.24073					
C =	1740.″6					1.93121
=	29′ 00.″6				=	85.35

Blue Mound triangulation ground above Platte Mound, 85.35 metres[1]=280.0248 feet.

Some of the most valuable results of the survey thus far have been these determinations of the relative heights of such prominent points as Blue Mound, Platte Mound, Quarry Bluff, Highland, etc.; and by reference to the base line on the Wisconsin river (the height of which *above the level of the sea* has been estimated at 725 feet), the height of these points above the level of the sea also is determined.

For Blue Mound we have:

	Feet.
East Base above sea level	723.97
Quarry Bluff above East Base	372.02
Quarry Bluff above level of the sea	1095.99
Blue Mound above Quarry Bluff	629.21
Blue Mound above level of the sea	1725.20

[1] (To convert metres into feet, multiply by 3.2809.)

Platte Mound is found to be 280.02 feet *lower* than Blue Mound, making its height above the sea level 1445.18 feet.

The height of Quarry Bluff is the average height of all the Wisconsin river bluffs above Prairie du Chien, as far as the great Devil's Lake Range, and East Base is but a few feet above the level of the Wisconsin river at the old Helena Ferry, near Spring Green.

The accompanying maps will show the work already done (up to date of maps), and the full scheme of reconnoissance as laid out in 1874. It is greatly to be hoped that nothing will interfere with the measurement of a second base-line and the comvletion of the work as originally marked out.

Yours respectfully,

JOHN E. DAVIES,

Prof. of Physics in the University of Wisconsin,
and Chief of Geodetic Survey in Wisconsin.

APPENDIX.

ACCOUNT OF THE MEASUREMENT AND RESULTING LENGTH OF THE SECONDARY BASE-LINE NEAR SPRING GREEN, SAUK COUNTY, WISCONSIN, IN 1878.

[A report made by the Chief of the Computing Division of the United States Coast and Geodetic Survey to the Assistant in Charge of the U. S. C. and G. Survey Office.]

COMPUTING DIVISION C. & G. S., March 7, 1879.

"The base-line measured near Spring Green, Sauk county, Wisconsin, in 1878, had for its immediate object to supply the needed length to the sides of that part of the triangulation of Wisconsin which follows the course of the Wisconsin river.

"A preliminary measure was made under the direction of R. D. Cutts, assistant C. & G. S., in the summer of 1875, and after the line had been fully graded, this was repeated under the direction of Dr. J. E. Davies, acting assistant C. & G. S., on July 7 and 8, 1875. Both measures were made with a 60 metre steel wire, kept under a constant strain of 30 pounds. The final measure with the subsidiary base apparatus was made in June, 1878, by Dr. Davies, of the University of Wisconsin, and party.

"The site of the base is a level, sandy prairie, bordering the Wisconsin river and upon its northern shore; it is intersected at two points by wooded sand-dunes and hollows, and passes for about one-eighth of a mile over cultivated fields. Some sand ridges had to be graded, which, varying in height from 6 to 15 feet, crossed the line almost at right angles; by means of scrapers, the inclination of the line was reduced to about 2°.0 with some exceptions, the maximum being 3° 36′. The Milwaukee and Prairie du Chien railroad passes within a few metres of the west end of the base. The ends of the line are marked by substantial monuments, set up in 1875. The azimuth of the base at east end is about 115½°, and its length about 4.68 klm., or about 2.91 st. miles; it was measured with the 4 metre contact-slide rods, Nos. 9 and 10.[1] These rods were compared with a

[1] The secondary base apparatus is described and figured in Coast Survey Reports for 1856 and 1857, appendix No. 45, reprinted with amendment in 1876.

standard rod at Washington, D. C., before and after the base measure. The line was subdivided into nine sections, the ends of which were marked by a copper tack driven into the top of a pine stub. A section was generally measured in the forenoon, and remeasured in the opposite direction in the afternoon. The whole line was gone over a third time and sections one and two were measured four times, thus affording ample means of ascertaining the probable error of measurement. The work was begun at east base June 4, 1878, under the direction of Assistant Cutts; after this Dr. Davies took charge of the work and completed it June 24th.

"During this time the highest temperature of rods recorded was 104° Faht. Special attention was paid by Dr. Davies to secure the greatest stability to the trestles, upon which the accuracy of the operation mainly depends. The whole number of working days was 15.

"A line of levels was carried from east base to west base (also to station Quarry Bluff), and connected at the railroad bridge over the Wisconsin river, with the line of railroad levels from Spring Green to Lake Michigan.

"D. J. Whittemore, Chief Engineer C., M. and St. P. R'y, informs Dr. Davies that the height of the grade (rails) at west end of bridge is 138.5 ft. ±1 ft. above the level of Lake Michigan, as it was in 1837, which is the datum level for Milwaukee. We have consequently:

"Top of monument at east base above Lake Michigan (1837)= 134.82 ft.

"Top of monument at west base above Lake Michigan (1873)= 136.09 ft., and at Quarry Bluff triangulation station = 505.49 ft. According to J. T. Gardner[1] the mean elevation of the lake may be taken = 589.15 ft., hence the average elevation of the base-line above the ocean, with the consideration that the rods were a little higher above the surface of the ground than the tops of the monuments, may be closely estimated at 725 feet, or 221 metres."

"Determination of length of 4 metre contact-slide rods Nos. 9 and 10.

"These rods were agate capped. Pending the determination of certain coefficients of expansion referred to in my report of January 10, 1879, I shall for the present assume such values and probable errors as appear to me most suitable.[2]

[1] The elevations of certain datum points on the Great Lakes, rivers, etc., U. S. Geological Survey of the Territories, F. V. Hayden, Washington, 1875.

[2] This happens to be the same height as the Lebanon base in Tennessee.

"Comparisons with standard iron rod No. 1, May 13, 1878, by J. Clark: Taking the length of the standard at 0°C=3.9998068±100, resulting from comparisons made by H. W. Blair, February 27–28, 1877, and assuming the coefficient of expansion of the iron standard for Fahrenheit scale=0.00000641±10, and that of the steel rods Nos. 9 and 10=0.0000061±1, we find after applying index corrections to the thermometers: Rod No. 9=4 metres at 33.1° Fahrenheit; rod No. 10=4 metres at 31.6° Fahrenheit, with the probable error of ±1.0° Fahrenheit.

"Similarly we find from the comparisons of July 9 and 11, 1878, by J. Clark: Rod No. 9=4 metres at 31.7° Fahrenheit; rod No. 10=4 metres at 31.4° Fahrenheit±1.2°. The average values were used for the reduction of the base, viz.: Rod No. 9=4 metres at 32.4° Fahrenheit±0.8° Fahrenheit; rod No. 10=4 metres at 31.5° Fahrenheit±0.8° Fahrenheit.

"The following table contains the resulting lengths for each section of the line and of each measure of a section, together with the resulting length of the base. It was taken from the office computation by Mr. M. H. Doolittle, who had collated his results with those given by the observer, Prof. Davies.

RESULTING LENGTH OF THE SPRING GREEN BASE-LINE AND OF ITS SUBDIVISIONS.

Sections.	No. of rods.	Average temperature.[1]	Correction for temperature.	Correction for inclination.	Measured excess.	Length of section.	Difference from mean.
		°	mm.	mm.	mm.	mm.	mm
I.........	1 to 100	71.90	+ 95.117	+ 44.872	0	400.05025	3.68
	1 to 100	63.36	74.298	32.556	4.00	.04574	0.83
	100 to 1	82.15	120.124	38.736	−36.00	.04539	1.18
	100 to 1	77.02	107.608	41.320	−21.40	.04489	1.68
	Mean.....	73.61				400.04657	
II........	101 to 220	71.77	+113.775	− 38.144	0	480.07563	1.22
	101 to 220	83.49	148.070	46.444	−22.30	.07933	4.92
	220 to 101	96.80	187.031	43.752	−75.60	.06768	6.73
	220 to 101	72.41	115.633	54.716	+14.10	.07502	0.61
		81.12				480.07441	
III.......	221 to 322	66.91	+ 84.619	− 29.988	0	408.05463	2.49
	221 to 322	84.46	128.275	37.812	−31.70	.05876	1.64
	322 to 221	79.11	114.976	28.012	−29.00	.05796	0.84
		76.83				408.05712	
IV.......	323 to 460	90.12	+192.574	− 69.628	0	552.12295	3.39
	323 to 460	77.86	151.343	42.496	+10.20	.11905	0.51
	460 to 323	83.40	169.964	64.376	+11.10	11669	2.87
		83.79				552.11956	
V........	461 to 591	76.96	+140.754	− 73.736	0	524.06702	1.45
	461 to 591	68.46	113.608	64.476	+17.50	.06663	1.06
	591 to 461	90.41	183.741	59.576	−61.10	.06306	2.51
		78.61				524.06557	
VI.......	592 to 740	80.97	+174.638	−107.652	0	596.06699	5.47
	592 to 740	72.73	144.712	96.976	+ 9.50	.05724	4.28
	740 to 592	90.42	208.961	113.032	−35.60	.06033	1.19
		81.37				596.06152	
VII......	741 to 900	83.21	+196.264	−119.468	0	640.07680	0.91
	741 to 900	95.65	244.818	103.492	−62.75	.07858	2.69
	900 to 741	92.51	232.561	107.412	−52.85	.07230	3.59
		90.46				640.07589	

[1] Mean correction, −0.°95 F. Line, Sections I to IX................ 4,676.64818

RESULTING LENGTH OF THE SPRING GREEN BASE-LINE AND OF ITS SUBDIVISIONS — continued.

Sections.	No. of rods.	Average temperature.	Correction for temperature.	Correction for inclination.	Measured excess.	Length of section.	Difference from mean.
		°	mm.	mm.	mm.	m.	mm.
VIII.....	901 to 1060	76.74	+171.038	−105.632	0	640.06541	5.09
	901 to 1060	89.87	222.259	109.604	−52.26	.06039	0.07
	1060 to 901	85.04	203.407	116.612	−31.65	.05515	5.17
		83.98				640.06032	
IX.......	1061 to 1169	75.22	+112.526	− 27.332	0	436.08519	2.03
	1061 to 1169	90 23	152.425	35.524	−23.75	.09315	5.93
	1169 to 1061	91.34	155.379	33.668	−38.40	.08331	3.91
		85.60				436.08722	

	m.
West Base in excess of end of bar 1169	+2.1863
Reduction to sea-level..	−0.1620
Resulting length of Spring Green base, in metres	4678.6725

The separate results by each measure are as follows:

Sections.	FIRST MEASURE FORWARD.		SECOND MEASURE BACKWARD.		THIRD MEASURE FORWARD.	
	Average temperature.	Length.	Average temperature.	Length.	Average temperature.	Length.
	°	m.	°	m.	°	m.
I [1].........	71.90	400.0502	79.58	400.0451	63.36	400.0457
II [1]........	71 77	480.0756	84.60	480.0793	83.49	480.0713
III........	66.91	408.0546	79.11	408.0588	84.46	408.0580
IV........	99.12	552.1230	83.40	552.1190	77.86	552.1167
V.........	76.96	524.0670	90.41	524.0666	68.46	524.0631
VI	80.97	596.0670	90.42	596.0572	72.73	596.0603
VII........	83.21	640.0768	92.51	640.0723	95.65	640.0786
VIII.......	76.74	640.0654	85.04	640.0551	89.87	640.0604
IX	75.22	436.0852	91.34	436.0833	90.23	436.0931

		° F.		m.	m Δ.
First measure, forward	Average temperature,	77.1;	length,	4676.665	0.017
Second measure, backward..	Average temperature,	86.3;	length,	.737	0.011
Third measure, forward.....	Average temperature,	80.7;	length,	.647	0.001
All measures		81.8		4676.648	
Index correction		−1.0		metres.	

[1] In the first and second section the mean of the first and fourth measurements has been introduced, hence certain small discrepancies between 1st and 2d table.

"The average temperatures during the measures was 80°.8, and an examination of the results show them not to depend upon the temperature, whether high or low, from which we may conclude that the temperature corrections are well founded. There is no decided difference in the results deduced from the forward and backward measures; this might have been expected from the nearly equal height of the base termini.

DETERMINATION OF THE ACCURACY OF THE MEASURED LENGTH.

"The probable error of the base measure depends first upon the probable error of the rods, and second upon the probable error of measure. To estimate the first part, we have at the temperature of comparison of rods with standard May 13, 1878, the probable error for each ±19.2 microns, and at the temperature of comparisons July 9 and 11, 1878, the probable error for each ±21.6 microns; at the mean temperature of comparison 75°.4 F. the length of a rod was subject to ±14.5 microns, and consequently at the mean temperature of measure, 80°.8 F., it was subject to ±14.5 ± 2.2 = ± 14.7. Hence probable error of base from this source ±14.7 times 1169 = ± $17^{mm}.184$. The errors introduced by the measurement proper are found from the discrepancies given in the last column of the first table. We have probable error of a section $\sqrt{\frac{.455\ \Sigma\ \Delta^2}{n(n-1)}}$ where n = number of measures, hence probable error of line $\sqrt{\frac{.455[\Sigma\ \Delta^2]}{[n(n-1)]}} = \pm\ 4^{mm}.456$ and by combination, probable error of the base-line ± 17.184 ± 4. 456 = ± $17^{mm}.75$, or a little over $\frac{2}{3}$ of an inch. In parts of the length of the base it equals ± $\frac{1}{263600}$, which fraction compares favorably with the degree of accuracy needed for principal triangulation. It appears plainly that the error arising from uncertainty in length of the measuring rods is the *principal* one, that due to the measurement proper being very small, in the present case, only $4.456\ \sqrt{3} = \pm 7^{mm}.72$, or $\frac{1}{606000}$ of the length for a *single* measure.

"This last fraction shows the capacity of the subsidiary apparatus for accuracy in a conspicuous way.

"We therefore have for the resulting length of the Spring Green Base of Wisconsin the value $4678^{m}.6725 \pm 0^{m}.0178$ and its logarithm 3.6701226 ± .0000017."

Respectfully submitted,

[Signed] CHAS. A. SCHOTT.

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PLATE 1.

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Fig. 1. View of the specimen used in description.

Lingulepis pinniformis — Owen 169

Fig. 2. View of a small dorsal valve.
3. View of a ventral valve of ordinary form.

Orthis Pepina — Hall 170

Fig. 4. Cast of a dorsal valve.
5. Cast of a ventral valve.

Leptæna Barabuensis — Winch 171

Fig. 6 and 7. Casts of a dorsal and a ventral valve, enlarged to two diameters.

Palæachmea Irvingi — W 173

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Ophileta (Raphistoma) primordialis — Winch 173

Fig. 10. Lateral view of a small individual enlarged to two diameters, showing the elevation.
11. Upper view of a larger individual, natural size.

Hyolithes primordialis — Hall 175

Fig. 12. View of a fragment of rock containing two individuals.

Bellerophon antiquatus — W 176

Fig. 13 and 14. Back and profile views of a specimen, enlarged to two diameters.

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Arionellus convexus — W 190

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Elliptocephalus curtus — W 191

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Agraulos (Bathyurus?) Woosteri — W 189

Fig. 19. View of a nearly perfect cast of the head.
20. Outline profile of the same.
21. Cast of a pygidium.

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Fig. 22 and 23. View of the central parts of the head and an outline profile of the same.

Ptychaspis granulosa — Owen sp 185

Fig. 24. View of a head which is destitute of the movable cheeks, and with imperfect posterior limbs.

Ptychaspis minuta — W 186

Fig. 25. View of a movable cheek, greatly enlarged.
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Conocephalus (Ptychaspis) explanatus — W 181

Fig. 27. View of an imperfect head, natural size.
28. Outline profile of the same, showing the curvature and elevation of parts.

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Primordial (Potsdam) Plate I.

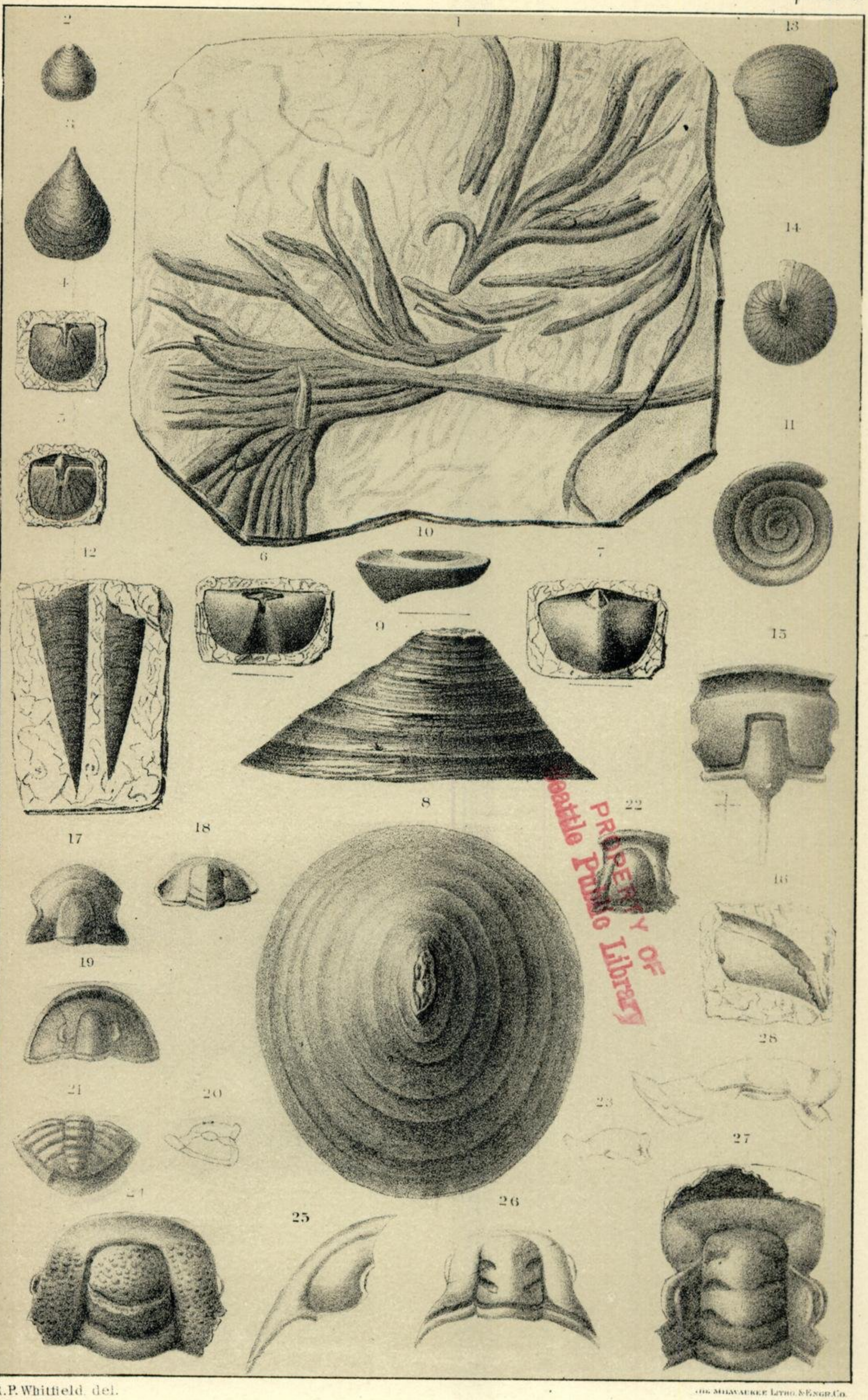

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PLATE 2.

