Vermilion district, Minnesota, with Clements, Grant + Leith: [specimens] 29411-29461. No. 319 Summer of 1899

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U. S. GEOLOGICAL SURVEY

FIELD SECTION BOOK

9-891

LAKE SUPERIOR DIVISION.

INSTRUCTIONS.

1. Ordinarily at least two pages of this book will be devoted to one section. On the left-hand page, place a map of as much of the section as has *actually been seen*. Denote rivers, lakes, marshes, etc., by the usual topographical signs. Denote the ledges of rock, when no structure is made out, by cross-hatching, making the cross-hatching cover as nearly as possible the areas occupied by the exposures. If the rock is a massive one, but still more or less plainly bedded, use the same sign with a dip arrow and number attached, showing the direction and amount of the dip. Denote a shaly or other very plainly bedded ledge by right parallel lines, and a ledge having a secondary structure by wavy parallel lines running in the direction of the strike, with dip arrow and number attached as before. The greatest care must be taken to avoid confusing slaty or schistose structure with bedding, and in all cases where there is the least doubt about the true bedding direction, indicate it by a query. To each exposure on the face of the map attach the number of the specimen representing it. In mapping the section count each of the spaces between the blue lines as 100 paces, and twenty of these spaces to one mile, or 2,000 paces. Usually the southeast corner will be placed at the bottom of the page, or at the first black line above the bottom of the page, and at the right-hand side. If, however, for any reason, it is desirable to show portions of an adjoining section, the southeast corner may be shifted up, or the map may be turned around and the north placed at the left-hand side of the page. The ruling of the left-hand pages is also arranged so that, if desirable, a larger or a smaller scale can be used, eight inches, two inches, one inch, or one-half inch to the mile. With the two-inch scale, the squares outlined in black represent sections, and those in red, quarter sections and "forties," while the space between the blue lines is 200 paces.

2. On the right-hand page place the notes descriptive of the exposures. Begin in each case with the number of the specimen, placing the number on the left-hand side of the red line, after which give in order on the right of the same red line the position of the ledges as reckoned in paces from the southeast corner of the section and the dip and strike when observable, the latter always being expressed from the north; for instance 4025, 250 *N.*, 300 *W.*, *Strike*, *N.* 78° *E.*, *Dip* 50° *S.* Then follow with a full description of the ledge. When topographical maps are used for locations this paragraph applies only in part.

3. Collect a specimen from every ledge, or wherever there is a change of rock on any one ledge, taking care to get fresh material, unless for a special purpose the weathered surface is desired. In case of trips made on foot or in canoes, for long distances, neighboring ledges, unquestionably of one kind of rock, need not be specimened. The position and extent of the ledges not specimened should be marked on the map, with notes that each is of a rock identical with specimen so-and-so. Under the same conditions small-sized specimens, trimmed to a uniform size of 2 x 2½ x ¾ inches will be allowed, but in all other cases *large-sized specimens*, trimmed to a size of 3 x 4 x 1 inches, must be selected, in accordance with section 3, chapter IV, p. 44, Regulations of the U. S. Geological Survey. Specimens should not be placed together without protection in the collecting bag, as the fresh surfaces, important in determining the character of rocks, are thus destroyed. They should be damaged by no temporary mark, but the numbers should be at once marked in at least two places upon the inclosing paper or cloth bags. Specimens may be permanently marked in camp by painting the numbers upon them in white upon a black background, using Silver White and Ivory Black oil tubes for color, with turpentine as a diluent.

4. On the last twenty-five pages of the book give, as may seem desirable, a general account of the examination of the region mapped in the previous pages, correlation of observations, sketches, cross sections, etc.

5. Forward this note book as soon as filled as registered mail matter to C. R. Van Hise, U. S. Geologist, Madison, Wis.

6—747

Sp. 29411-29461

Summer of 1899.

Vermilion district, Minn.,
with Clements, Grant, &
Leith.

Notebook 319

August 29th.

With Grant went from Snowbank lake, via Round lake, to Disappointment lake.

Near the portage out of Round lake (N. E. side of lake) found beautifully banded mica schist, the softer layers of which had weathered out leaving the harder layers in protruding ridges. This mica schist is cut by granite in dikes diagonal to the lamination. One dike is distinctly red, the other broader one is pinkish gray.

At end of portage on Disappointment lake the same schist is seen.

Following N. shore of Disappointment lake E. to the large projecting point, we find the rock to become more and more coarsely conglomeratic. Constituting this big point is a conglomeratic rock, the matrix of which contains both biotite and hornblende rather abundantly, and which contains innumerable pebbles and boulders of hornblendic rock, and many of them porphyritic and close to granite porphyry or microgranite and apparently an intermediate rock. Conglomerate not closely examined to ascertain full range of pebbles. On the weathered surface the pebbles generally dissolve faster than the matrix making numerous roundish depressions. The rock has not been strongly mashed, for, while the pebbles have their longer dikes in the planes of schistosity, one could not say the lesser dimension in the other direction is not explained by the original shingling action of the pebbles. The rock is very irregularly veined by quartz and by quartz and feldspar, and possibly by some granitic veins. All these factors give the rock a very rough, knotty, appearance on the weathered surface. When fractured, however, the rocks breaks cleanly through matric and pebbles alike, the pebbles having very clear cut outlines.

Passing S. from this point, S. of some small islands to the main shore near an old claim cabin; at the shore is a dense granular gray rock which has a distinct rift but no well devel-

M.S.

29411 oped cleavage, - spec. 29411. While at first sight the rock appears to be massive, when closely examined it is seen to be in bands varying considerably in coarseness and having the appearance of bedding. At the shore these bands dip S. 40° to 45° . A few paces in from the shore the rock assumes a conglomeratic aspect and in places has developed within it large

met. sw. by Gabbro?

29412 patches of biotite, - spec. 29412.
In farther from the shore the con-
glomeratic aspect is perfectly dis-
tinct, the pebbles being well rounded,
clean cut and, like those on the
point to the N., little mashed. Across
a little valley to the S., immediately
under a hill containing rock next to
be described, the rock is especially
massive appearing and here might be
mistaken, if the banding were ignored,
29413 for an igneous rock, - spec. 29413.
In mineral content, banding and con-
glomeratic character, this rock is so
closely allied to the mica schist and
conglomeratic schist to the N. and W.
that there can be little doubt that
all are parts of the same formation.
On the hill just spoken of are remark-
able, banded, quartzose, and magnetite-
bearing rocks well banded and dipping
steeply to the S. 60° to 70° . The
bands rich in quartz and those rich
in magnetite vary in width, are in-
terlaminated; and also there are pres-
ent various admixtures of the two.
Besides the quartz and magnetite, es-
pecially in the magnetitic varieties,
one sees very large individuals with
well developed cleavage, each in-
closing sundry individuals of quartz
and magnetite. Grant says this miner-
al is amphibole or pyroxene. A green

mineral also seems to be present which Grant thinks is olivine.

