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AND

NATURAL HISTORY SURVEY

OF MINNESOTA.

The Twenty-first Annual Report, for the Year 1892.

N. H. WINCHELL,
State Geologist.

MINNEAPOLIS:
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1893.

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ADDRESS.

MINNEAPOLIS, MINN., Oct. 20, 1893.

To the President of the Board of Regents:

DEAR SIR.—The twenty-first annual report of the Geological and Natural History Survey of the state is herewith submitted. It embraces statements relating to progress in the strictly geological portion of this enterprise, and to the General Museum and the library accessions. The botanical and zoological departments of this work have been placed, by the Board of Regents, under the personal direction respectively of Prof. Conway MacMillan and Prof. Henry F. Nachtrieb, and they will make independent reports directly to the regents.

Respectfully submitted,

N. H. WINCHELL,

State Geologist and Curator of the General Museum.

CONTENTS.

I.

SUMMARY STATEMENT AND COMPARATIVE NOMENCLATURE.

In the season of 1892 the field work of the survey was continued in the northeastern part of the state, where the economic development of the new iron range (the Mesabi) continued unabated. Considerable time was spent on the central and western portions of the Mesabi range, with a view to learn the geological relations of the ore bodies. By this time, as shown in the report of H. V. Winchell published in the last annual report, some general idea had been gained of the position and forms of these ore deposits, warranting an attempt at a more systematic description, which should serve at least for many practical purposes and as a preliminary statement of many of the geological environments. At the same time this early reconnoissance brought to light many new facts and features, the full elucidation and publication of which will require careful chemical and petrographical research, and a comparison with the similar features of the iron ranges of adjoining states.

Dr. U. S. Grant continued an examination, which he had begun, of a granitic area near the eastern extension of the Mesabi range, viz: that about Kekequabic lake, and extended his field studies, with careful detail, to the eastern end of Otter Track lake, and southward to and beyond Little Saganaga lake. Later he spent much time on the eastern end of the Mesabi range proper, westward from Gunflint lake, examining the relations of the gabbro and the magnetites to the Pewabic quartzyte.

Simultaneously with this the writer extended his field work over a region not before visited by him, including Snowbank lake and the region between it and the Kawishiwi river, and subsequently with Dr. Grant reviewed some of the important portions of the region of Kekequabic and Ogishke Muncie lakes.

In May a reconnoissance was made by the writer, accompanied by Messrs. Grant and Schuchert, of the region about Potsdam, N. Y., with the view to obtaining, if possible, some data for the settlement of some of the pending questions respecting the stratigraphic position of the true Potsdam sandstone. This trip was continued to Keeseville, N. Y., on the east, and to Gouverneur, N. Y., on the west.

Mr. E. O. Ulrich spent a year at Minneapolis, and much progress was made on the paleontology of the Trenton and Hudson River formations, the results being incorporated in volume III of the final report, still in press. Of this volume several chapters have already been issued separately, viz:

Chapter I. Cretaceous fossil plants from Minnesota. By *Leo Lesquereux*, pp. 1-22, 2 plates. Published Feb. 15, 1893.

Chapter II. Microscopical fauna of the Cretaceous in Minnesota, with additions from Nebraska and Illinois. By *Anthony Woodward* and *Benjamin W. Thomas*, pp. 23-54, 3 plates. Published Feb. 15, 1893.

Chapter III. Sponges, Graptolites and Corals, from the Lower Silurian of Minnesota. By *N. H. Winchell* and *Charles Schuchert*, pp. 55-95, 2 plates. Published June 6, 1893.

Chapter IV. On Lower Silurian Bryozoa of Minnesota. By. *E. O. Ulrich*, pp. 96-332, 28 plates. Published Jan. 15, 1893.

Chapter V. The Lower Silurian Brachiopoda of Minnesota. By *N. H. Winchell* and *Charles Schuchert*, pp. 333-474, 6 plates. Published June 6, 1893.

During the year also the twentieth annual report has been published, and Bulletin VII, devoted to the mammals of the state, by Prof. C L. Herrick, has been issued from the press and distributed. The work of Dr. P. L. Hatch, on the Birds of Minnesota, has been published through the zoological department of the survey, under the supervision of Prof. H. F. Nachtrieb.

The following papers relating to the geology of the state have also been published elsewhere by members of the Geological Survey corps, viz:

The geology of Hennepin county. *N. H. Winchell.* (In the "History of Minneapolis", by *I. Atwater.*)

An approximate interglacial chronometer. *N. H. Winchell.* American Geologist, vol. x, p. 69, August, 1892.

Preliminary descriptions of new Brachiopoda from the Trenton and Hudson River groups of Minnesota. *N. H. Winchell* and *Charles Schuchert.* American Geologist, vol. ix, p. 284, May, 1892. (Advance copies were distributed to American paleontologists, April 1, 1892.)

The Kawishiwin agglomerate at Ely, Minn. *N. H. Winchell.* American Geologist, vol. ix, p. 359, June, 1892.

Some problems of the Mesabi iron ore. *N. H. Winchell.* American Geologist, vol. x, p. 169, September, 1892.

Frondescent hematite. *N. H. Winchell,* American Geologist, vol. xi, p. 20, January, 1893.

The geology of the iron ores of Minnesota. *N. H. Winchell.* Trans. Geol. Soc. Australasia, Melbourne, vol. 1, pp. 171-194, 1892.