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Arenicolites Woodi — W 177

Fig. 1. Vertical section of a layer of sandstone containing the borings, showing their irregular character. Near the middle along the upper margin is a series of the semilunate borings showing their juxtaposition.

2. View of the summit of the same block as fig. 1, showing several series of the semilunate borings.

3. View of a part of the upper surface of a large block of sandstone, showing the little hillocks found around the openings on the natural surface, and also the trailings and horizontal borings of the worms.

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Primordial

(Potsdam sandstone.)

Plate 2.

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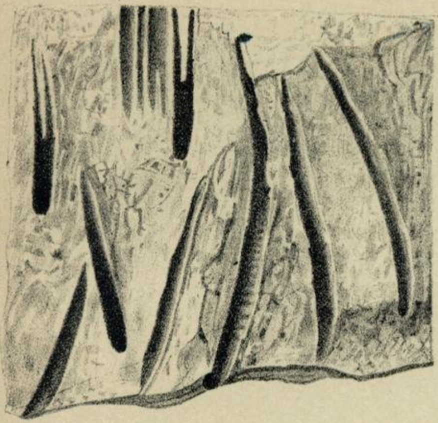

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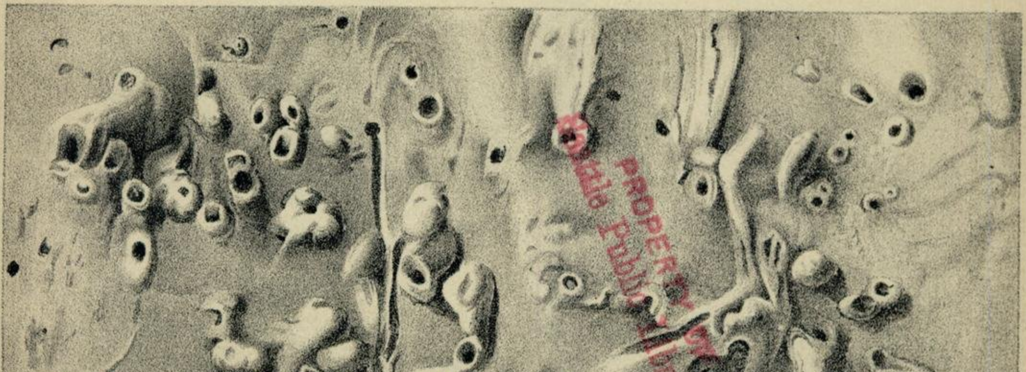

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PLATE 3.

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DIKELLOCEPHALUS MINNESOTENSIS — Owen 187

Fig. 1. View of a small imperfect pygidium.

CONOCEPHALITES CALYMENOIDES — W. 179

Fig. 2. View of a specimen showing the body and a part of the head, as obtained by gutta-percha from the natural mould. Enlarged to two diameters.
3. View of a glabella and fixed cheeks. Two diameters.
4. A segment from the upper part of specimen fig. 2, enlarged to four diameters.
5. Outline of the segment, showing the elevation of the lobes. Two diameters.

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Fig. 11. Lateral view of the specimen used in description, restored at the upper part, from a gutta-percha cast in the natural mould.

METOPTOMA SIMILIS — W. 196

Fig. 12 and 13. Dorsal and outline profile views of the specimen described.

METOPTOMA RECURVA — W. 196

Fig. 14 and 15. Vertical and profile views of a large specimen, both figures somewhat restored.

METOPTOMA BARABUENSIS — W. 195

Fig. 16 and 17. Vertical and lateral views of a large specimen.

METOPTOMA RETRORSA — W. 197

Fig. 18. Lateral view showing the commencement of the recurving of the apex.

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(Potsdam & L. Magnesian.)

Primordial

Plate 3.

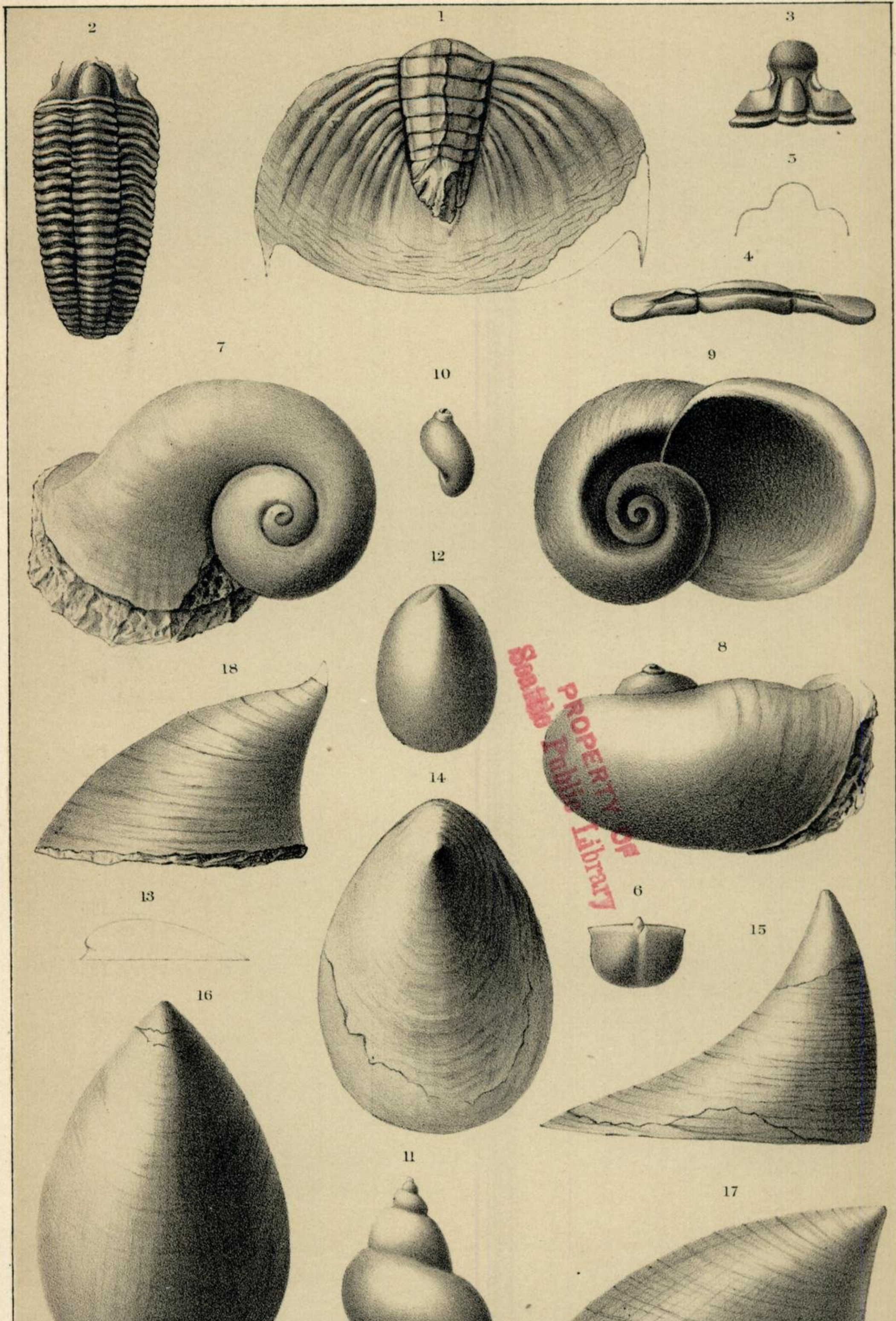

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PLATE 4.

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EUOMPHALUS STRONGI — W. 200

Fig. 1 and 2. Lateral and profile views of a very well preserved specimen.

ILLÆNURUS CONVEXUS — W 203

Fig. 3 and 4. Views of the glabella and fixed cheeks and outline profile of the same.
5. View of a pygidium of the species.

DIKELLOCEPHALUS BARABUENSIS — W 201

Fig. 6. View of the glabella and fixed cheeks of a well preserved specimen of full growth.
7. Outline profile of the same.
8. View of a left cheek supposed to belong to the species.
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10. View of a left cheek of a different form and species from fig. 8, but associated with it.

DIKELLOCEPHALUS EATONI — W 202

Fig. 11. Upper view of a large imperfect head of the species.
12. Front view of the same, showing the great breadth of the thickened anterior marginal rim.
13. Lateral or profile view of the same, showing the great convexity.
14 and 15. Upper and lateral views of a left cheek of the species.
16. Upper view of an imperfect right cheek.
17. View of a pygidium found associated with the other parts and supposed to belong to the species.

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Primordial

(Lower Magnesian.)

Plate 4.

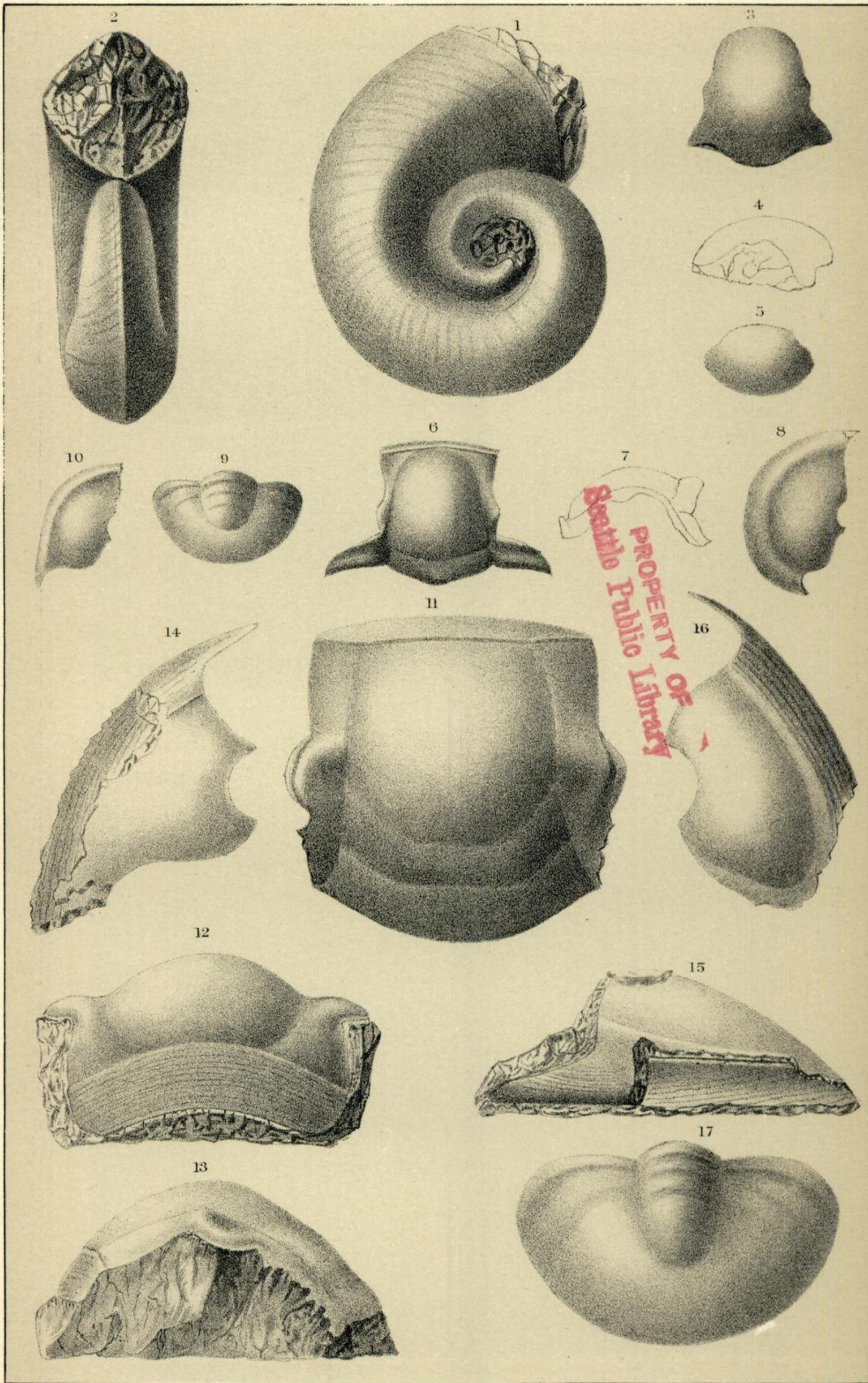

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PLATE 5.

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ILLÆNUS OVATUS — Conrad 238

Fig. 1. View of a small nearly entire cast of this species, from the Buff limestones of Beloit.
2. View of a larger head, destitute of movable cheeks, from near the same place.

ASAPHUS SUSÆ — Calvin 236

Fig. 3. Dorsal view of a specimen from the Trenton formation just south of the state line. The thorax has been shortened by one of the segments being crowded beneath.

ASAPHUS HOMALONOTOIDES — Walcott.................................... 237

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Fig. 9. View of a left valve from Hess' quarry, Beloit.

CYPRICARDITES NIOTA — Hall 208

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MURCHISONIA HELICTERES — Salter 220

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Silurian (Trenton limestone.) Plate 5.

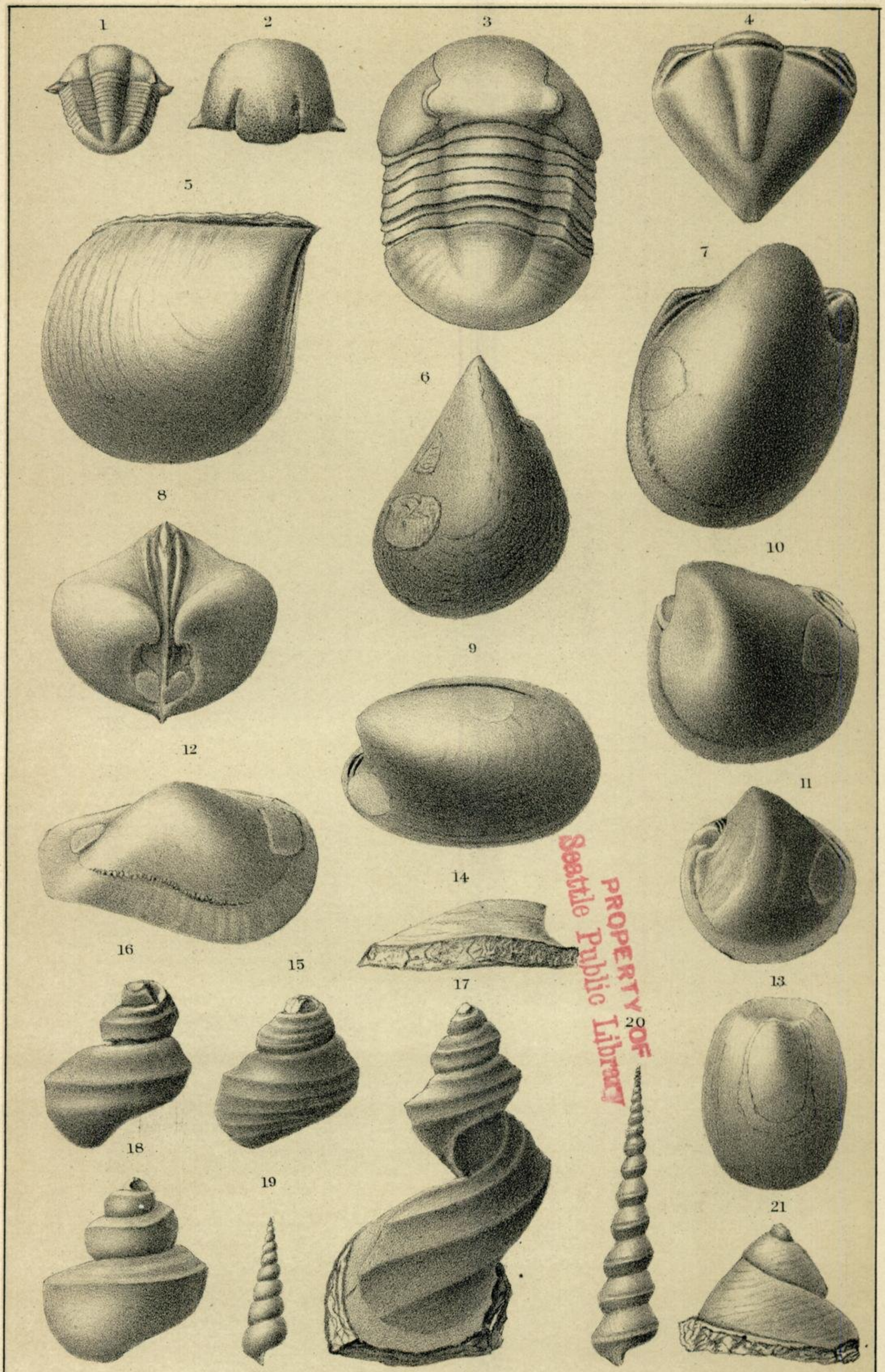

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PLATE 6.