29414 A quartz-magnetite band carrying big cleavable crystals with parallel orientation, cleavage of which controls rift at right angles to bedding of rock and approximately at right angles to each other, - probably regular unit prism pyroxene cleavage.

29415 Quartzose band, greater dimension across bedding. Also shows apparent orientation of mineral particles.

29416 Magnetite-bearing material containing much of a green material showing no cleavage, - probably olivine.

A short distance over crest of hill to the S. the banded rock again occurs in places and here has a vertical dip. Going perhaps 100 steps further S. gabbro is found which contains a distinct inclusion of the gray rock along the shore and a very large mass probably an inclusion.

Grant attributes the exceptional features of the metamorphism of the gray granular micaceous rock and of the quartz-magnetite rock to the contact effect of the gabbro.

If this is true, and the explanation seems to me reasonable, we have a very interesting case of the development of a rock with a texture closely approximating an igneous texture by metamorphism. I have before held that such a texture can develop by metamorphism only under static conditions, with a possible exception of marble which is exceedingly mobile. Since the intrusion (or possible extrusion) of the gabbro there have been no important orogenic movements, and thus the case corresponds with this idea. The gray rock is the best case I know of of a heterogeneous sediment developing into a rock, the texture of which is analogous, in massiveness at least, to that of an igneous rock. However the profound metamorphism has left the delicate banding of the rock almost intact as well as the pebbles it contains; in these respects contrasting sharply with recrystallization under dynamic conditions. The bands of different materials and the pebbles are not quite clean cut, the newly developed crystals frequently running across the contacts, which results in a little vagueness at the borders.

We next visited the island to the N. and found the rock to be conglomerate intermediate in character and in fineness between the conglomerate in the peninsula to the N. and to the gray rock on the main land to the S. Skirting the S. shore, as we went W. to portage again, we found the rock to be a micaceous graywacke very distinctly showing banding and having a marked parallel orientation of the mica. Moreover, this arrangement giving cleavage seemed to be quite
29417 parallel to bedding. Spec. 29417.

Crossing portage into Round lake again, at the portage the rock is a
29418 distinct mica schist, spec. 29418, again with cleavage parallel to bedding, which as noted on going out is very decided and clear. This mica schist is to a remarkable degree like the mica schist at the upper part of the upper slate member at English lake near Penokee gap. The most crystalline part of this upper slate member runs from Penokee gap W. and here the basal member of the Keweenawan is again a great gabbro mass. The lower members of the upper slate at

Penokee gap, although at lower horizons and therefore presumably more deeply buried and moreover containing intrusions of diabase or diorite, is a comparatively little metamorphosed black slate. Grant's explanation to the Disappointment lake rocks is equally if not more applicable at English lake.

At a point only a few miles W. of the Montreal river again at the top of the upper slate member and near the gabbro the rock is a gray,coarse, strongly micaceous graywacke, the only recognizable clastic material being the coarse quartz and feldspar.

In Michigan, E. of the Montreal river, the bottom members of the Keweenawan are comparitively thin bedded diabase, and amygdaloids, and here the top layers of the upper slate are ordinary,little metamorphosed, black slates.

Some distance W. of Penokee gap erosion has cut down so that the gabbro comes in contact with, if indeed it does not cut across, the iron formation and the lower members of the Penokee to the Archean. Here the iron formation has an exceptional character, being a green dense actinotite, magnetite quartz rock, there being here no chert nor jasper. It thus approaches the quartz magnetite rock of Disappointment lake. In the W. end of the Penokee-Gogebic range, i. e. in the parts where the gabbro approaches close to or is incontact with the iron formation, no iron ore, nor indeed even an approach to an iron ore, has been found. On the Michigan end of the Gogebic range the Keweenewan as the result of erosion, is again upon the iron-bearing formation, a part of the formation itself even being removed by erosion. Yet at Sunday lake, directly under the diabases of the Keweenawan, are the Sunday lake and Brotherton mines.

As noted in Mon. 19 both E. and W. of the mines, for a few miles, the iron formation is actinolitic and magnetitic; no ore bodies have been found and here occur considerable masses of coarse, fresh diabase, presumably intrusive, which may be the correlation of the great gabbro.

Near the portage in passing out of Round lake to Snowbank lake a mica schist was found which is cut by granite dikes and has many granite dikes from those of a fraction of an inch across to those nearly a foot across parallel to the foliation, - spec.
29419 29419.

The rocks were examined at a number of points on the N, W. side of Snowbank lake. Here again is a beautiful instance of complex granitic injections in a mica schist. Many of the granite dikes,especially the small ones, follow the foliation, or nearly so, but many also, and especially the large ones, cut the foliation at various angles up to right angles, and this is the case with some of the small granite veins also, even to those a fraction of an inch across. The complicated injection relations of the granite to the mica schist is scarcely exceeded, so far as my experience goes, except in the case of the Manhattan schists of New York City and especially N. E. of New York City at a suburban place on Long Island Sound. At the sound the schists are even more coarsely crystalline and the parallel and cutting injections even more complex, so that the rock is a coarse banded injection gneiss, and yet the sedimentary part of it is certainly of upper Silurian age. At Snowbank lake this exceedingly crystalline rock probably belongs to the upper of the two sedimentary series. Both are remarkable cases of contact-dynamic metamorphism , if one chooses to pick out two of the main causes.

August 30th.

With Grant went from Snowbank to Flask and thence to Moose, thence to old camping ground on portage to Wind lake, making reconnaissance on the way. Close study made on return trip.

We reexamined the ledges of slate, graywacke and conglomerate containing jasper N. of Moose lake with special reference to the point as to whether there are here one or two conglomerates The observations fully confirm statements of previous day. No slate or jasper fragments were found in the sedimentary rocks, except contiguous to the interbanded jasper where they were much broken or contiguous to broken slate. The upper part of the evenly banded graywacke and slate contains no discoverable fragments of jasper and slate. The coarse conglomerate above the highest jasper band grades by interstratification into coarse graywacke and the graywacke by interstratification into the slate, which is identical in appearance with much of the Moose lake slate. No reason was discovered for placing more than one structural break between the Moose lake slates and the greenstone schist to the N.

The Moose lake slates were examined

at a number of points on the islands and shores; an important rock is a great fissile slate which in places is distinctly banded; at many places the banding is at various angles to the cleavage. At one place these bedding bands are directly transverse to the cleavage and therefore across the topographic ridges. At one place the banding and cleavage have a very close correspondence, although when examined closely there are the usual minute discrepances. At various places the rock is an extremely finely fissile sericitic schist showing no other structure than the cleavage. At one place this appeared to grade into a less mashed rock which took on the peculiar spotted appearance of some of the much mashed porphyries on the main land to the S. These rocks weather pinkish and yellowish rather than green, as do the unmistakable slates. On fresh fractures they are light gray rather than greenish black. On the large island N. of portage into Flask lake these rocks are very carbonateous, a part of the carbonate being iron carbonate as shown by the abundant laminite and hematite on the weathered surface. On the top of this island the rock is cut by a fresh diabase.

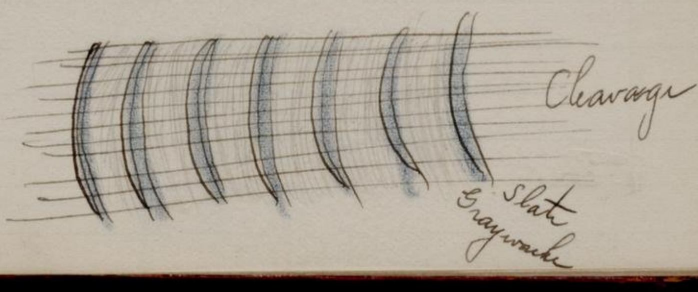
On the high point S. of jasper locality (Moose lake) extending E. into the bay, the rock is typical orbicular greenstone, the ridge being at least several hundred paces long. In the center of this mass the spheroids are little mashed and show their peculiar peripheral structure within the spheroids, but the rock has a more altered appearance than at Ely. On the sides of the ridge the spheroids are much flattened, the rock in places passing into a greenstone schist in which the spheroidal structure is obliterated. Between this green schist having its peculiar irregular textures and structures, and the typical orbicular greenstone of the core there are gradation varieties. The intermediate phases show a certain coarse banding which by a careless observer might be mistaken for sedimentation. The greenstone ridge breaks off abruptly and the low ground is presumably occupied by the Moose lake slates.

About 125 steps on trail from Moose to Flask lake a ridge of greenstone conglomerate is found, having a greenstone-schist-like material for matrix and containing pebbles of various kinds, among which are greenish gray felsite weathering white (in abundance) dense greenstone like the orbicular greenstone, a few of gray or black chert or jasper, banded slate (rather numerous) many of which have a sedimentary appearance, grayish green porphyry weathering white and on the surface showing the very numerous porphyritic crystals of feldspar, green schist similar to the main masses of green schist on Moose lake, are more important.

The conglomerate belt traced to the N. to the brow of the hill becomes very schistic so that it is very difficult to discriminate pebbles and matrix. At one place in direct and sharp contact with the conglomerate is a schistic having many little whitish spots on the weathered surface evenly distributed and having an igneous look. At another place at the contact there has been movement and brecciation. About 10 steps N. of the contact, the schistise rock is seen to be a schistose porphyry of intermediate character. On the weathered surface the innumerable white porphyritic crystals of feldspar are well seen evenly distributed. When broken these crystals are seen as fresh feldspar with small quartz in a greenish sericitic matrix.

Continuing to the N. W. toward the lake
there are numerous small outcrops of
this porphyry. It gradually becomes,
however, more and more fissile until
it passes into a beautifully, evenly
and finely laminated fissile slate,
but even this slate upon the cleavage
51 surfaces shows the flattened pheno-
29420 crysts, spec. 29420. This slate here
is a part of the Moose lake slates.
This mashed porphyry affords one of the
best examples I have seen of an even-
ly fissile rock developing from a mash-
ed eruptive. The conglomerate con-
tains so much of the recomposed por-
phyritic material directly in contact
with it that the matrix resembles the
porphyry. Also the pebbles of por-
phyry are so mashed as to merge into
the matrix and make the two rocks so
resemble each other that for a short
time I thought the porphyry was a gray-
wacke, and that the conglomerate graded
up into the porphyry (supposed gray-
wacke) and this into the Moose lake
slates and thus a probable or at least
possible unconformable junction was
first described as a gradation. A lit-
tle way back from the contact to the
S. are very numerous pebbles and even
boulders of porphyry which were matched
in the field and found to be identical
with the porphyry belt to the N.

The conglomerate is cut by a porphyry which in places where much mashed becomes a gray sericitic slate very similar to that on the island to the N. The conglomerate is cut by a dense green rock bearing numerous hornblende crystals. At the contact with the conglomerate in the intrusive are many fragments of conglomeratic material, both pebbles and matrix. At a place farther S. this same green rock is cut and includes fragments of red granite to be mentioned subsequently. Apparently cutting the dense green rock is an intermediate porphyry, which also contains inclusions not easily identified but apparently some of them form the more basic rock with which it is in contact. The conglomerate continued for about 115 paces from the shore of Moose lake S. along the trail to 290 paces. Then the dense basic rock containing hornblende phenocrysts, and elsewhere plainly cutting the conglomerate, appears and continues to 355 paces. A red granite is now found, fragments of which appeared to be in the more basic rock just mentioned, and this continued to 458 paces. A second broad belt of conglomerate, identical with the first for the most part, next appears and continues to 745 paces; And then slates to 830 paces. The southern part of the conglomerate became much finer and indeed contains numerous broad bands of non-conglomerate graywacke and slate and the two interlaminated. Some of the graywacke bands are several feet across. The slate bands are mostly narrower, being from a few inches to one or two feet across The strike of the bands of conglomerate and interbedded slate and graywacke is parallel to the ridge until the last ridge is reached, before the slate is found. In passing to this ridge the bedding curves rapidly and in this ridge very generally has a structure averaging about at right angles to the ridge, but curving to the W. on either side. It is evident we have here the end of a fold which seemed to be synclinal and pitching steeply to the W. The cleavage follows the strike of the ridge and therefore cuts the bedding at various angles up to perpendicularity. The relations are roughly thus



This ridge was followed for perhaps a third of a mile to the W. The transverse banding became less distinct and the rock finally passed into a somewhat evenly massive fine grain-
Gw
29421 ed slate conglomerate, spec. 29421 the weathered surface of which shows many porphyritic crystals and which resembles the supposed porphyry near the lake shore N. of the northern belt of conglomerate. However, numerous slate fragments show its undoubted fragmental character. In the coarser varieties of this material where it is a somewhat coarse conglomerate many large fragments of slate and two of jasper were seen. This fine graywacke conglomerate has subordinate slaty bands. The conglomerate of the ridge appears to grade into the slate already mentioned. This slate occupies a little valley which W. of the trail becomes steep sided and rather deep.