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Pleurotomaria subconica — Hall 216

Fig. 1. Lateral view of a very perfect cast, from Hess' quarry, near Beloit.

Raphistoma nasoni — Hall 215

Fig. 2 and 3. Lateral and upper views of a specimen showing the usual characters, Hess' quarry, Beloit.

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Fig. 17 and 18. View of the flat side and front profile view of a cast of large size. Below Carpenter's quarry, Beloit.

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Silurian — (Trenton limestone) — Plate 6.

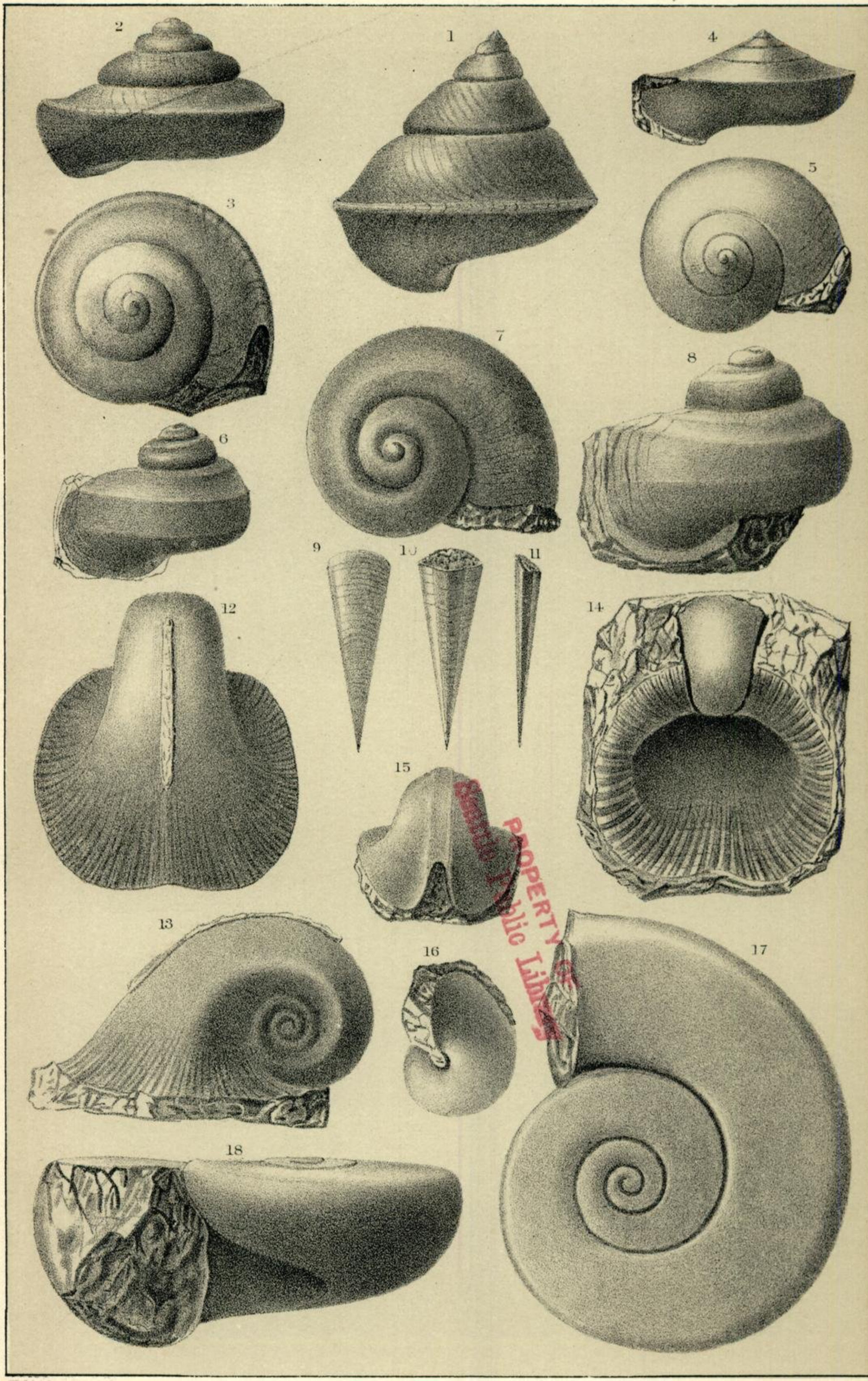

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Fig. 1. View of a specimen as obtained from a gutta-percha cast in the natural mould. Bristol, Dane county, Wis.

CYRTOCERAS BREVICURVATUM — W 234

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Fig. 16. View of the edge of the lower end of the same, showing the relation of the inner tube to the outer, and to the septa.

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Silurian (Trenton limestone.) Plate 7.

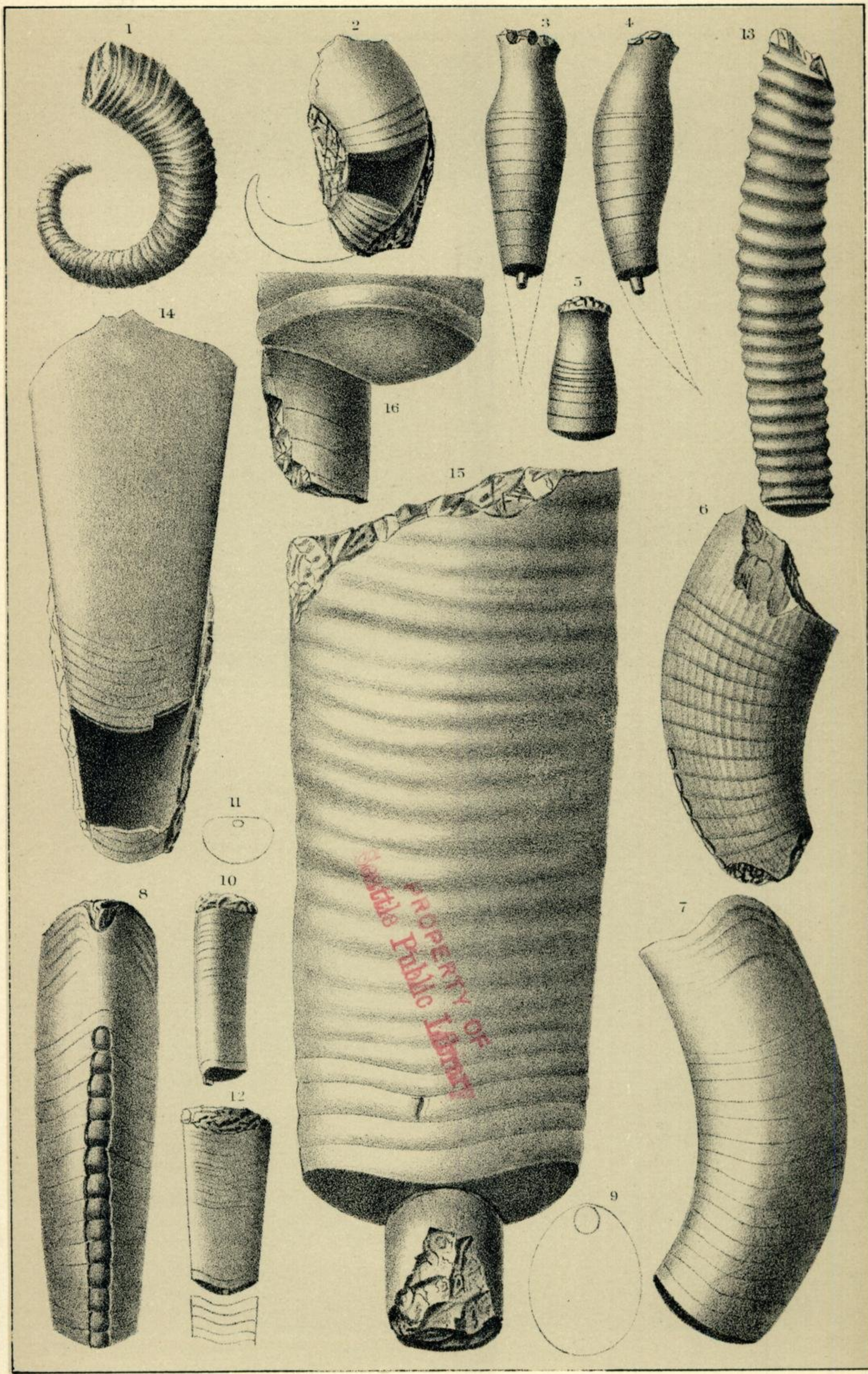

PLATE 8.

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ORTHOCERAS (ACTINOCERAS) BELOITENSE — W 226

Fig. 1. View of a specimen preserving a part of the outer chamber, and several of the preceding ones, showing the gradual shortening of the chambers toward the upper part. Some fragments of the shell adhering have a smooth surface

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PLATE 9.

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LINGULELLA IOWENSIS — Owen 242

Fig. 1. View of a large specimen showing the general form of perfect individuals. The left side of the figure shows the condition of a cast, and on the right is represented a portion of the shell.

FUSISPIRA VENTRICOSA — Hall.. 245

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MACLUREA CUNEATA — Whitf 246

Fig. 5. View of the flat side of a specimen from Whitewater, Wisconsin.
6. Profile view of the same specimen.

MACLUREA SUBROTUNDA — Whitf 246

Fig. 7. View of the flat surface of a specimen from Whitewater, Wisconsin.
8. Profile view of the specimen looking on the aperture.

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Silurian

(Galena limestone.)

Plate 9.

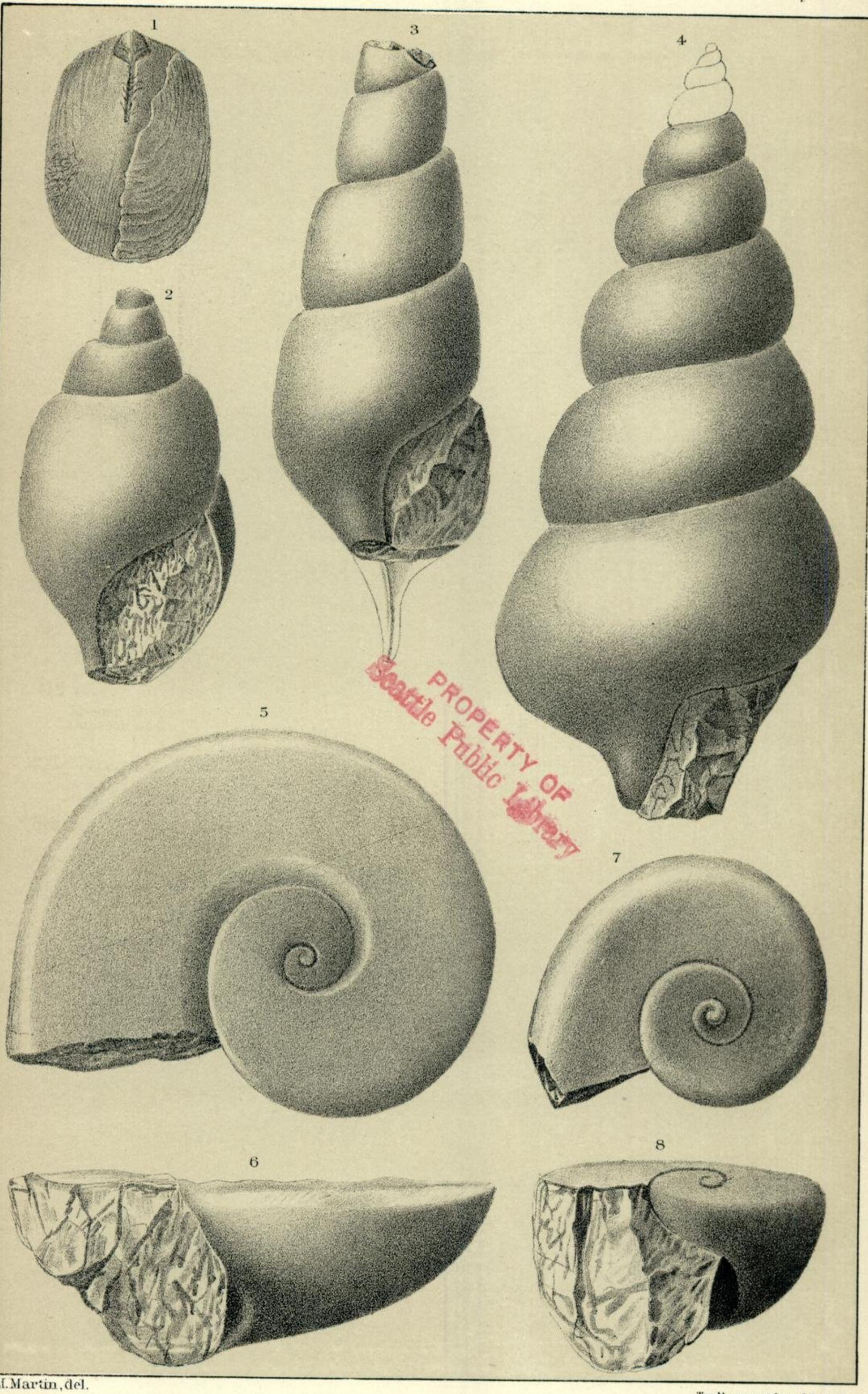

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PLATE 10.

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Fig. 1. View of the specimen described, being a cast of the dorsal valve in sandstone. Fig. enlarged to two diameters.
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Fig. 4. View of a more perfect pygidium than the one originally used, showing two distinct rings on the axial and on the lateral lobes.
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Fig. 6. View of a cast of this species, found in the Trenton limestone at Rockton, Illinois.

RECEPTACULITES OWENI — Hall................................ 239

Fig. 7. View of the upper surface of a fragment, showing the general characters. Galena limestone.

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ORTHOCERAS (ACTINOCERAS) BELOITENSE — W.................. 226

Fig. 9. View of a fragment, showing the cast of the siphuncle and the filling of the same, as also the thickenings of the septa.
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CREPICEPHALUS ? GIBBSI — Whitf.............................. 184

Fig. 12. View of a left cheek as obtained by gutta-percha in the natural mould.
13. View of a pygidium referred to the same, being found on the same block of sandstone.

DIKELLOCEPHALUS LODENSIS — Whitf .... 188 and 341

Fig. 14. View of the right cheek mentioned in the description.

HEMIPRONITES AMERICANUS — Whitf 243

Fig. 15. Dorsal view of a perfect specimen from near Oshkosh, Wisconsin.
16. Dorsal view showing the valve slightly concave on the umbo.
17. Cardinal view showing the area, deltidium and foramen.

(Miscellaneous.)

Primordial & Silurian

Plate 10.

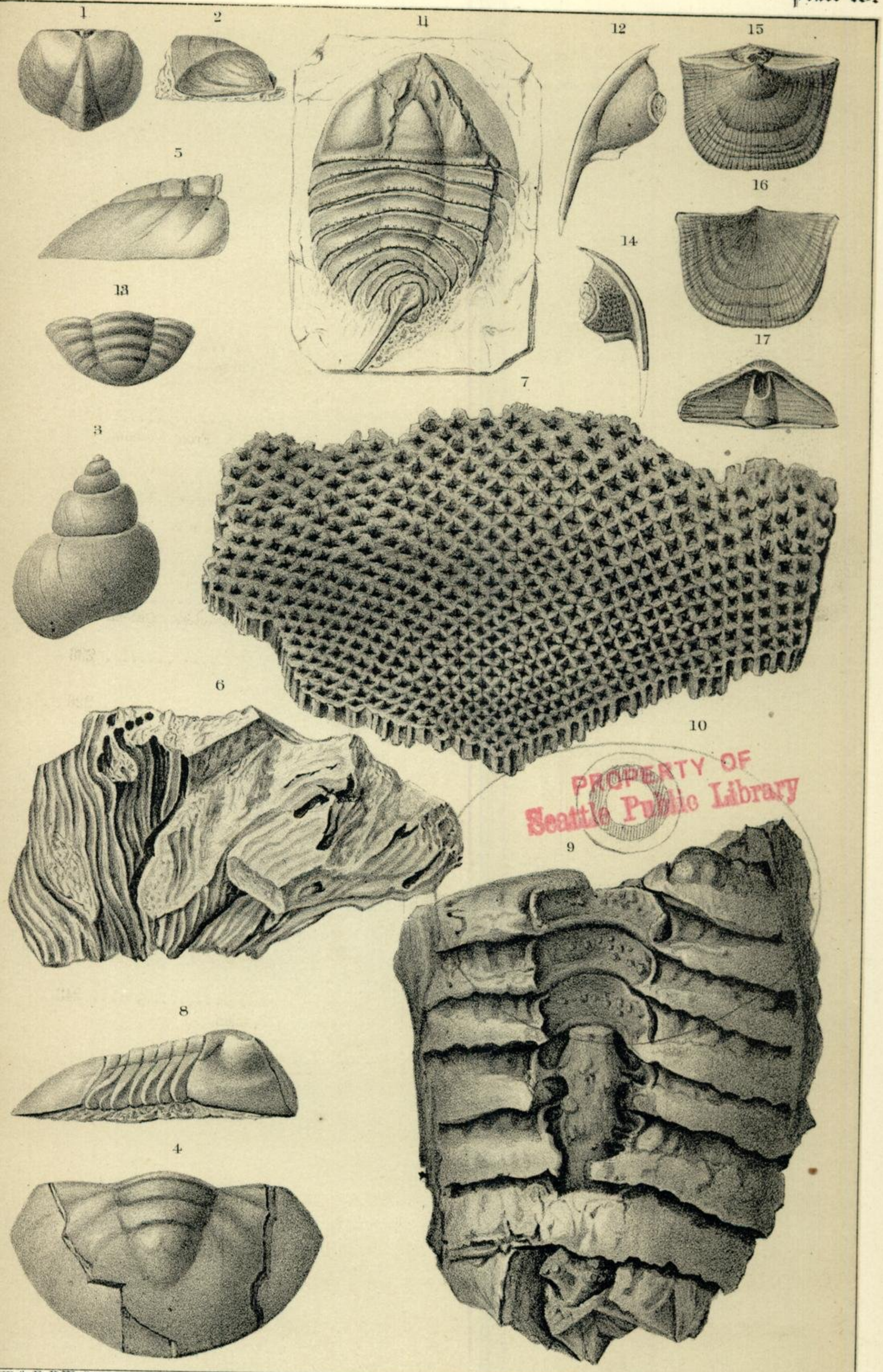

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PLATE 11.