The rock next found on the trail toward Flask lake is an exceedingly peculiar porphyritic rock which extends from 830 to 1040 paces. This rock has many white porphyritic crystals of feldspar evenly distributed, but has a graywacke-like matrix. Near the slate it is dis-
F.P.
29422 tinctly schistose, spec. 29422. Its main mass is massive and it includes

many black fragment-like areas, spec.
29423 29423. Note. In spec. the 3 rifts of the rock appear to correspond to the 3 cleavages of the porphyritic feldsparǂs. When this rock was traversed in the morning I had no doubt of its igneous origin, but in examining it more closely I wondered if the inclusions could be fragments and the rock a sediment or at least a tuff within which porphyritic crystals had later developed.

The peculiar porphyritic appearance of certain phases of the graywacke suggested this question, and the porphyritic appearance of both led me to wonder if I was mistaken as to the igneous character of the porphyritic rock near the lake, and as to the unconformable relation between this rock and the conglomerate. In short the question arises as to how far the development of porphyritic crystals by metamorphism can produce likenesses to the porphyritic structure of eruptives. The apparent sharp contact between the porphyritic rock and the first conglomerate and the close likeness between the porphyritic rock and some of the pebbles of the conglomerate are not explained by this idea of subsequent porphyrization, but a weak point of the day's work is that specimens of the porphyry and of the supposed porphyry pebbles were not collected for microscopical study.

The rock next found at 1145 paces continued to the end of the portage at Flask lake at 1620 paces. This rock is the peculiar volcanic conglomerate or tuff or agglomerate or one or more combined, which plays so important a role at Kekequabic lake and vicinity. Where first found the matrix is the dominant material and this is similar, if not identical, to the hornblende porphyry cutting the first conglomerate. It contains numerous small fragments which have the appearance of being inclusions. The rock has the appearance of a lava having numerous inclusions. Grant found the same rock across the deep ravine, a locality mentioned, some distance W. of the trail. As we pass from this phase of the rock toward the end of the portage, it assumes a more conglomeratic appearance, having great rounded boulders of porphyry of various kinds. This seems to be clearly a volcanic conglomerate, i. e. the material largely of volcanic origin either from lavas in the water or from ashes dropped upon the water, was worked over by the sea. The same volcanic conglomerate was found all the way on the portage from Flask to Snowbank lake. At one place a felsite dike was seen.

Leaving the portage and going along the shore we saw what appeared to be granite dikes cutting this rock and the next point was occupied by the Snowbank lake granite. The exposure supposed to be cut by granite was not examined whether a metamorphic effect of the supposed granitic intrusions could be detected.

August 31st.

Make the point that the peculiar dense conglomerate is later than the conglomerate because the same dense matrix cuts the conglomerate.

The conglomerate reappears at the mouth of Snowbank lake and continues through Crooked lake, but the matrix is very micaceous and in places schistose so the rock really becomes a mica schist. This effect is attributed to the granite. At the mouth of Crooked lake appear the peculiar sericitic, gray, fissile slates minutely banded in places exactly as at Moose lake. If the lower plastic series exist to the E., it must be mainly fragmentary. To the E. from Tower the jasper becomes less important and is perhaps replaced by the Knife lake plastics, largely of volcanic origin.

In going to the N. E. through Ensign lake the slates continue but become gradually less fissile and peculiar and more green and slaty. At the portage from Ensign lake they weather rough and present a less tuffaceous appearance. In Bass lake there are dense green slates which should be called graywacke slates, containing much hornblende and resembling closely the matrix of the

Snowbank lake conglomerate. There appears to be a gradation between the different varieties. On the portage to Knife lake the slates are especially dense and graywacke-like but with very definite appearance. They have a dark green color, contain much hornblende, and one thinks of their development from volcanic action.

Knife lake, September 1st.

Point at S. side of arm of Knife lake at E. end of Narrows, S. 9, 1/4 Sec. 24. T. 65. R. 7.

We here find the fine black flinty slates with aphamitic texture interbedded with coarse grit in which the clastic viens are distinctly visible, and with conglomerate containing what appears to be slaty pebbles. There are gradations between the different varieties. The bedding is perfectly distinct and strikes about N. 70 W. (magnetic) and dips 45 to the S.

29424 This spec. is a conglomerate.

Along the shore of Knife lake before reaching the portage to Epsilon lake the rock became a coarse sericitic, somewhat schistose graywacke, and at this portage is a dense green.rock containing many porphyritic crystals of
29425 feldspar,- spec.29425. The feldspars are fresh and brilliant and if allogenic must have been regenerated.

In Epsilon lake the Knife lake slates appeared, and at the portage to Zeta lake the bedding is well marked and vertical, the cleavage being at right angles to it. The Knife lake slates continue to the narrows of Zeta lake, where Grant shows me a peculiar conglomeratic rock, the debris of which is largely granitic. This statement applies both to the pebbles and to the individual grains. In places upon the weathered surface the rock especially resembles a granite. The matrix for the most part is a dark green dense massive material containing many porphyritic crystals of feldspar and also of hornblende.

Sw

29426 Specimen of matrix.

C

29427 Specimen showing weathered surface.

C

29428 Specimen showing granite and apparently also slate pebbles.

Immediately after the narrows of Zeta lake are passed the Knife lake slates appear and continue to Ogishke Muncie lake. Can the conglomerate just mentioned by connected continuously with the main Ogishke conglomerate on Ogishke Muncie lake?

From Ogishke Muncie lake to Clements camp on Peter lake no close observations were made.

September 3rd.

With Grant went to Bashitanaqueb lake where he showed me a peculiar fine grained phase of rock which has been called granulitic gabbro. The rock has a remarkable horizontal jointing as a result of which it looks at a short distance, like a bedded rock in layers of from 2 to 6 inches thick. It also has a sheeted structure striking in a general way E. and W. and dipping steeply to the S. This structure is shown by the differential weathering. At right angles to both these structures is a vertical jointing. At the place where this system of structures were seen the relations to the coarse gabbro was not discovered, but a little farther S. on the shore of the lake the coarse gabbro, of apparently normal variety, has sharp knife-edge contacts with the fine grained material and includes numerous rounded and irregular masses of it. These vary from small size to very considerable lenticular masses a number of feet long. If both rocks are considered as parts of the great gabbro mass, it seems to me that Grant is right in supposing the coarse gabbro is somewhat later. A little farther along the shore to the S. again irregular relations between the two rocks were seen with sharp contacts, but here it was not evident which was the cutting rock. (See 29429)

A reconnaissance was made as to the relations of the iron-bearing formation (supposed Animikie), and the conglomerate to the N. and the associated greenstone from the W. end of Fay lake about 2 miles E. The provisional work indicated the conclusion that the conglomerate was deposited unconformably upon the greenstone, that it grades into a fine grained sediment, and that conformable with this is the iron-bearing formation. The conglomerate is a broad belt at the W. and narrows to a feather edge at the E. between the greenstone and iron-bearing formation. This relation might be explained by overlap. The iron-bearing member gradually approaching nearer to the greenstone until it was deposited directly upon it.

Gw

29429 One of Winchell's Muscavados, according to Grant, who divides Winchell's Muscavado into 2 or 3 different kinds of rock.

contact

Loon Lake

September 5th.

Grant, Clements, Leith, and I crossed Gunflint lake, to the portage to Loon Lake; thence across portage; thence across Loon lake to bluff on S. W. part of the lake.

On crossing portage to Loon lake we saw at intervals slate and porphyritic diabase, which Grant said were sills in the black slate.

On the S. W. point of Loon lake at the top of the bluff is gabbro, below which is a set of beds of the Upper Graywacke of the Animikie. Between the graywacke and Animikie beds there is a space of 3 or 4'.

Gab The lowest mass of the gabbro is
29430 represented by spec. 29430.

Below this is a very much metamor-
29431 phosed quartzite, 29431, and below
this, down to the surface of the water,
three specimens were taken in order,
29432 from the top down, 29432, 29433, and
29433 29434, representing the metamorphosed
29434 graywacke slate.

Apparently there is here a gradation in the metamorphosm. The slate is distinctly bedded, with a flat dip to the S., about 20°.

29432 is an almost crystalline-looking rock, and may possibly be a phase of the gabbro.

29436 At the next point to the E. spec. 29436 was taken; the dip is 13° to the S.

29437 29438 At a point about a mile farther E. along the S. shore of the lake, the rock is still a fine grained, dense graywacke. The different layers differ in coarseness. Two phases are represented by specs. 29437 and 29438.

At the headland about 1-1/2 miles farther along, where the arm of the lake goes S., the rock is interbanded slate, graywacke slate, and coarse graywacke, approximating quartzite.

29439 Graywacke slate.

29440 Quartzite.

September 5th.

Went to section along railway track N. of Gunflint lake, about a mile W. of the E. end of the lake, with Clements, Grant, and Leith.

N. of the railway track, from 75 to 150 paces, is a belt of greenstone, using that term in a general sense. In its interior it is massive. In places it is distinctly spheroidal, with different bands. In going toward the S. it becomes distinctly schistose; the spheroidal layers are flattened, and this gives a rough banding to the rock. At its border at some places is 50 to 100' of finely fissile lammated schist, in which the spheroids are entirely destroyed, evidence of them being the much mashed bands already mentioned. Thus we have a gradation from a somewhat massive normal spheroidal-weathering greenstone to a fissile-schist. Resting directly upon this rock is a band which extends to the S. of the railway. This band is distinctly lighter in color than the green schist. Near the green schist it has in places a somewhat conglomeratic appearance, but not with sufficient distinctness to be sure that the rock is a conglomerate. It is finely and uniformly laminated here, so uniformly in fact, that I thought at first it might be a mashed eruptive. However, this uniformly laminated rock passes upward into a distinctly banded rock which has the appearance of a sedimentary slate, which indeed, must be a water deposited rock. The rock has certain bands with porphyritic crystals, which may be parallel injections. Indeed, these injections are very numerous, giving the rock the appearance of alternating slate and graywacke.bands. However,this may be, there are undoubted bands of porphyry which have been injected in a parallel manner. At the three contacts examined there was, in one place, distinct parallelism of foliation and abrupt change in character. In the second place, there was the same change of character, but with conglomeratic appearance. At the third place, there was abrupt change in material so that one could be discriminated from the other, but the relations were somewhat obscure, so that they might be regarded as evidence of intrusion of the lower rock, or perhaps equally well as sediments laid down upon green schist.

The spheroidal weathering greenstone, as described, is essentially the same rock in its appearance from the center to the outside that we have found all the way from Tower.

29441 The clastic rock at the base, where there are numerous roundish areas which may be fragments.

29442 From the banded slate adjacent to the railway.

29443 From a graywacke-slate band, which may possibly be the mashed, parallel injected rock.

29444 The graywacke and slate bands together.

29445 The mashed intrusive porphyry contains many porphyritic crystals of feldspar, which show somewhat regular orientation.

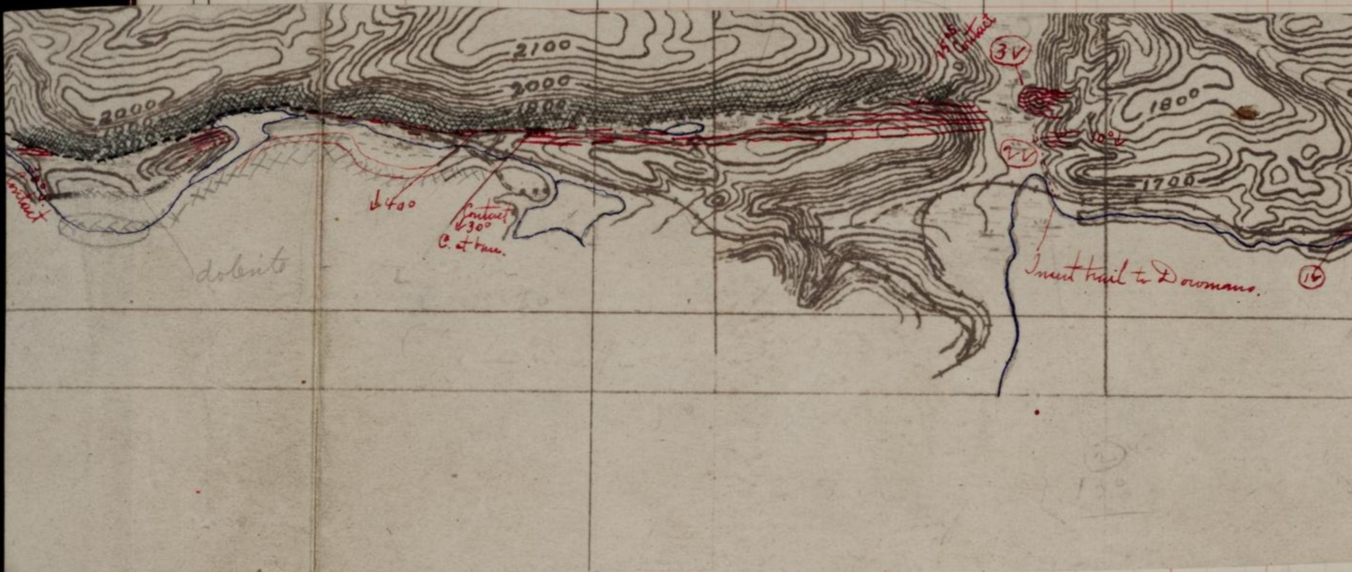
29446 Peculiar reddish jasper from the Animikie on the railway, ~~W.~~ of the E? above described section, having numerous blood-red round jasper areas in a darker matrix. Remains of glauconite or carbonate. The rock is not in place.