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ALVEOLITES IRREGULARIS — W. 251

Fig. 1 and 2. View of a fragment, natural size, and a portion enlarged to ten diameters, showing the form of cells and macculæ. From Iron Ridge.

MONTICULIPORA PUNCTATA — W. 249

Fig. 3 and 4. View of a specimen, natural size, and a portion enlarged to five diameters. Delafield, Wis.

FISTULIPORA LENS — W. 256

Fig. 5 and 6. View of the upper surface of a specimen, natural size, and an enlargement to ten diameters of a portion. From Delafield, Wis.

MONTICULIPORA (?) ORTONI — Nicholson 251

Fig. 7 and 8. View of the upper side of a specimen, natural size, and an enlargement to three diameters. Delafield, Wis.

MONTICULIPORA MULTITUBERCULATA — W. 250

Fig. 9 and 10. View of a fragment, natural size, and an enlargement of a portion to eight diameters. Delafield, Wis.

MONTICULIPORA RECTANGULARIS — W. 249

Fig. 11 and 12. A fragment, natural size, and an enlargement to eight diameters. Delafield, Wis.

CHÆTETES FUSIFORMIS — W 248

Fig. 13 and 14. View of a specimen enlarged to two diameters and a section enlarged to ten diameters. Iron Ridge, Wis.

TREMATOPORA ANNULIFERA — W. 254

Fig. 15. View of a specimen enlarged three diameters.
16 and 17. View of another specimen enlarged to two diameters, and a portion enlarged to twelve diameters. Delafield, Wis.

FISTULIPORA SOLIDISSIMA — W. 255

Fig. 18. View of a specimen, natural size.
19. A section enlarged to eight diameters. Delafield, Wis.

FISTULIPORA RUGOSA — W 255

Fig. 20 and 21. Views of a specimen, natural size, and a section enlarged eight diameters. Delafield, Wis.

TREMATOPORA GRANULATA — W 253

Fig. 22 and 23. A fragment, natural size, and a portion enlarged to ten diameters. Delafield, Wis.

STICTOPORA FRAGILIS — Billings sp. 253

Fig. 24. An enlargement of a bifurcating fragment showing the arrangement of cells. The outline above indicates the natural size. Delafield, Wis.

Silurian (Hudson River Group.) Plate 11.

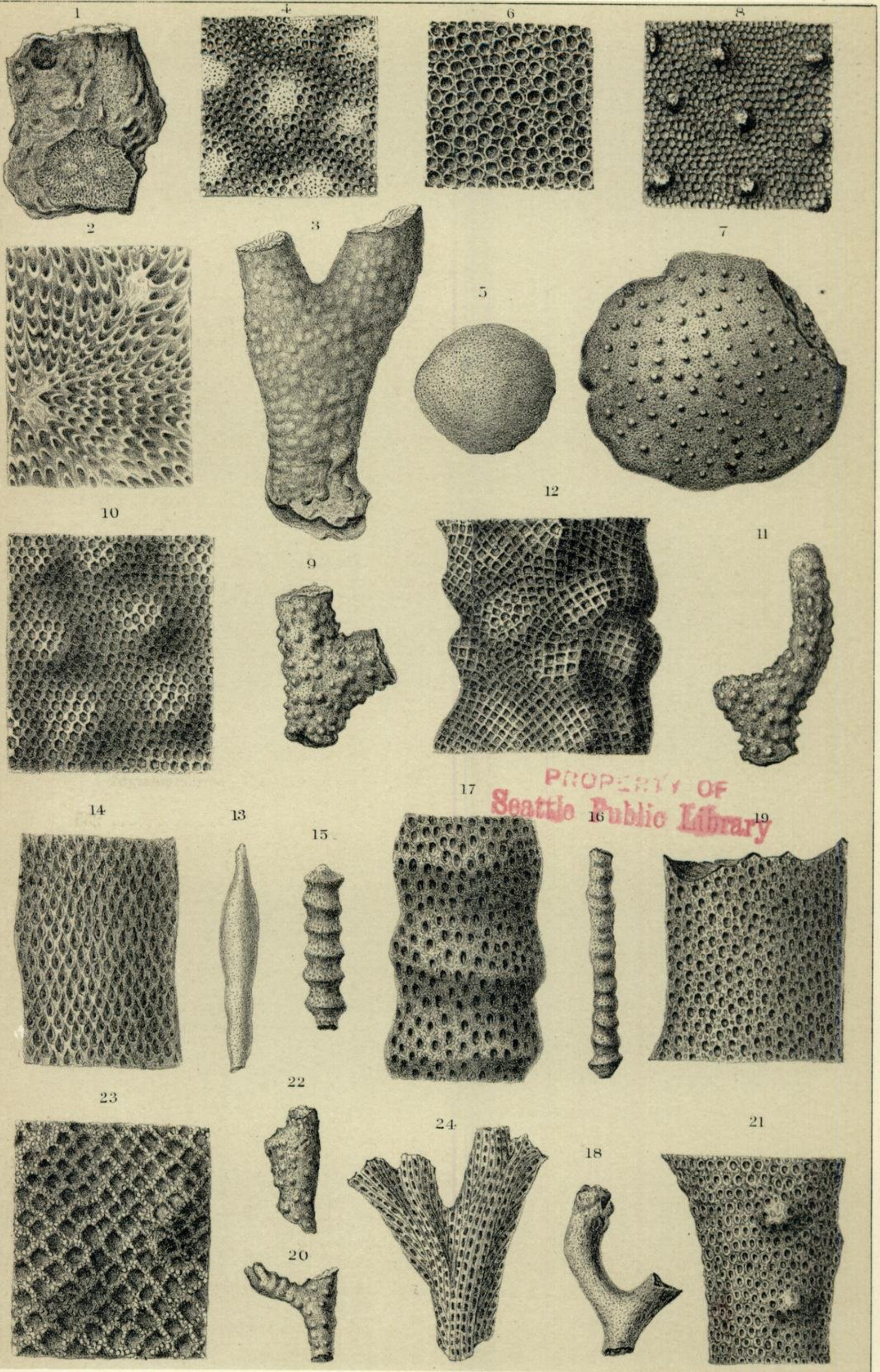

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PLATE 12.

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FENESTELLA GRANULOSA — W. 252

Fig. 1. View of a frond enlarged to two diameters.
2. A portion of the same greatly enlarged to show the cells and other features. Delafield, Wis.

CONSTELLARIA POLYSTOMELLA — W. 257

Fig. 3 and 4. View of a fragment of a frond, natural size, and an enlargement of a portion to show the arrangements of parts. Delafield, Wis.

ORTHIS TESTUDINARIA — Dalm. 258

Fig. 5–7. Dorsal, ventral and profile views of a specimen of this species from Delafield, Wis.

ORTHIS PECTINELLA — Conrad. 259

Fig. 8. Ventral view of a specimen of ordinary size from Delafield, Wis.

STREPTORHYNCHUS CARDINALE — W. 261

Fig. 9 and 10. Dorsal and profile views of a specimen from Delafield, Wis.

STROPHOMENA WISCONSENSIS — W. 263

Fig. 11 and 12. Dorsal and profile views of a specimen of large size but of the general form.
13. View of a more abruptly curved form, with mucronate hinge extremities. Delafield, Wis.

STROPHOMENA UNICOSTATA — M. and W. 262

Fig. 14. View of the flat valve of a specimen showing the single strong central rib. Delafield, Wis.

STROPHOMENA KINGI — W. 261

Fig. 15 and 16. Ventral and profile views of a specimen of the ordinary form. Delafield, Wis.

ORTHIS OCCIDENTALIS — Hall. 260

Fig. 17 and 18. Views of the opposite sides of a large ventral valve from Delafield, Wis.

RYNCHONELLA NEENAH — W. 265

Fig. 19. Ventral view of a very narrow form.
20–22. Dorsal, front and lateral views of a specimen of ordinary form. Delafield, Wis.

RHYNCHONELLA PERLAMELLOSA — W. 265

Fig. 23–25. Dorsal, ventral and profile views of a specimen of ordinary form from Delafield, Wis.

RHYNCHONELLA CAPAX — Conrad. 263

Fig. 26 and 27. Dorsal and profile views of a large and very coarsely plicated specimen from Stockbridge, Wis.

Wisconsin Geological Survey.

(Hudson River Group.)

Silurian

Plate 12.

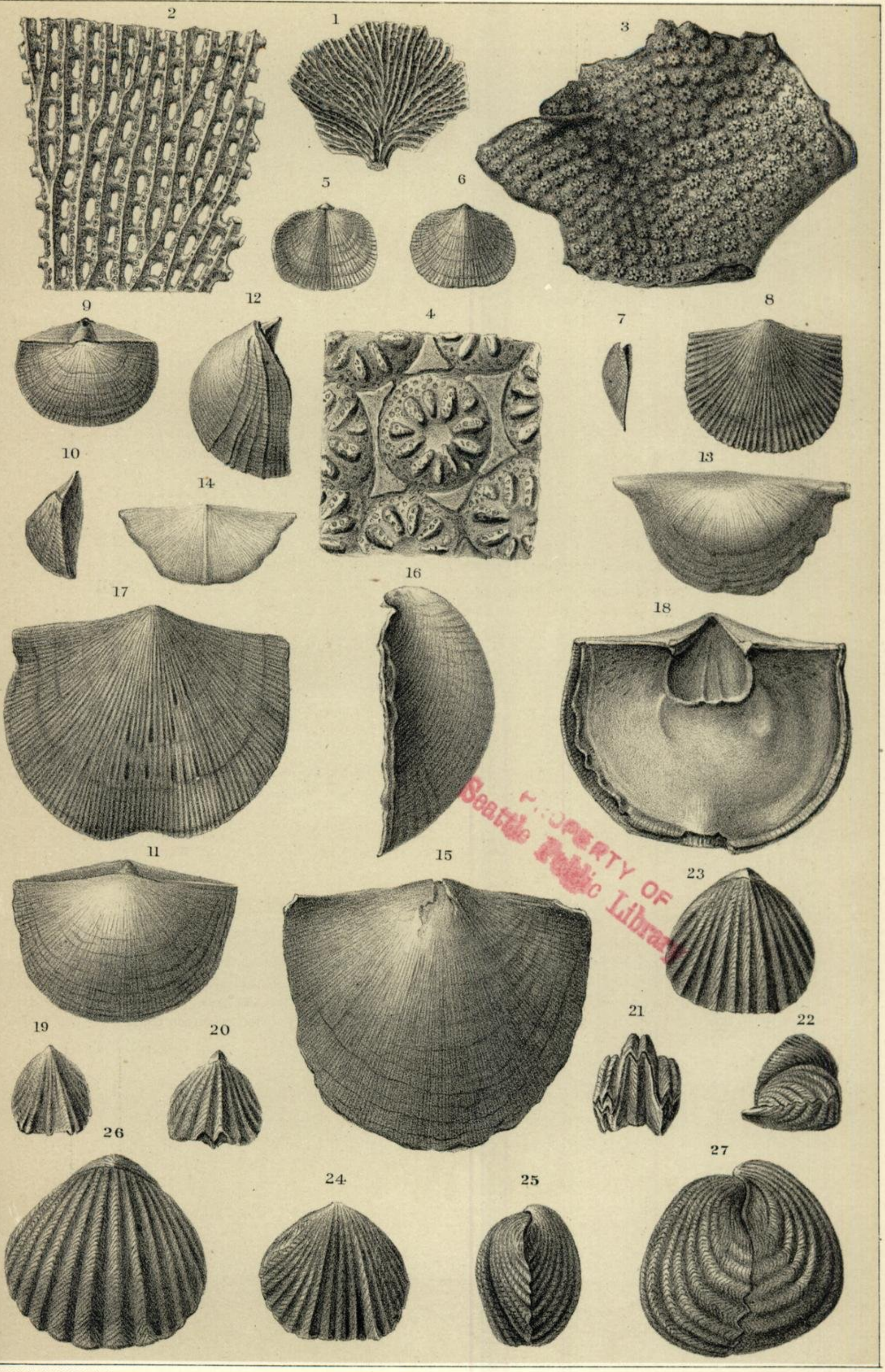

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PLATE 13.

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CERIONITES DACTILOIDES — Owen sp 267

Fig. 1. View of the upper surface showing the cells with the minute pores in the center.
2. Profile view showing the more crowded cells.
3. Lower surface of the same specimen.

RECEPTACULITES HEMISPHERICUS — Hall........................ 269

Fig. 4. Lateral view of a specimen showing more than a hemispherical form.

HALYSITES CATENULATUS — Lin.................................. 271

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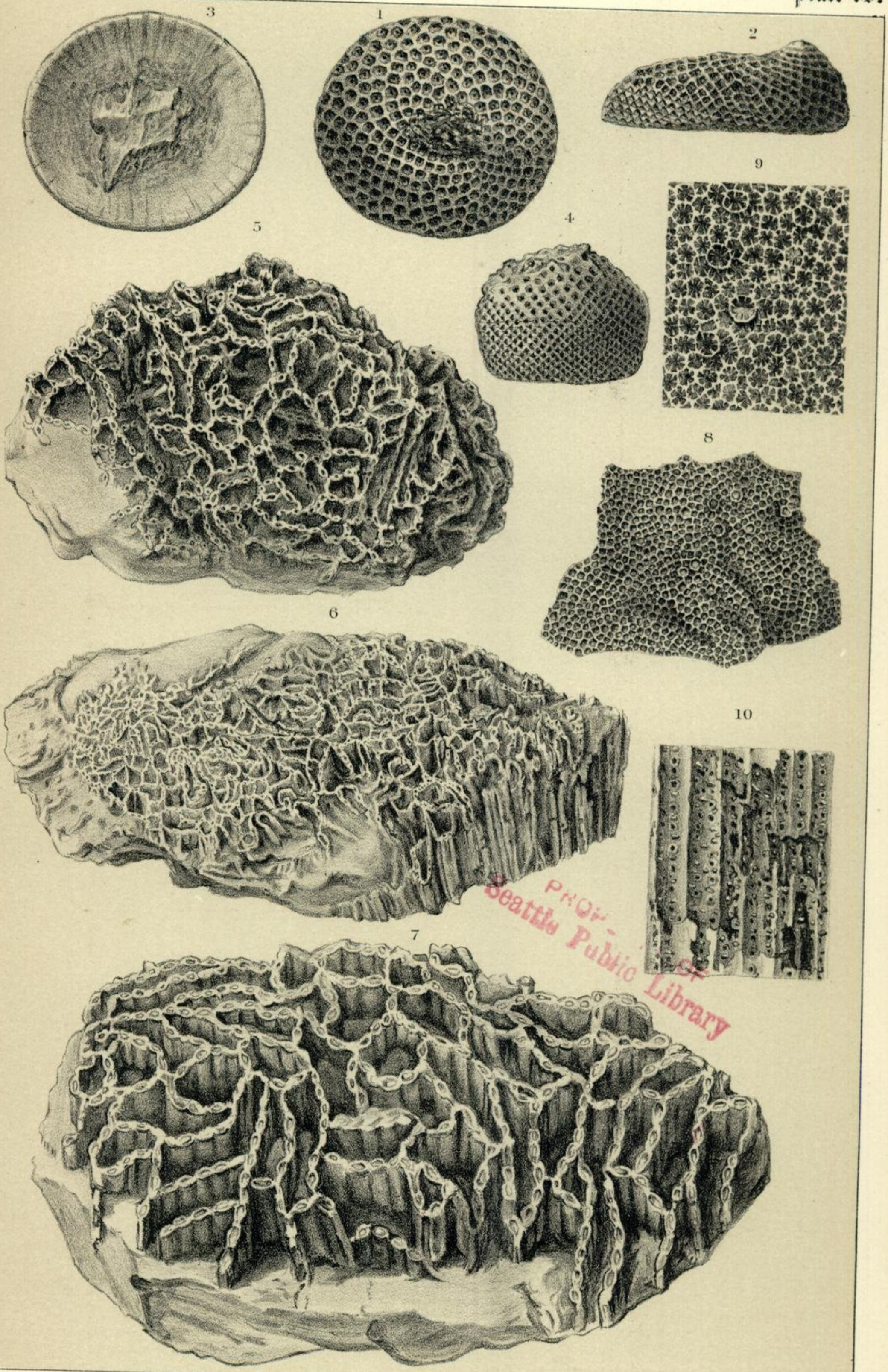
6. View of a specimen of the variety MICROPORA from Bailey's Harbor, Wisconsin. (See page 272.)
7. A specimen of H. LABYRINTHICA Goldfuss, from Sturgeon Bay. (See page 272.)