The contact between the slate and the green schist swings away from the railway track, and a little farther to the W. (about 1/4 of a mile) the green schist appears at the railway track.

No attempt was made to trace out the belt of slates to the W. in order to ascertain whether it is a synclinal belt.

A little farther on, on the crinkled green schist in the railway cut, is found the Animikie iron formation, well banded, and resting with a slight dip to the S. on the edges of the schistose crinkled greenstone. At one place Clements found a foot of conglomerate, the base of the iron formation, containing green schist and quartz pebbles. Above this is a layer of chert, white and banded, a foot wide in places, and somewhat brecciated.

The iron formation proper does not appear at the particular point where the conglomerate was seen, but it does appear a few paces to the E.


2100
2000
1800
1700
3V
2V
Contact
Contact
30°
10°
dolerite
Inset trail to Dowmans.
1V

S.

T.

R.

September 6th.

Gunflint lake to Paulson's mine, with Grant, Clements, and Leith.

At point I on the topographic map, see opposite page, the rocks are essentially metamorphic silicate rocks of the actinolite series containing bands of sugary quartz, entirely different from the hornstones and flints of Gunflint lake,- just as different as the metamorphic silicates are from the ferruginous cherts and slates of Gunflint lake. In character of rock and degree of metamorphism, the material is here comparable to the extremely metamorphosed Negaunee formation of the Lower Marquette series.

Spec. 28959, of Clements, shows the sugary actinolite bands.

At location II, on opposite map,
29447 two specimens were collected, 29447
29448 and 29448. These are from the Animikie, just W. of the topographic break. The rock is here a very coarsely banded rock, similar to that which runs E. and W. from the Paulson mine. The alternating bands are predominantly of quartz or iron silicate, and some of the bands show an admixture of the two. The bands, which are dominantly quartzose, are in some cases 6 or 8" wide. These certainly are much

An. 29447 is best phase of 22946 metamorphosed by gabbro!

more crystalline than Clements' spec. 28959.

The intervening mile was not examined to see whether or not the transition is gradual, but apparently there are no exposures, as the ridge from which the specimen was taken continues to the E., joining on to the well recognized ridges of the Animikie, containing sills of diabase. The dip is 10° to the S.

29449 From location III on map. The rock is a typical banded magnetite-actinolite-slate, in which the quartz bands are much smaller and more subordinate than in the ridges just described. To the S. this ridge extends for 100 paces along the trail just S. of Dowman's house. At the N. end, the dips are very flat to the S., 8° or 10°. A little farther on they become flatter, and a little farther on still they begin to turn up steeply, so that a change from a flat dip to one of 30° or 40° to the N. is very common. At the N. end of the ridge, the dips average 75°. There are many sharp rolls and minor crinkles upon this area, showing that it is a closely folded series. Some of the minor folds are as sharp as those of the

Vermilion and Menominee districts.

The interpretation of this area by Grant is that just to the S. of the southernmost exposure of jasper, an anticlinal ridge of Archean green schist comes in; that to the N. is a synclinal of iron formation resting on both sides on the green schist. With this general interpretation of the phenomena, the observed facts correspond.

Crossing the little swamp, about 200 steps wide, along the trail, we found on the W. side of the swamp the iron formation, with southern dip, resting upon the greenstones which make up the main mass of the ridge to the N. The actual contact is not seen, but a space of only 2 or 3 feet separates them. Near the contact the iron-bearing rocks dip 20° to 25° to the S. Across the valley to the S., the dip of the formation is 15°. The rock is not more crystalline nor coarsely banded than the most changed varieties found E. of the valley.

At one of the test pits E. of the Paulson mine, and just N. of the main ridge of iron formation material, the rock at the top is a typical bedded iron formation rock, as shown at the pit.

The lower part of the pit is full

of water, but on the dump is material presumably taken from the pit's bottom, which has a distinct conglomeratic appearance. The matrix is, however, very coarsely crystalline, and the supposed pebbles are well rounded and of a darker color for the most part. There are some few pebbles of a lighter colored rock. This supposed conglomerate resembles very closely, if it is not identical with, the conglomerate N. of the iron-bearing formation of Fay lake and vicinity, Clements' spec. 28960.

A pit about 50 paces farther N. starts in iron formation, but from the bottom of it has been taken out a large mass of material consisting of somewhat massive greenstone, but upon the surface of some of the blocks is a distinct conglomeratic appearance. The same dark pebbles above mentioned are contained, and also many well rounded pebbles. There can be little doubt that this is the basal conglomerate of the Animikie.

In the pits W. of the Paulson mine, , along the spur of the track about 200 paces W., is a test pit in which there is a contact of the Animikie iron formation and the greenstone. The Animikie has a thick bed of coarse quartzite about one foot thick. Conglomerate is thown out of the bottom of the pit.

~~Fay Lake. September 7th.~~

In the three days trip with Grant, Clements and Leith, I became more impressed than before with the important part played by the intrusive sills. As has been well known, in the vicinity of Thunder bay they control the characteristic features of the topography. The same is true of the Gunflint lake district. The sills occupy the majority of the higher hills, although slate is ordinarily below and perhaps makes up the larger part of the rock. Oftentimes the dip of the slates is approximately that of the tops of the ridges, although ordinarily the sills dip more steeply than the slope of the tops of the ridges. The uniform dips of both sills and ridges to the S. give steep northward sloping sections and gentle south sloping surfaces. Between the row of cliffs and the surface to the N. made by another sill lie the lakes and oftentimes the portage courses.

In general appearance the sills certainly approach ~~to~~ the gabbros. One of the most characteristic features of them are the porphyry crystals of feldspar. One of the larger of these sills, which gives porphyry crystals of feldspar, is so like the gabbro that Grant regarded it as an off shoot of the gabbro. Other sills he regarded as different for reasons given in the Minnesota report. The bases for this belief are, however, of such a character as to be largely if not wholly explained by the difference in magnitude of the sills and the gabbro. The abundance of the sills close to the gabbro from Gunflint lake to Thunder bay, and their mineralogical likenesses, seem to ally them very closely with the gabbro, and probably means that they are intrusives of the same age as the great gabbro masses.

The observations made during the three days combined with those of the previous days throw considerable light upon the question as to whether the gabbro is intrusive or extrusive. Certainly all the evidence collected is in favor of its intrusive character.

1. In the first place the gabbro metamorphoses in a profound manner, as described by Grant, the various rocks with which it comes in contact. This is true whatever part of the Animikie formation or of the Archean it reaches.