ASTROCERIUM VENUSTUM — Hall 270

Fig. 8. View of the upper surface of a weathered fragment from Rockland ledge, Wis.
9. Enlargement of the surface as it appears under a lens.
10. Enlarged vertical section showing pores and spines.



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ZAPHRENTIS RACINENSIS — W. 277

Fig. 1 and 2. Lateral and basal views of a cast of the cup, as they generally appear. Racine, Wis.

CYATHAXONIA WISCONSINENSIS — W. 267

Fig. 3. Lateral view of a cast of the cup, showing the lamella which have filled the fossett on the right side below. Racine.
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SYRINGOPORA VERTICILLATA — Goldf. 272

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CYSTOSTYLUS INFUNDIBULUS — W. 274

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CYSTOSTYLUS TYPICUS — W 274

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9. Vertical section of the same piece as above, showing in the lower part near the center a bifurcation of corallite.

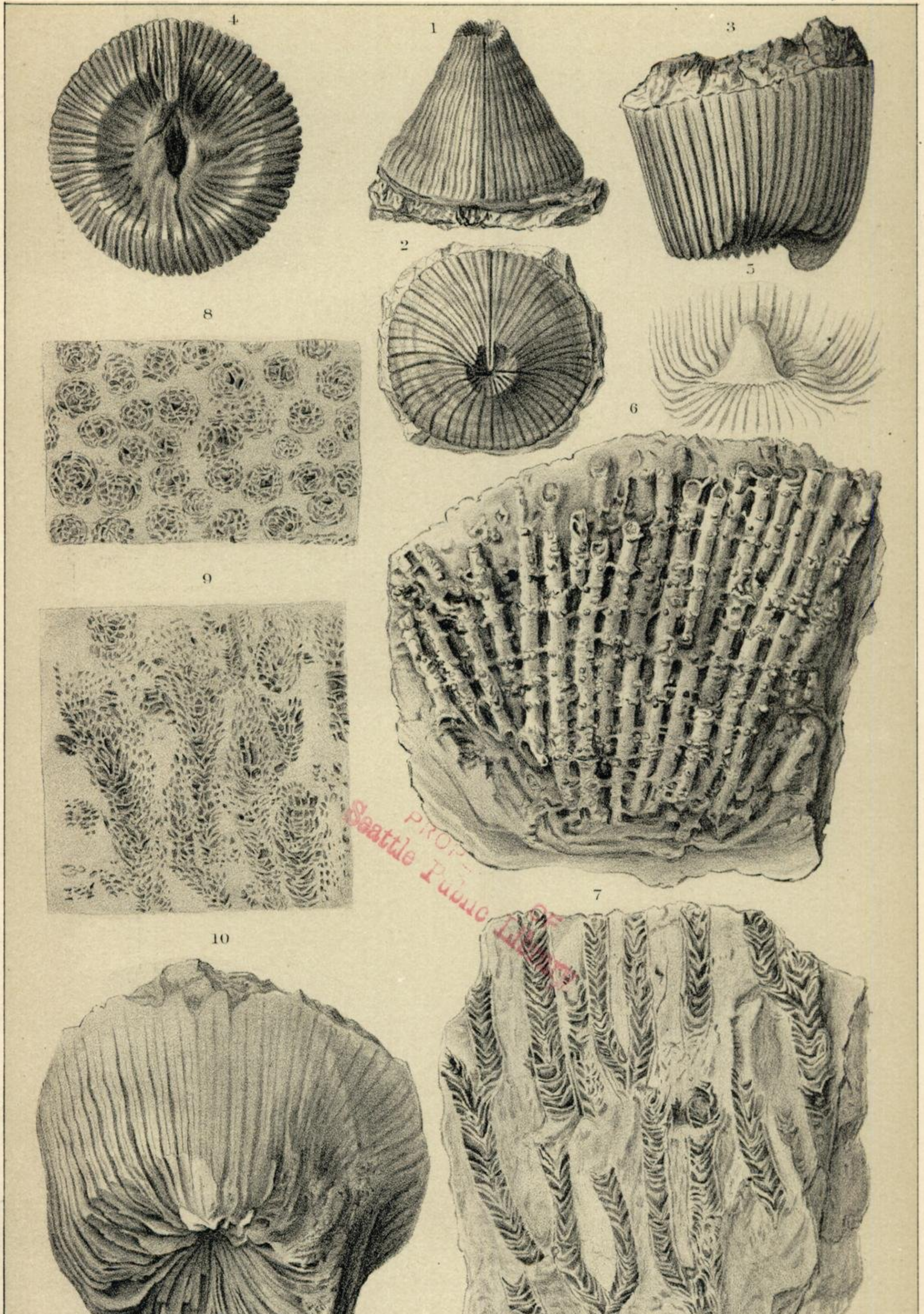
OMPHYMA STOKESI — Ed. and H. 279

Fig. 10. Oblique basal view of the cast of a cup.

Wisconsin Geological Survey.

(Niagara limestone.)

Silurian — Plate 14.



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AMPLEXUS FENESTRATUS — W. 278

Fig. 1. View of a specimen showing the cup with the margin partially removed.
2. Interior view of the cup, showing the fossett.
3. Lateral view of another individual, showing the apparent fenestrules of the surface.

OMPHYMA — *Sp. undet* 279

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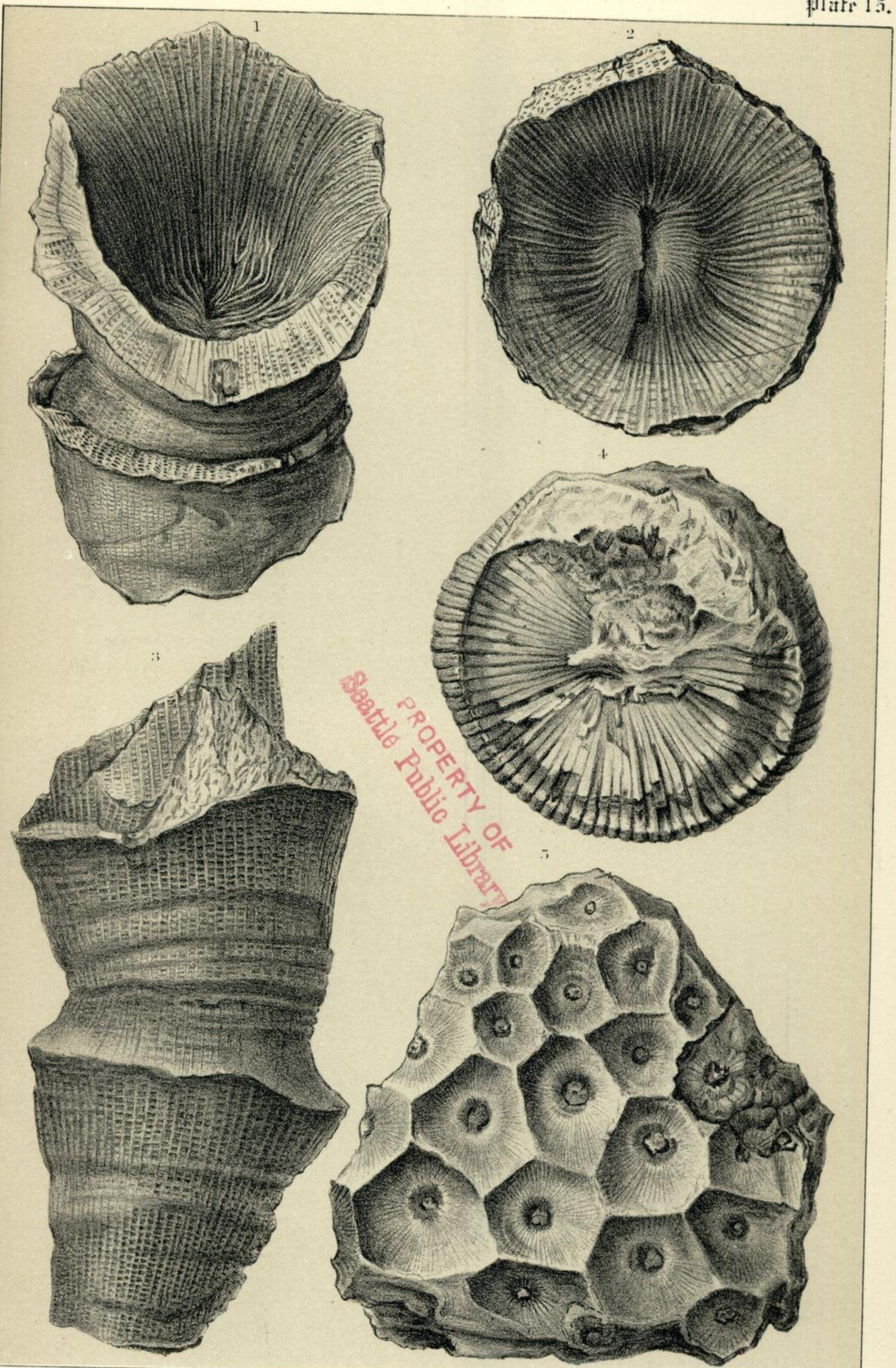
STROMBODES PENTAGONUS — Goldf 275

Fig. 5. View of the upper surface of a specimen of the usual form. A portion near the upper right hand corner shows the cystose structure of the interior. Red River, Kewaunee county, Wis.

Silurian (Niagara Group.) Plate 15.



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Caryocrinus ornatus — Say 280

Fig. 1. Lateral view of an internal cast of the ordinary form.
2. Lateral view of one of a broad topped variety.

Glyptaster occidentalis — Hall 281

Fig. 3. Basal view of a large cast showing the features of the species. From Racine.
4. Lateral view of the same specimen.

Eucalyptocrinus commutus — Hall........................... 285

Fig. 5. Lateral view of an internal cast.
6. Basal view of the same.
7. Exterior of the calyx as obtained from a gutta-percha cast in the natural mould. Copied from the 20th Rept. State Cab. N. Y.
8. Outline diagram of the upper portion as obtained from a gutta-percha cast.

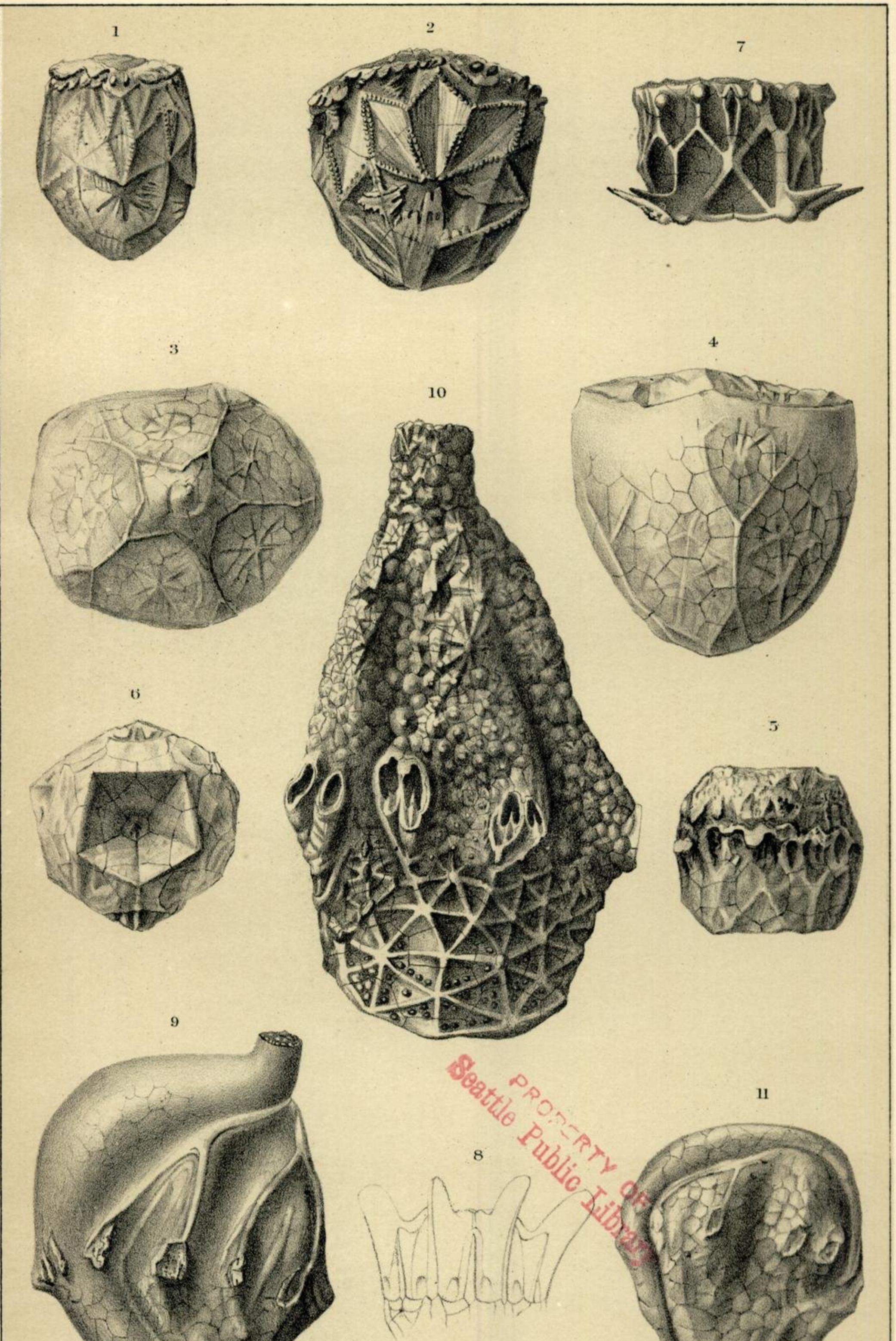
Glyptocrinus nobilis — Hall 283

Fig. 9. Lateral view of a cast of the interior of medium size.
10. Exterior of a body as obtained from a cast in the matrix. Copied from the 20th Report State Cab. N. Y.

Glyptocrinus armosus — McChesney 284

Fig. 11. Lateral view of a small individual cast, showing the downward bending of the tube, instead of an upward curving as in *G. nobilis*.

Silurian (Niagara limestone.) Plate 16.



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Spirifera radiata — Sowerby 287

Fig. 1 and 2. Dorsal and cardinal views of a cast of the species, from Racine.

Pentamerus bisinuatus — McChesney 290

Fig. 3. Dorsal view of a medium sized specimen of the species, showing the single process of the dorsal valve.

Pentamerus oblongus — Sowerby 288

Fig. 4. Profile view of a large specimen from Elmore, Wisconsin.
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6. Cardinal view of the last mentioned specimen.
7. Dorsal view of a cast in white chert from Port de Morts, Wisconsin.
8 and 9. Two views of a peculiarly formed variety abundant at Ashford, in the Upper Coral beds.

Pentamerus occidentalis — Hall 314

Fig. 10. Profile of a specimen from the Niagara beds, Wisconsin, showing the great gibbosity of the shell.

Pentamerus ventricosus — Hall 291

Fig. 11–13. Dorsal profile and front views of a specimen from Pewaukee, Wisconsin, showing a less extension of the front and elevation of the fold than is usual at other localities.

(Niagara limestone.)

Silurian

Plate 17.

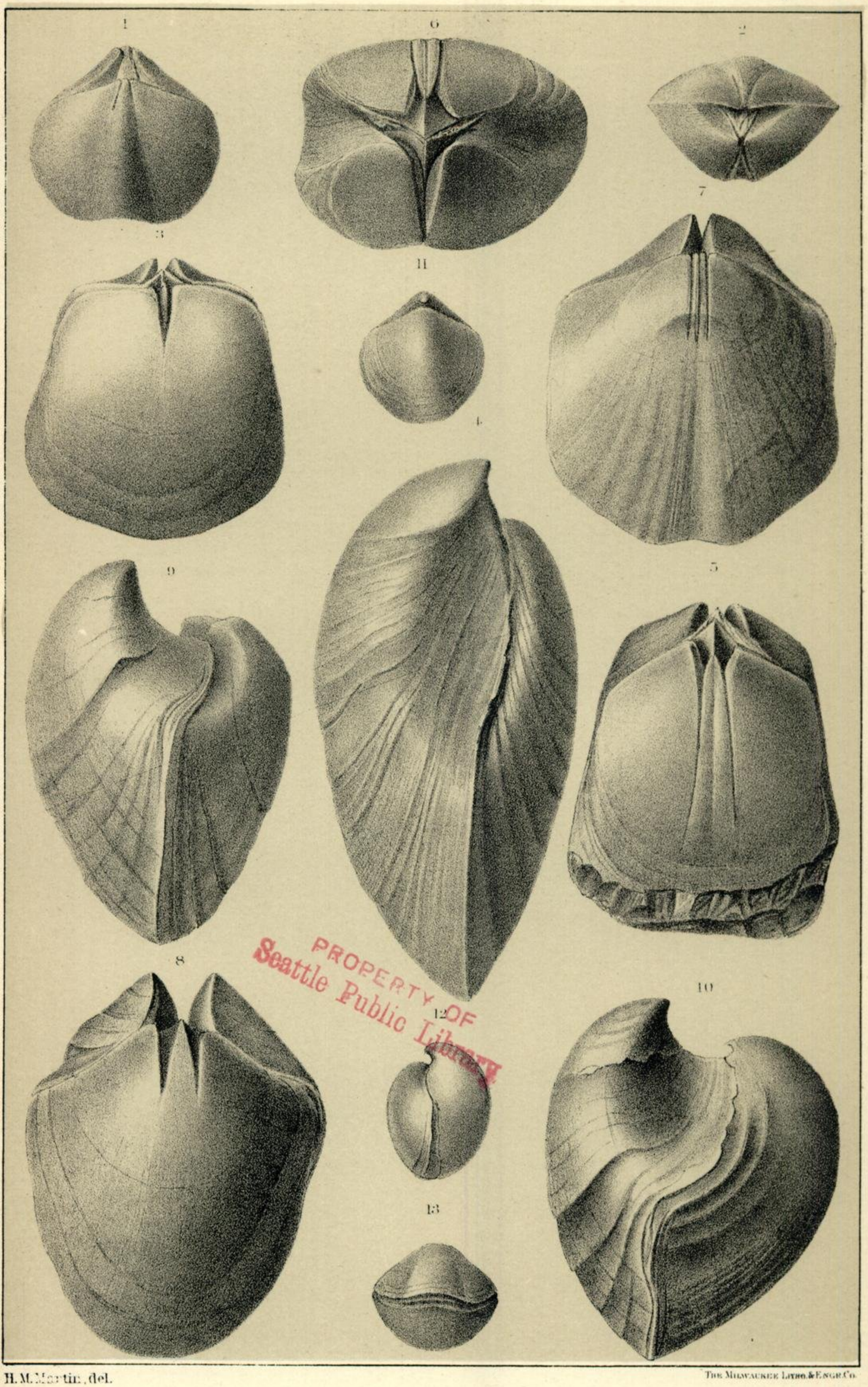

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PLATE 18.