2. The contact is an irregular one in a major way, and the sills appear to be irregular also in a minor way. The major irregularities might

be explained by the erosion before the time of the gabbro on the hypothesis of extrusion but the minor irregularities are difficult to explain on this hypothesis. The minor irregularities are of different kinds. In the first place fragments of the Animikie iron-bearing member seem to be inclosed in the gabbro. Of course this would be possible even though the gabbro were an extrusion. In the second place, in the railway track between Paulson's mine and Gunflint lake, just before the important cross valley is reached, the Animikie, although having a monoclinal dip up to the gabbro, at the gabbro has large masses with northern dips. These Grant regarded as vast fragments, many feet across, 50 feet or more, included in the gabbro. However, the evidence upon this point is not conclusive, for the gabbro does not appear in masses again to the N. of the fragments, but directly adjacent to them. To the N., in one place, the gabbro is seen inclosing various fragments of the iron-bearing formation.

3. It seems to be a very general truth that the Animikie becomes steeper on its approach to the gabbro. In many cases this increase in steepness in the Animikie is marked, as for instance, at Disappointment lake.

These phenomena could possibly be explained by extrusion but it is far more consonant with the idea of a great batholitic intrusive mass which bends the layers down below the gabbro as it intrudes itself along the general surface between the Animikie and the overlying rocks, whatever they were.

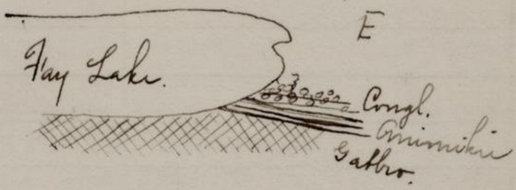
4. The great diabase sills if connected with the gabbro, as already suggested, would be another point in favor of the intrusive character.

5. In short all of the phenomena observed, that of profound metamorphism, of areal distribution, of included fragments, of dip, of diabase sills, are better explained upon the hypothesis of intrusion rather than of extrusion.

September 7th.

Examined relations of rocks on Fay lake. Here on the N. shore are the peculiar metamorphosed greenstone conglomerates and also the iron formation. For the most part one passes from one to the other without clear exposures. The conglomerate is so massive that strikes and dips are for the most part impracticable. However the schistosity of the schistose green stone conglomerate and the bedding of the iron-bearing carbonate agree. At one place about the middle of the N. shore the contact is just missed. Here the greenstone conglomerate occurs ~~and~~ with fragments larger than one's fist, grading to the S. into a fine grained conglomerate. This grades into a coarse graywacke and this into the peculiar fine grained mica-schist rock constituting the top of this member at various places. If the gradation in coarseness of the conglomerate be taken as the strike it is certain that the strike of the schistose conglomerate and graywacke is the same as that of the iron formation immediately adjacent. In all respects the phenomena here corresponds with those seen at Disappointment lake, and indicate conformity of the conglomerate and the iron member with a fine grained clastic rock as a gradation phase. After the rock has become an iron-bearing member it contains bands which are difficult or impossible to discriminate from the underlying fine grained almost quartzose phase of the conglomerate formation. The strike and dip of the iron formation varies greatly in this vicinity. See Leith's notes.

The strike of the rocks is such as to carry the above rocks to the S. side of Fay lake, and here, as the lake is diagonal to the strike, the gabbro, iron formation, and conglomerate may be seen along the shore.



Here the break between the iron formation and the conglomerate is about 6 feet, but hanging upon the face of

the N. side of the iron formation is the fine grained sediments seen on the N. side of the lake next to the iron formation. Here, however, the gradation to the conglomerate can occupy but a few feet, for after the unexposed space of about 6 or 8 feet the conglomerate appears. The iron formation at its lower part again contains the beds difficult to dis-
au criminate from the graywacke. In places the iron formation is finely
29450 banded and in a single spec. 29450, shows both the quartzose and the other phases. The quartz is here very coarsely crystallized and the processes of the contact action of the gabbro must have been long continued in order to so coarsely crystallize the quartz. The material is similar to the quartzite of ~~Red~~ Rib hill, which again is believed to have been so coarsely recrystallized as the result of the intrusion of the Wausau augite-syenite. No orientation of the quartz was noted. This coarse quartz is typical of the iron formation near the gabbro and is a beautiful illustration of static metamorphism.

au
Going down to the gabbro a layer of
29451 material, 29451, is found, 3 or 4 feet across, which is believed to be an off shoot of the gabbro. However, this

material so resembles many of the narrow bands in the iron formation as to lead to the conclusion that if one is intrusive, many of the others are. I have little doubt that this is the case, and that near the gabbro the iron formation has many parallel injections. The color of the rocks is similar. The supposed off shoots of the gabbro are fine grained and the Animikie is so coarsely crystallized that the two are difficult to certainly discriminate. In its parallel injection we have the explanation of Chauvenet and Merriam, that the iron formation is but a phase of the gabbro.

Continuing S. of E. along the contact of the iron formation and the gabbro, by following the strike I would now be on the gabbro and now on the iron formation. In order to keep on the contact I could not follow the strike of the rock, but had to keep off, stepping one way or the other by a few paces. At many places I was unable certainly to tell whether the gabbro was a sill or the main mass until this had been determined by running the exposure out, and in other places was unable to tell whether the very bands of gabbro-like material were fine granulitic gabbro or iron

formation. ¶ This course was continued
to a small lake about one half mile
S. E. of Fay lake, to the N. side of
the W. end. Here a little cross
swamp and the gabbro makes the shore
of the lake. Now going N. of the E.
side of the swamp I find a succession
of heavy ledges of very coarsely
crystalline gabbro. Going perhaps
100 or 150 steps, the gabbro becomes
29452 distinctly finer grained, 29452, and
appears to be rather rich in magnetite
Still going toward the iron formation
about 50 steps farther, the gabbro is
29453 still finer grained, 29453,and is so
rich in iron that for a time I was
doubtful whether or not I had a belt
of the iron formation. However, the
structure is perfectly massive and
traversing back and forth convinced
me that there was gradation between
this and the previous specimen.

Passing to the N. the gabbro at the
end of the exposure becomes very fine-
29454 ly crystalline, 29454, but contains
very coarse crystals of a mineral
taken to be hypersthene, ~~which~~ and is ric
in magnetite, so that it startlingly
resembles many of the specimens taken
from the iron formation. However
there is no question whatever as to
the complete continuity of this mate-
rial with the coarse gabbro at the

lake. Also in this material there begins to appear a very fine banding at intervals, although it does not have the manner of weathering of the ledges, or give any appearance of banding in them.

Passing now an interval of 15 or 20 feet, there comes another ridge which has heretofore been regarded as typical iron formation, or rather the upper part of it. Here are interstratified bands of a
29455 fine crystalline rock, 29455, closely resembling the last phase of the gabbro, bands of material having mag-
29456 netite, 29456, which still more closely resembles the gabbro, and bands of material which show the quartzite ac-
29457 tinolite layers, 29457, so representative of the iron formation. I went back and forth ~~rapidly~~ repeatedly from the gabbro to the iron formation and would have been wholly unable to discriminate, indeed was unable to discriminate, between the fine gabbro-like phase of material 2 to 6 inches wide interstratified with the undoubted ore formation, and the finer phase of the gabbro.