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LEPTODOMUS UNDULATUS — W. 293

Fig. 1. View of a right valve of the species.
2. Anterior profile showing the convexity.

LEPTODOMUS NEGLECTUS — McChesney's sp. 292

Fig. 3. View of a right valve, showing the surface striæ on portions.
4. Anterior profile of the same individual.

EUOMPHALUS MACROLINEATUS — W 294

Fig. 5. View of a specimen preserving the inner volutions only, as obtained by a gutta-percha impression.
6. View of another fragment showing part of the outer volution, also obtained from an impression.

PLEUROTOMARIA RACINENSIS — W 296

Fig. 7 and 8. View of the aperture and summit view of a specimen of the species.

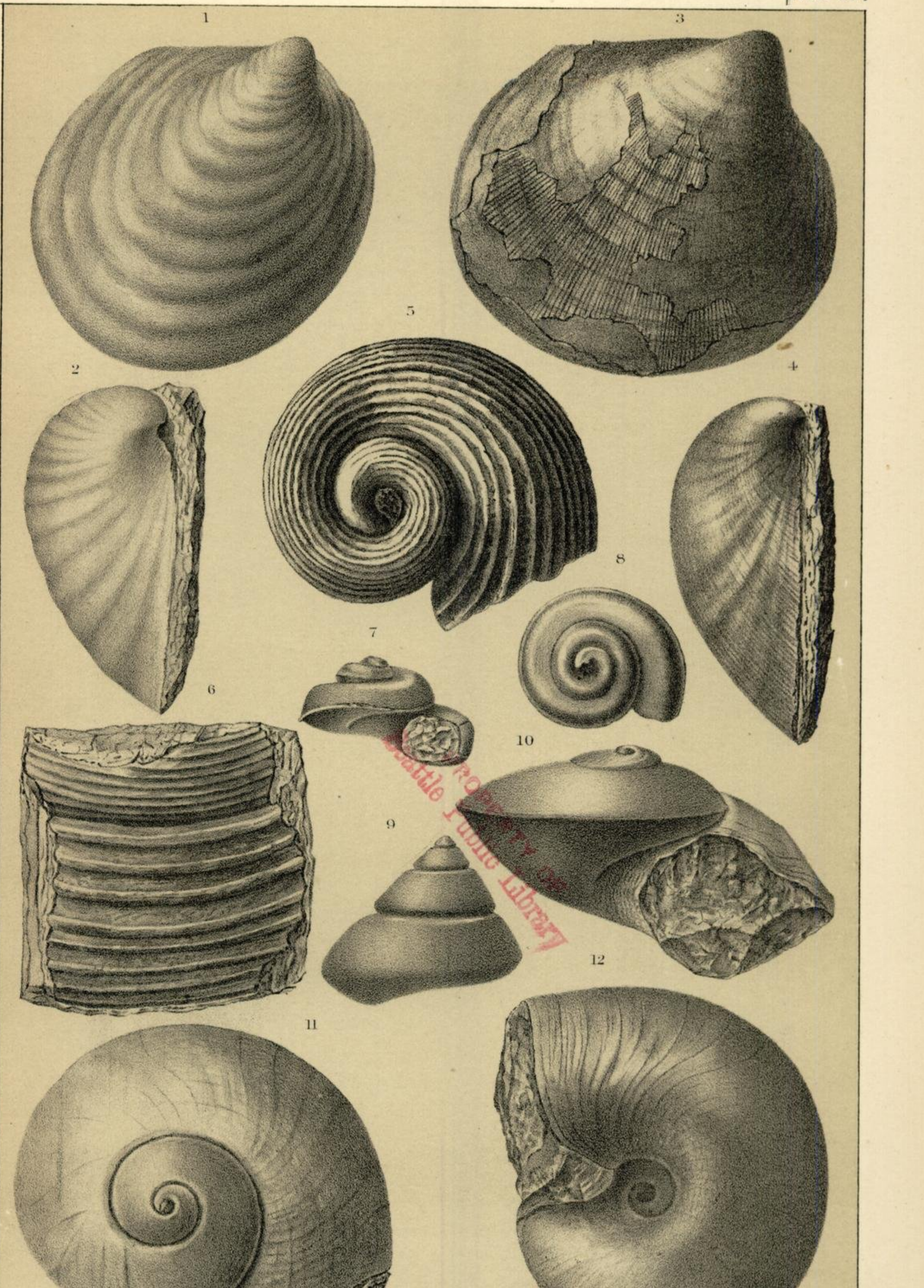
PLEUROTOMARIA LAPHAMI — W. 296

Fig. 9. Lateral view of a cast of the species. Others have been noticed of much larger size.

RAPHISTOMA NIAGARENSIS — W. 295

Fig. 10. View of the aperture of the type.
11 and 12. Summit and basal views of the same specimen.

Silurian (Niagara Group.) Plate 18.



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ORTHOCERAS ANNULATUM — Sow 298

Fig. 1. View of a fragment of a medium sized individual, showing the general form and portions of the shell. Wauwatosa.

ORTHOCERAS WAUWATOSENSE — W 297

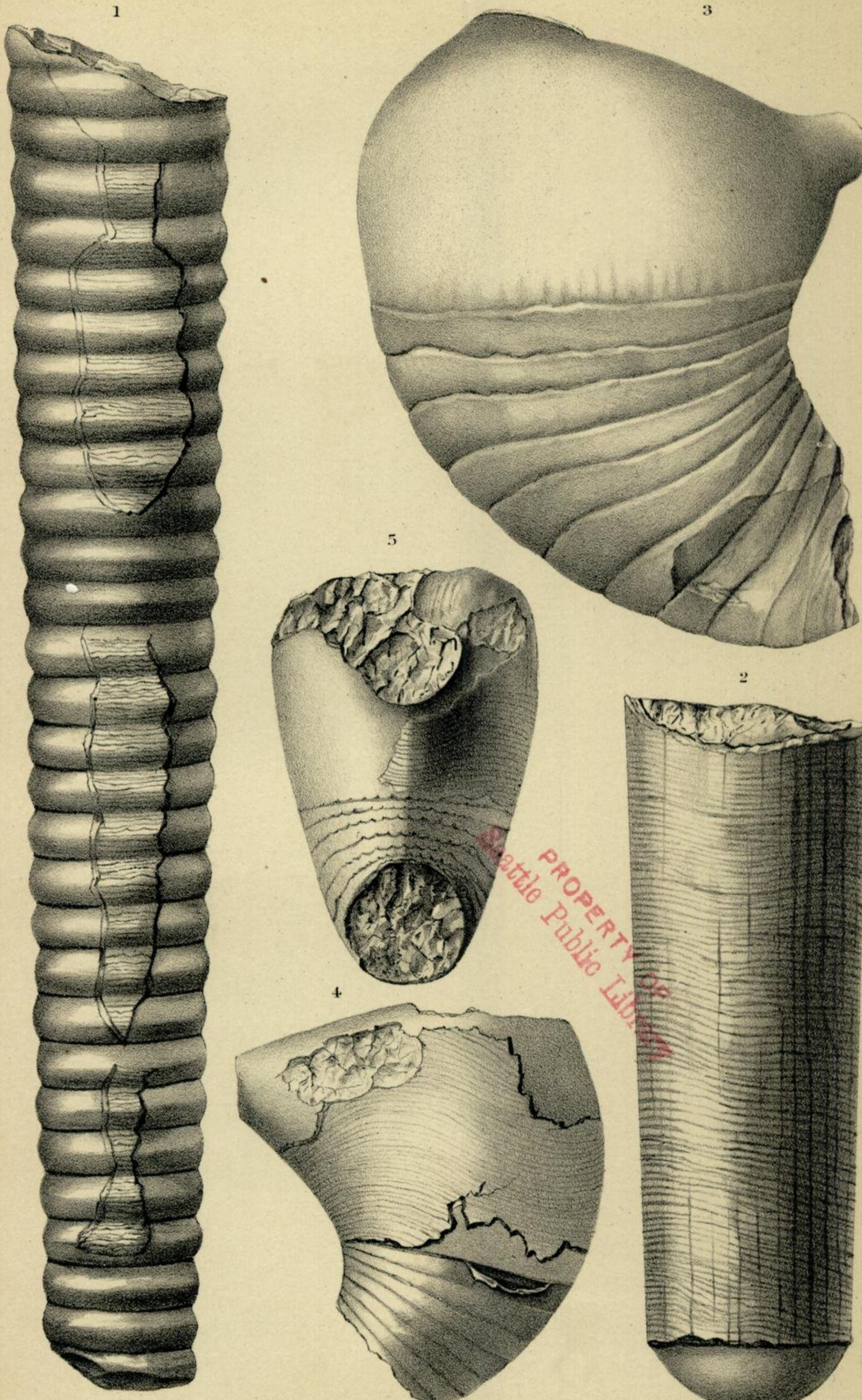
Fig. 2. View of a fragment preserving the shell, and surface features, also showing the convexity of the septa.

PHRAGMOCERAS NESTOR — Hall 301

Fig. 3. Lateral view of a compressed specimen, showing the general form. Waukesha.

PHRAGMOCERAS HOYI — W 300

Fig. 4. Lateral view of the specimen used in description.
5. Inner profile view showing the thickness of the specimen. Near Wauwatosa.



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PHRAGMOCERAS LABIATUM — W. 302

Fig. 1. Lateral view of the outer chamber, showing the junction of the lip with the body portion.

2. View of the summit of the same, showing the lobation of the aperture.

PHRAGMOCERAS HOYI, var. COMPRESSUM — W. 301

Fig. 3. Lateral view of the specimen described.

CYRTOCERAS INFUNDIBULUM — W. 300

Fig. 4 and 5. Dorsal and ventral views of the specimen described, showing the expansion and curvature of the shell, and the surface marking.

DISCOCERAS CONOIDES— Hall 299

Fig. 6. View of a Gomphoceras-like cephalopod containing the D. conoides within in the position of a siphuncle.

LITUITES MULTICOSTATUS — W. 303

Fig. 7. View of the specimen described.

ILLÆNUS MADISONIANUS — W 307

Fig. 8. Dorsal view of one of the larger individuals, showing the general form and proportions.

9. Lateral view of the same, showing the elevation.

ILLÆNUS PTEROCEPHALUS — W 309

Fig. 10. Front view of the head, showing the wing-like movable cheeks.

11. Upper view of the same, showing the cheeks very short and compressed.

12. Profile view, showing the rotundity and elevation of the head.

Silurian (Niagara limestone.) Plate 20.

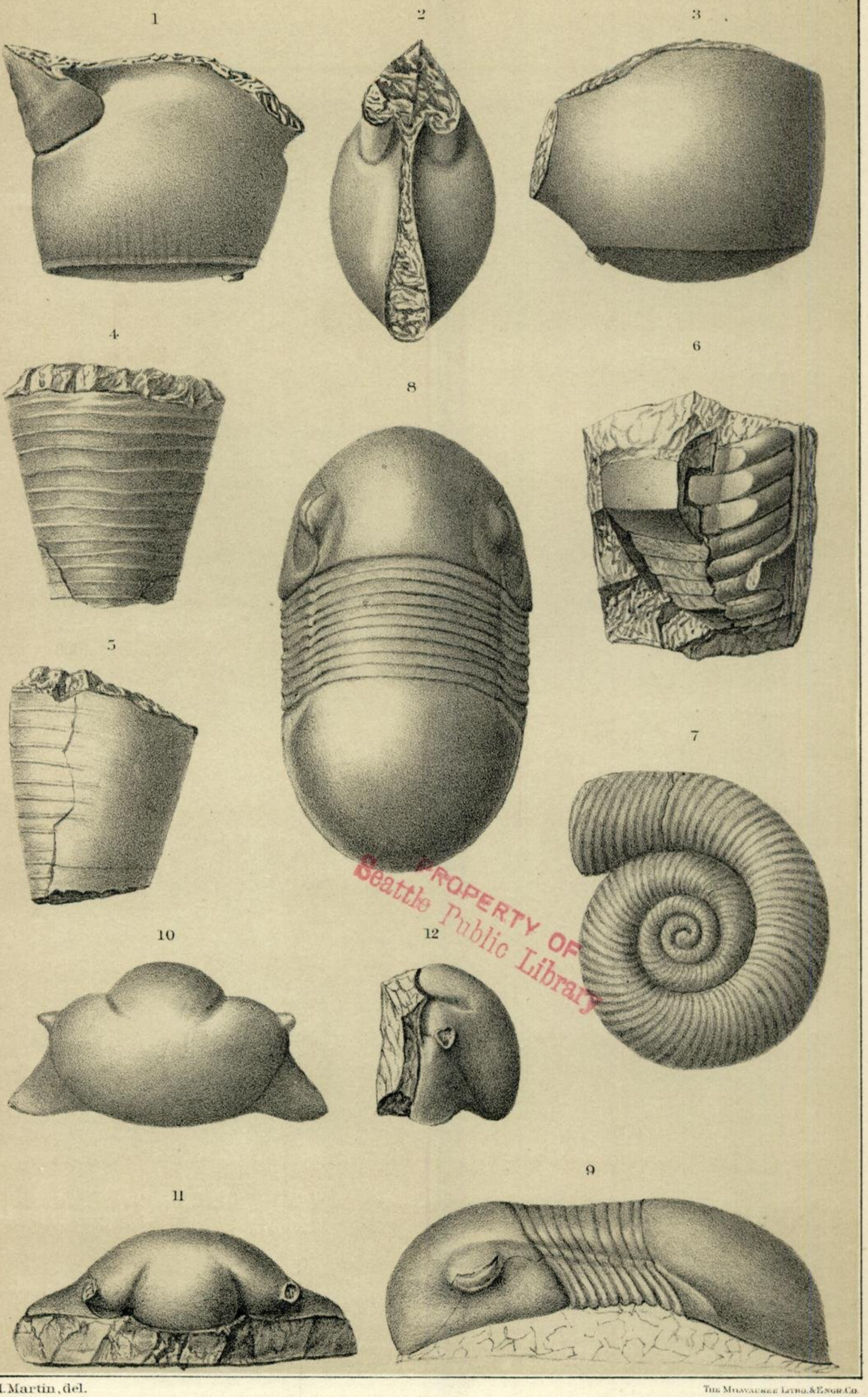

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PLATE 21.

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SPHÆREXOCHUS ROMINGERI — Hall 321

Fig. 1 and 2. Dorsal and profile views of a specimen, preserving the glabella and fixed cheeks.
3. Front view of the same, showing the downward bending of the frontal margin. Racine.

ILLÆNUS IMPERATOR — Hall 306

Fig. 4. View of a small head, denuded of the fixed cheeks.
5. A pygidium of a smaller individual. Both specimens are from Burlington, Wis.

ILLÆNUS INSIGNIS — Hall 305

Fig. 6. Upper view of a large head, showing the prominent eyes.
7. Profile view of the same, showing the great elevation.
8. Upper view of a small pygidium.
9 and 10. Upper and profile views of a large pygidium associated in the same block with the head. The specimens are from Wauwatosa, Wis.

ILLÆNUS IOXUS — Hall 304

Fig. 11 and 12. Front and profile views of a specimen somewhat above the medium size. Fig. 11 shows, below the base, the depression of the under infolded border of the head. Wauwatosa.

Wisconsin Geological Survey.

Silurian (Niagara limestone.) Plate 21.

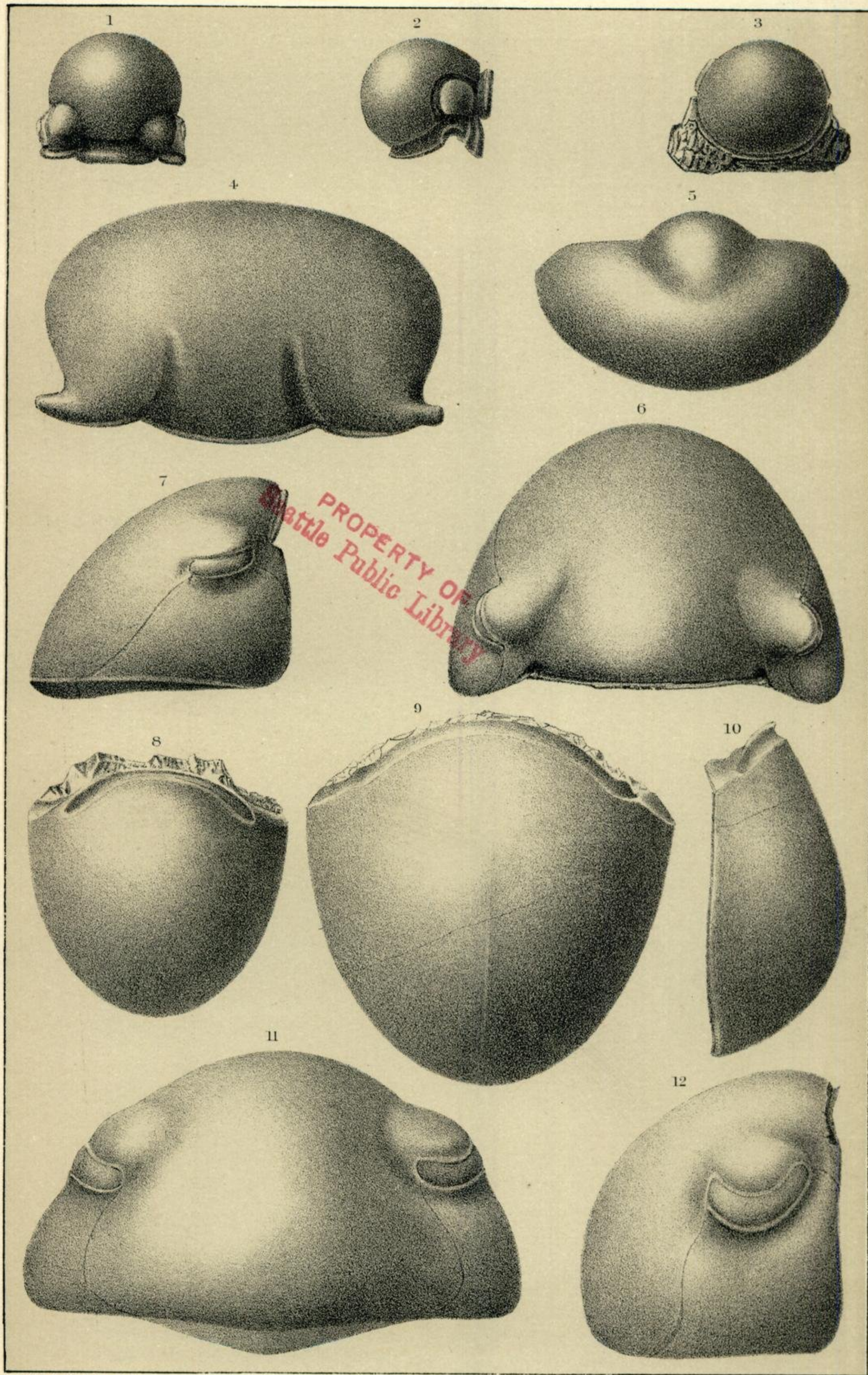

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PLATE 22.

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BRONTEUS LAPHAMI 310

Fig. 1. A fragment of a glabella, representing only the middle of the head.
2. View of a small pygidium, showing the posterior margin entire, but imperfect at the upper lateral angles.
3. View of a large imperfect pygidium, preserving the entire upper portion of the shield; the lower part restored from other specimens.
4. Outline profile of the specimen, fig. 3.

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Silurian (Niagara limestone.) Plate 22.

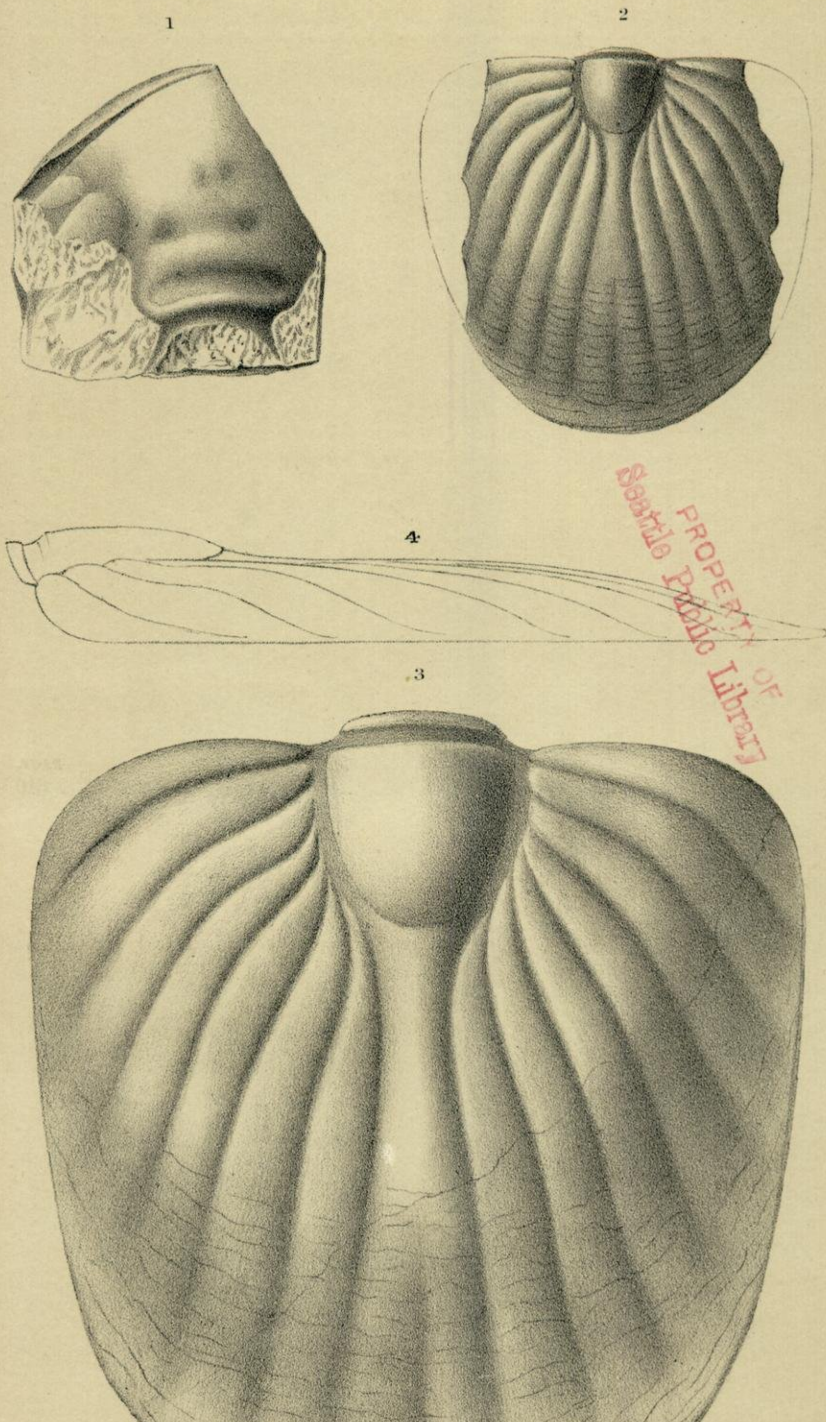

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PLATE 23.

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Pentamerus occidentalis — Hall 314

Fig. 1 and 2. Ventral and profile views of a ventral valve from the Mayville beds at Williamstown, Wis., showing the strongly plicated surface.

Stricklandinia multilirata — W.......................... 315

Fig. 3 and 4. Ventral and cardinal views of an internal cast, retaining both valves, the dorsal slightly pushed backward from its true position. The latter view shows the cavities of the processes of the dorsal and that of the spoon-shaped process of the ventral valve.

5. View of a dorsal valve showing indications of the muscular imprints.

Favosites occidens — W.................................... 313

Fig. 6. Lateral view of a specimen showing transverse diaphragms.

7. View looking upon the surface, and showing the two forms of cells. The figure is of a part of a larger specimen from Ozaukee, Wis.

Amplexus annulatus — W.................................... 314

Fig. 8 and 9. Lateral and summit view of a fragment of the species, showing the annulations in one and the size of the diaphragm in the other.

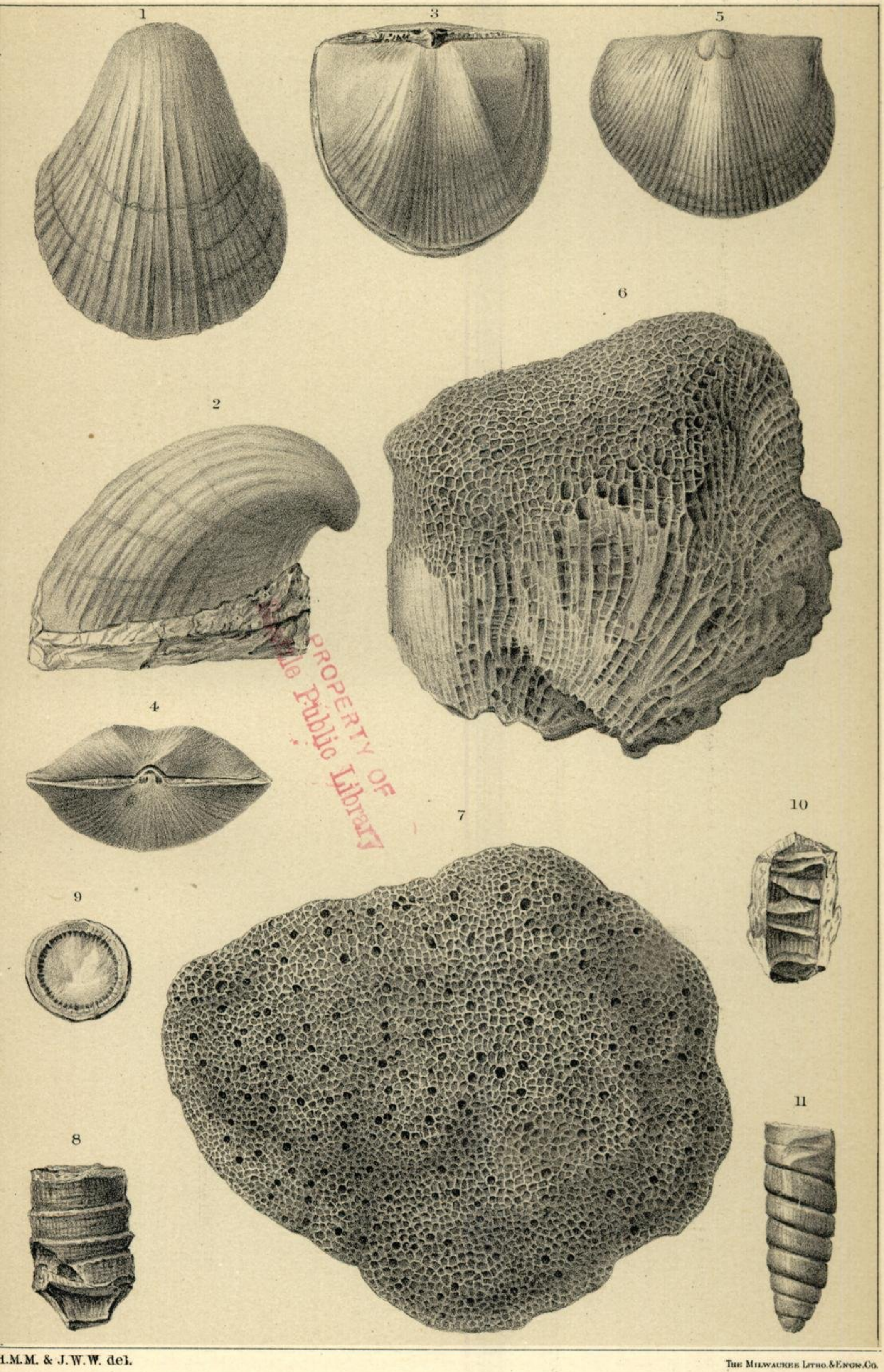
10. Longitudinal section of a fragment showing the diaphragms.

11. View of the exterior of a small, regularly annulated specimen, as obtained by a gutta-percha cast in a natural mould, left by the removal of the fossils by decay. Carlton.

Wisconsin Geological Survey.

(Guelph limestone.)

Silurian | Plate 23.



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LOXONEMA MAGNA — W. 317

Fig. 1. View of the specimen described.

HOLOPEA MAGNIVENTRA — W 316

Fig. 2 and 3. Lateral and basal views of a specimen showing the general form.

MURCHISONIA CHAMBERLINI — W 317

Fig. 4. Lateral view of a specimen as obtained from a plaster cast made in the natural mould in the rock.

ORTHOCERAS CARLTONENSIS — W. 318

Fig. 5. View of a small specimen showing the distant flutings, and the lines marking the septa.

CYRTOCERAS RECTUM — W 319

Fig. 6 and 7. View of the inner side and a profile view of a specimen. The latter figure shows the curvature of the shell.

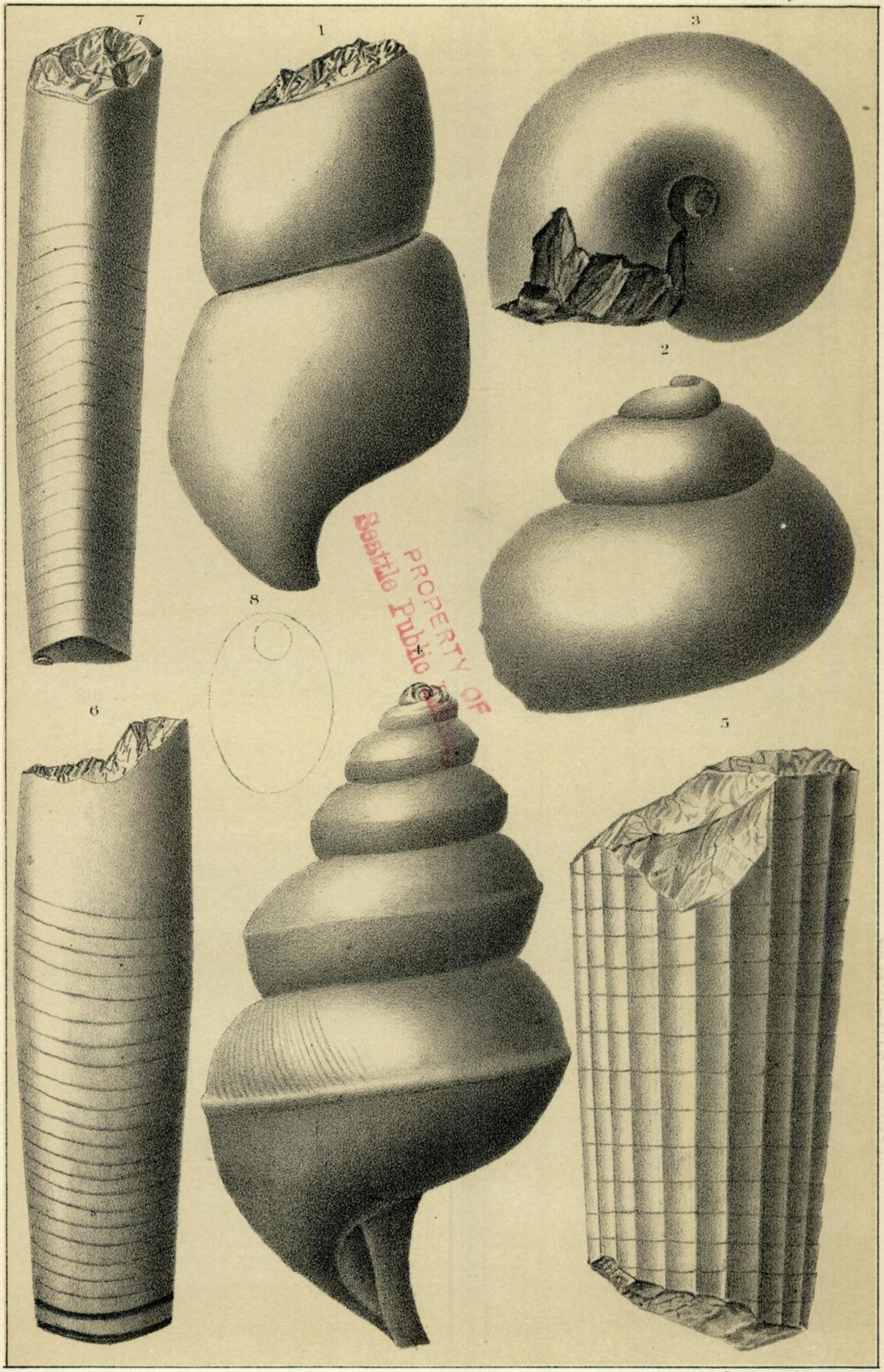
8. Outline figure of the section at the point of greatest diameter, where the sides are nearly regularly and less angular than below.

Wisconsin Geological Survey.

(Guelph limestone.)

Silurian

Plate 24.



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ORTHIS OBLATA — Hall 320

Fig. 1. View of a ventral valve, natural size, obtained by gutta-percha impression in the natural mould.
2. View of a dorsal valve, obtained in the same manner as fig. 1.

ORTHIS SUBCARINATA — Hall.. 320

Fig. 3. Cast of a ventral valve, twice enlarged.
4. View of a dorsal valve, twice enlarged, from gutta-percha cast.

MERISTELLA NUCLEOLATA — Hall 321

Fig. 5. View of a ventral valve, from a gutta-percha cast.

PTERINEA AVICULOIDEA — Hall 322

Fig. 6 and 7. Views of a left and right valve of specimens of medium obliquity among those in the collection.