The ledges of iron formation material at the S. side of the formation are distinctly more coarsely banded than they are to the N. This seemed to be a general fact, at least, for the iron formation which

I studied. I attributed this difference to parallel injection of the gabbro, the coarser black bands being believed to be no more or less than off shoots of the gabbro. These would vary from those of less than an inch, how small I could not see, to those 3 or 4 feet wide, and to those which have been recognized as distinct sills. Between those 2 inches wide and those which have been recognized as sills, I think there can be no question as to gradation. Whereever the banding becomes very narrow, as in the lower part of the iron formation, many of the black bands although only a fraction of an inch across resemble the granulitic phase of the gabbro more closely. How many of these are truly gabbro material I am unable to say. I suppose that we have here the same close mingling of gabbro material and sedimentary material which we have in the case of the injection of the schist by granites, as in the case of Snowbank and Disappointment lakes. It has already been said that the upper part of the ore formation takes on a more distinctly sedimentary character. In this same section, when the ore became finer
29458 banded, spec. 29458, was taken, ~~a sill~~ and still
29459 farther N., 29459, representing the

peculiar quartzose silicate phase. Still farther N. in a cliff, spec.
29460 29460, all the bands together appear. The dark crystalline bands may be in part gabbro.

In the iron formation E. of the little swamp above mentioned certain phases of what is believed to be gabbro contain very coarse crystals of hypersthene, or some similar mineral,
29461. 29461.

In the ~~facts~~ discovered during the day I think we have the complete explanation of the mapping of Grant and Chauvenet and the difference of opinion between Grant and Bayley on the rock determinations. Chauvenet and Bayley worked over the country and spent much of their time in the gabbro formation; coming to the large metamorphosed iron formation and noting the change in the gabbro as it approached the ore, and noting the bands of gabbro material in the iron formation, they concluded that the whole was but a basal phase of the gabbro. They collected their specimens indiscriminately as doubtless the Minnesota Survey did, collecting both gabbro and iron formation material as gabbro. Bayley, recognizing the undoubted gabbro, supposed that the quartzose and magnetitic bands were all of gabbro. Grant, on the other hand, working with the Animikie and platting it, was led to connect the actinolite magnetite bands structurally with the Animikie. He perhaps did not closely study the relations of this material with the gabbro and concluded ~~that~~ the whole was Animikie. As a matter of fact it is part one and part the other. It is a sedimentary formation with parallel banding which has been injected in a most complex fashion by the gabbro, these injections, varying as already described from great sills to layers so small that they cannot be recognized.In the upper portion next to the gabbro a large part of what has been regarded ore formation is injection gabbro. In the Ore formation remote from the gabbro a small part of it is gabbro. It is there mainly a profoundly metamorphosed carbonate. Between the two there are all gradations It is a significant fact that all of the mines are collected at the base of the formation,farthest from the gabbro. Here the iron formation is more nearly pure and there has been better concentration. Of course we must connect that with the fact that this is the natural place for the ore to develop in any case, and therefore the position of the ore at this place is only partly explained by the absence of the gabbro injections.

The question of the difference of opinion as to the amount of titanium is also explained on the same basis. Doubtless an average specimen of the mineral near the gabbro would be found to contain a considerable amount of titanium. The iron formation away from the gabbro, being mainly a water concentration, would contain little titanium. This is to be verified by analysis.

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cf. metamorphic action of gabbro on animikie of Loon lake.

September 8th.

With Clements examined the outcrops on the N. shore of Fay lake and thence N. across the small lake to the area of greenstone.

At the shore of Fay lake we found, about 100 paces from the iron formation outcrops and along the strike from them so that the outcrops would be but a little lower than the iron formation, a fine grained variety of Winchell's muscavado, which in going up ~~by~~ the hill appear to grade into a coarse graywacke-like variety. A little higher up the hill the rock becomes distinctly conglomeratic. If the strike of the zone separating the fine-grained and conglomeratic rock be taken as the true strike, this would correspond closely with the strike of the iron formation. There is a sheeted structure in the rock which has a steep dip to the S.

On the flanks of the greenstone ridge Clements showed me the typical greenstone conglomerate, and at one locality it seemed to be in direct contact with schistose greenstone, although for the major part of the exposure the relations are not so sharply cut. After the last ledges of distinct greenstone-conglomerate was found the ledge has a broken appearance, some phases of which resemble conglomerate. Undoubtedly most of the exposure is breccia but small parts may be conglomerate with the possibility of the little masses being explained as clasolites.

In the afternoon we traced out the contact of the gabbro and the iron formation from the E. end of Fay lake to the swamp N. of Flying Cloud lake. The contact between the gabbro and the iron formation between the two lakes can be somewhat closely located. It is swinging in and out in minor rolls, the exact contact being found on a bluff at the N. W. point of Fay lake.

Following now the E. side of the swamp to Bingoschick lake (Winchell), the iron formation is first found much farther N. The change in the gabbro in approaching the iron formation has been described in the previous days' notes and also the similarity of the bands in the iron formation to certain parts of the gabbro. The silicious bands are found in the upper part of the mass which is undoubtedly gabbro. Whether these are inclusions or would widen out into residual layers if they could be traced along the strike and dip, is uncertain. The platting shows a marked banding of the iron formation to the N. and the relations indicate there a sharp flexure or a fault. A sill of diabase or gabbro was found in the iron formation on opposite sides of the swamp in such relations as to indicate the probability of a fold rather than of a fault. The strikes of the iron formation W. of the little swamp are in places nearly N. and S. or at right angles to the normal strike of the iron formation a short distance to the S. W. The fact heretofore observed at various contacts and noted by Grant especially, that the dip of the iron formation rocks becomes steeper in the gabbro, was also plainly apparent in the afternoon's work, the dips running from 30° to the S. or less at the road to vertical or even overrunning dips near the gabbro 80° to the N.

The detailed work along the contact at this place, the one contact along which I have taken detailed work, shows that the Animikie for this locality is as much a folded formation as the Agamok slates or any other of the sedimentary formations of this area. It is probable that detailed work at other localities along the contact would show various flexures which have not been detected, especially as this very important flexure was not even suggested by mapping the iron formation rocks along the trail a short distance to the E. and W. Nor would it have been detected if the strike of the formations had been taken continuously along the road, so rapidly does the sharpness of the fold die out in passing N. from the gabbro. These observations of the folding of the Animikie at this locality fully agree with the statement made by Grant as to the folding about the Paulson mine and with the observations made by our party E. of the Paulson's mine on the trip from Gunflint lake to camp. See note book of previous day and Leith's plat.