LEPERDITIA ALTA — Conrad.. 323

Fig. 8. View of a left valve, twice enlarged.
9. View of a small block containing many worn specimens.

LINGULA PALÆAFORMIS — Hall.. 324

Fig. 10. View of a dorsal with part of the ventral valve.

DISCINA MARGINALIS — Whitf.. 325

Fig. 11. View of ventral valve, the shell partly removed, showing dorsal valve beneath.

STROPHODONTA INEQUISTRIATA — Conrad.....................

Strophodonta inequistriata (Con.) Hall; Pal. N. Y. Vol. IV, p. 106, pl. 18, fig. 2.

Fig. 12. View of an internal cast of this species; natural size.

ORTHIS IMPRESSA — Hall 326

Fig. 13. View of a cast of a ventral valve showing the muscular imprint.
14. Cast of a large dorsal valve.
15. Cardinal view of a still larger internal cast, showing the convexity of the dorsal valve.

CHONETES CORONATA — Conrad sp.. 327

Fig. 16. View of the imperfect impression, as obtained by a gutta-percha cast in the natural mould.

CHONETES DEFLECTA — Hall ....

Chonetes deflecta — Hall; Pal. N. Y. Vol. IV, p. 126, pl. 21, figs. 7 and 8.

Fig. 17. Cast of a dorsal valve, twice enlarged, showing the features of this species.

STROPHODONTA DEMISSA — Conrad sp.. 327

Fig. 18. Impression of a dorsal valve, showing the characteristic striæ.

CYRTINA HAMILTONENSIS, var. recta — Hall..............................

Cyrtina Hamiltonensis, var. recta — Hall; Pal. N. Y. Vol. IV, p. 268, pl. 44, figs. 34–37.

Fig. 19–21. Dorsal, ventral and cardinal views of an internal cast of a specimen of this variety, twice enlarged.

SPIRIFER EURUTINES, var. FORNACULA — Hall.......................... 330

Fig. 22. View of the dorsal valve referred to this species.

SPIRIFERINA? ZICZAC — Hall sp 332

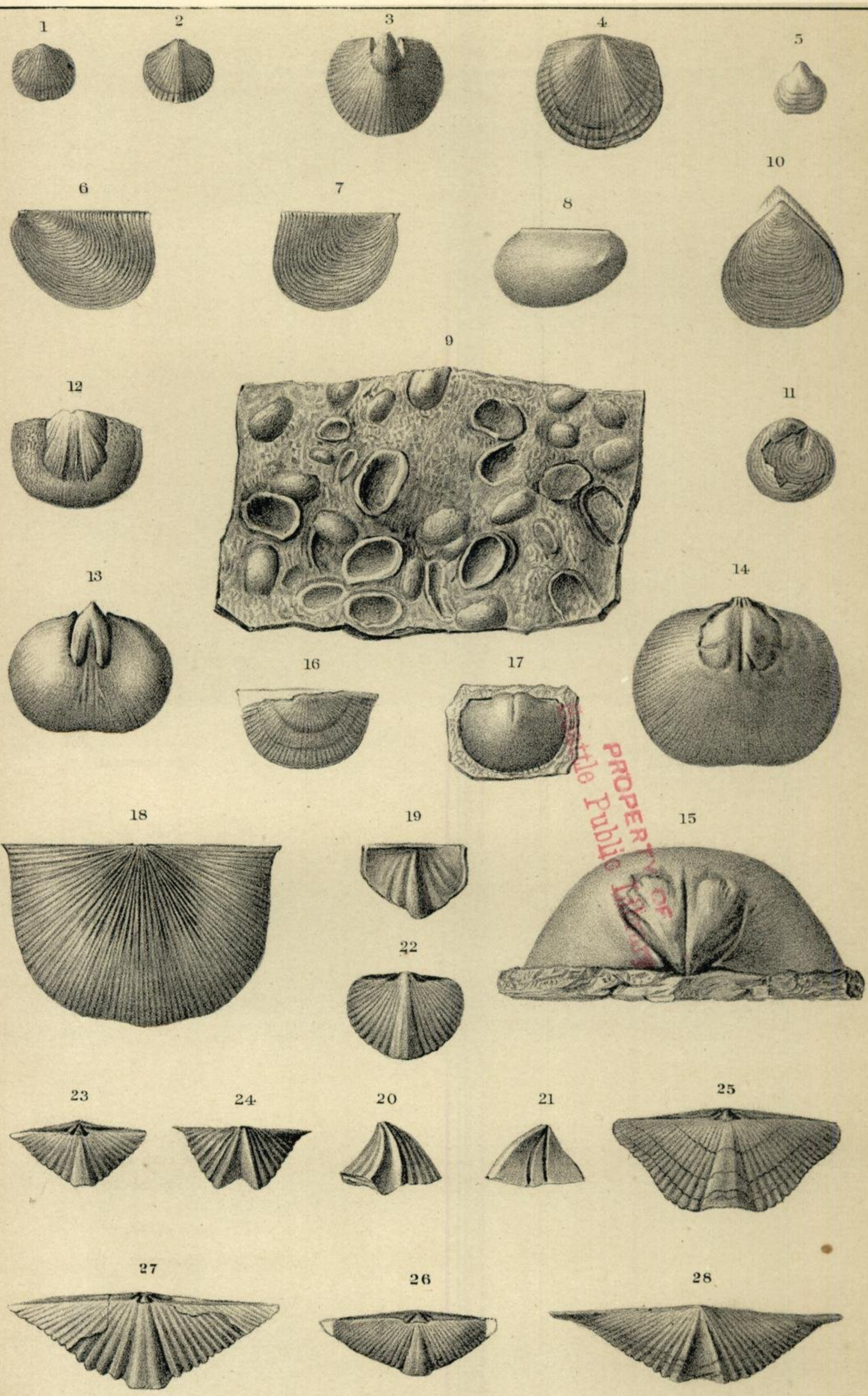
Fig. 23 and 24. Views of a dorsal and ventral valve of this species.

SPIRIFERA AUDACULA — Conrad.. 329

Fig. 25. View of a dorsal valve of the ordinary form, as seen among the New York specimens.
26. View of a smaller and more elongate dorsal valve, quite common among the New York specimens.

SPIRIFERA MUCRONATA — Conrad 328

Fig. 27. An imperfect dorsal valve of the shorter form.
28. View of a ventral valve of the more extended form. Both forms are common in New York. The former in the soft shales and the other in the arenaceous beds of Eastern New York.



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SPIRIFERA (CYRTINA) ASPERA — Hall 331

Fig. 1. View of the front of the ventral valve of an internal cast.
2. Cardinal view of the same specimen.

SPIRIFERA ANGUSTA — Hall.................................... 329

Fig. 3. View of an imperfect ventral valve of this species.

SPIRIFERA PENNATAS — Owen 330

Fig. 4. View of a ventral valve, slightly restored on the front margin.

ATRYPA HYSTRIX — Hall..................................... 333

Fig. 5. View of a ventral valve as obtained by a gutta-percha cast.

ATRYPA RETICULARIS — Linn 333

Fig. 6. View of a dorsal valve.

ATRYPA SPINOSA — Hall 333

Fig. 7 and 8. Views of a dorsal and ventral valve referred to this species.

LEIORHYNCHUS KELLOGGI — Hall................................ 334

Fig. 9. View of a dorsal valve of this species.

MODIOMORPHA CONCENTRICA — Con. sp 335

Fig. 10. View of a left valve of a small sized specimen.

PALÆANEILO EMARGINATA — Con. sp......... 337

Fig. 11. View showing the impression of a right valve in the rock.

PALÆANEILO NUCULIFORMIS — Stevens......................... 336

Fig. 12. A cast of the right valve showing the form, and also the teeth on part of the hinge.

PALÆANEILO CONSTRICTA — Con. sp...................................... 335

Fig. 13 and 14. A left valve of the elongate form and a right one of the shorter form, both common in New York.

GOMPHOCERAS BREVIPOSTICUM — Whitf 339

Fig. 15. View of the specimen described, showing the septa in the lower part, and indications of the siphuncle. The sinus of the lip is seen on the right side of the figure.

GOMPHOCERAS FUSIFORME — Whitf........ 338

Fig. 16. View of a specimen showing the general form, and indications of septa, also the sinus in the lip.

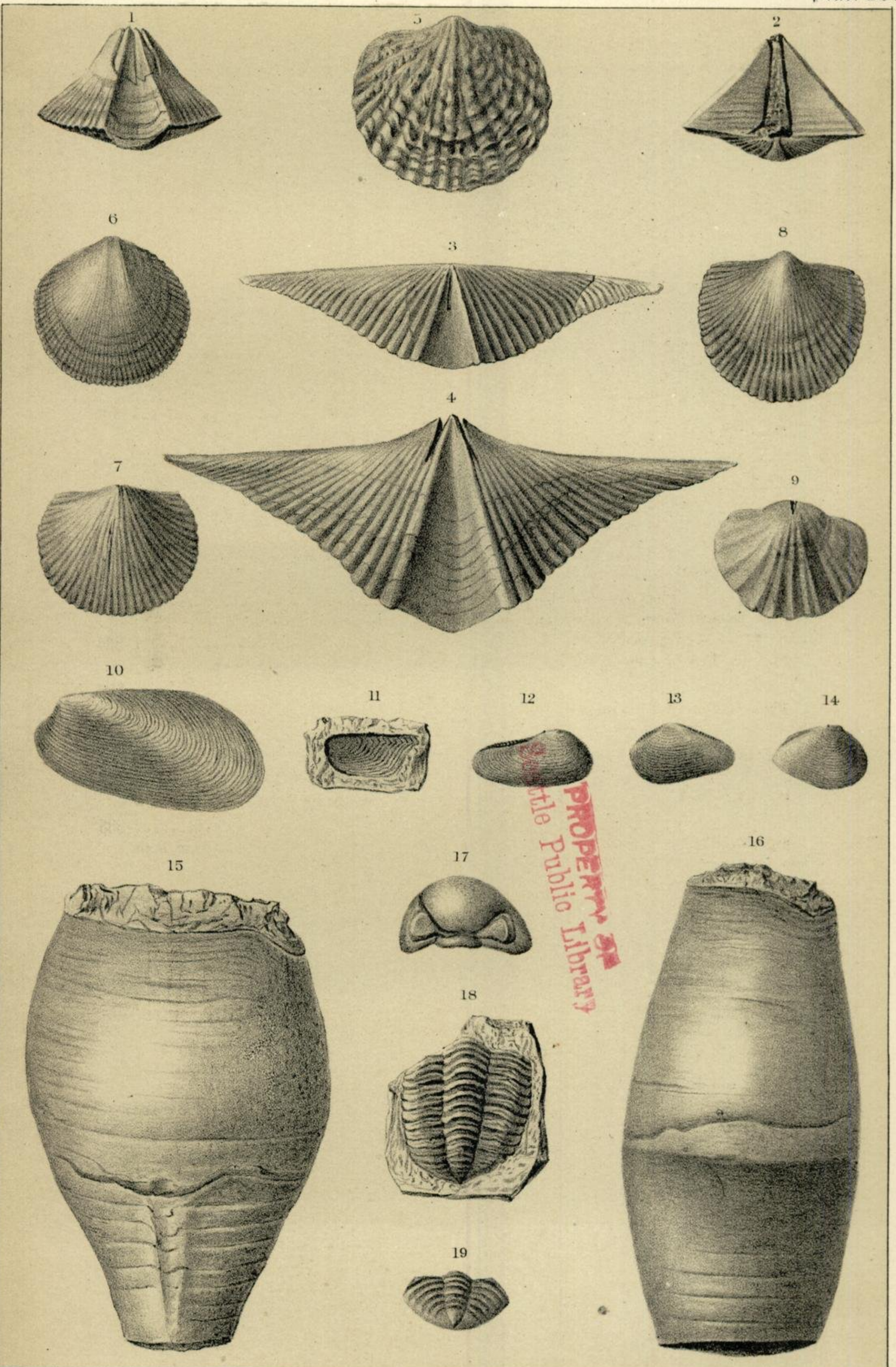
PHACOPS RANA — Green 339

Fig. 17. View of an internal cast of a head of the species.
18. View of the thorax and pygidium
19. View of a separated pygidium.

(Hamilton Group.)

Devonian

Plate 26.



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LINGULA ELDERI — Whitf.... 345

Fig. 1. View of the exterior of a dorsal valve, from a gutta-percha cast in the natural mould.
2. Profile view of a cast retaining both valves.
3. Dorsal view of a cast, natural size.
4. Enlargement of the same. a, a, anterior adductor muscular scars; d, scar of divaricator muscle; ad, adjustor muscle scars; ad, posterior adductor muscle scars; ps, track of pallial sinuses. 1, inner ramifications or branches of same; 2, posterior branches of same.
5. Ventral side of a cast enlarged; ca, scars of central adjustor muscles; p, ad, and aa, posterior adjustors and anterior adductors combined; pa, posterior adductors and external adjustors combined; d, position of divaricator muscle.

LINGULELLA STONEANA — n. sp 344

Fig. 6. View of a specimen, natural size.
7. The same enlarged.

DINOBOLUS PARVUS — n. sp 347

Fig. 8. Dorsal side of the specimen described.
9. Ventral side.
10. Profile view, enlarged, showing the bending upward of the cardinal process.

HOLOPEA OBESA — n. sp 348

Fig. 11. Back view of the specimen, natural size, but somewhat restored on the surface.

DIKELLOCEPHALUS LODENSIS — Whitf.................... 188 and 341

Fig. 12. View of a specimen preserving the left cheek, the thorax and pygidium nearly in position.
13. View of a glabella and fixed cheeks, presumed to be of the same species.

DIKELLOCEPHALUS CRASSIMARGINATUS — n. sp 344

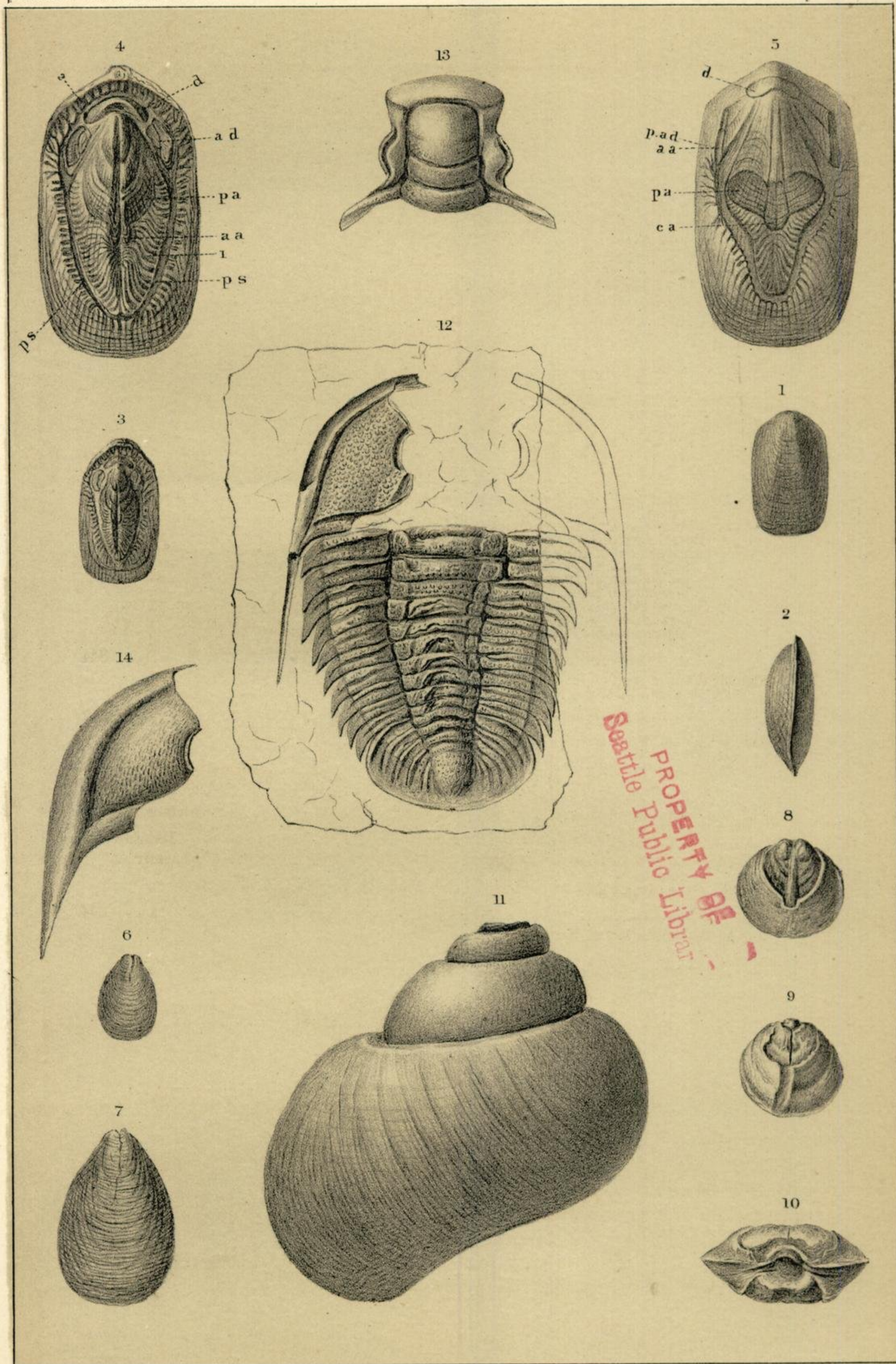
Fig. 14. View of a left movable cheek of this species.

Wisconsin Geological Survey.

(Potsdam & Trenton.)

Primordial & Silurian

Plate 27.



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