The stratigraphic position of the Ogishke conglomerate of northeastern Minnesota. *U. S. Grant.* American Geologist, vol. x, p. 5, July, 1892.

Note on an augite sode-granite from Minnesota. *U. S. Grant.* American Geologist, vol xi, p. 383, June, 1893.

New Lower Silurian Ostracoda. *E. O. Ulrich.* American Geologist, vol. x, p. 263, Nov., 1892.

Two new Lower Silurian species of Lichas (subgenus Hoplolichas). *E. O. Ulrich.* American Geologist, vol. x, p. 271, Nov., 1892.

Classification of theories of the origin of iron ores. *H. V. Winchell.* American Geologist, vol. x, p. 277, Nov., 1892.

A classification of the Brachiopoda. *Charles Schuchert.* Am. Geol., vol. xi p. 141, March, 1893.

New Lamellibranchiata. *E. O. Ulrich.* Am. Geol., vol. x, p. 96, August, 1892.

Mesåbi developments. *H. V. Winchell.* Iron Trade Review, Cleveland, April 19, 1892.

Cost of mining on the Mesabi. *H. V. Winchell.* Iron Trade Review, Cleveland, July 21, 1892.

Is there a shortage of bessemer ore? *Anon.* (*H. V. Winchell*). Iron Trade Review, Cleveland, Feb. 16, 1893.

The Mesabi iron range. *H. V. Winchell.* American Institute of Mining Engineers, Schuylkill Meeting, vol. xxi, pp. 644-686, Oct., 1892.

The Biwabik mine. *H. V. Winchell* (with *John T. Jones*). Am. Inst. Min Engineers, Montreal Meeting, vol. xxi, pp. 951-961, Feb., 1893.

Minnesota iron mines. *Anon.* (*H. V. Winchell*). Published in "Minnesota, a brief sketch of its History, Resources and Advantages," by authority of the State Board of World's Fair Managers, pp. 119-123, Pioneer Press, St. Paul, 1893.

Prof. J. E. Todd, of Vermillion, S. Dak., was engaged to complete the survey in the northwestern portion of the state, extending from the Red river valley eastward to the east side of Beltrami county, and he has spent the months of July and August in that region. His accompanying preliminary report shows in outline the progress he has made. It will require another similar season's campaign to clear up sufficiently for report the geological features presented in that area.

The work of the year has been very largely paleontological. Some re-examinations were made by Messrs. Schuchert and Ulrich, under the guidance of Mr. Scofield, of the fossiliferous Lower Silurian outcrops in the southeastern part of the state, with the view to determine more exactly the stratigraphic range of the fossils belonging to the survey collection, and for the purpose of further collection at the same points.

COMPARATIVE NOMENCLATURE.

The former annual reports of the Minnesota survey have presented, occasionally, short discussions and tabulations of the Pre-Silurian rocks of Minnesota, embracing different portions of the series. These have also sometimes contained references to their supposed parallels in other parts of the Northwest. Owing to occasional misapprehensions by other geologists of the stratigraphy of these rocks, as we have made it out, and the misuse of some of our terms, an attempt has been made to place the Minnesota strata in proper order in the adjoined table. This table also expresses the stratigraphy of the Wisconsin reports, issued under the direction of Prof. Chamberlin, the terms used by the present Michigan survey and the general terms used by the United States and Canadian geological surveys. The table has had the approval of Messrs. Wadsworth, Van Hise and Selwyn, for their respective portions.

PRE-SILURIAN ROCKS OF MINNESOTA.

MINNESOTA.

PALEOZOIC.[3]	CAMBRIAN.[2]			St. Peter sandstone.[1] Shakopee limestone. Richmond sandstone. Lower Magnesian limestone. Jordan sandstone. } St. Croix series. St. Lawrence limestone. } St. Croix series. Dresbach sandstone. } St. Croix series. Hinckley sandstone. (L. Superior sandst.)
	TACONIC.[4]	Keweenawan (Nipigon).	Upper.	Brown sandstones. Fond du Lac.
			Lower.	Traps and amygdaloidal rocks of the northwest coast of Lake Superior (except those of the Animikie).
				Norian. (Gabbro and anorthosytes?)
		Unconformity?		
		Animikie.		Slates, iron ores, etc., of the Mesabi range.
				Sioux,[5] Pewabic and Wauswaugoning quartzytes (Potsdam)[6].
Great unconformity.				
ARCHEAN	ONTARIAN.	Keewatin.		Sericitic schists, green schists, greenstones, slates, graywackes, conglomerates, jaspilyte, iron ores, etc., of the Vermilion range.
		Coutchiching.[7] (Vermilion).		Holocrystalline mica and hornblende schists.
	Eruptive unconformity.			
	LAURENTIAN.			Gneiss.

SUPPOSED EQUIVALENTS.

Wisconsin Reports.

PALEOZOIC.	CAMBRIAN	St. Peter. Willow River. New Richmond. Main body of limestone. Madison. } Potsdam. Mendota. } Potsdam. Sandstone. } Potsdam. L. Superior sandst. } Potsdam.
	Unconformity.	
	KEWEENAWAN	*Upper.* Horizontal Sandstones. *Lower.* Traps, Amygdaloids, Conglomerates.
Unconformity.		
ARCHEAN.	HURONIAN	Divided into twenty-one parts.
	Unconformity.	
	LAURENTIAN.	

Michigan (Wadsworth).

PALEOZOIC.	CAMBRIAN	Calciferous.
		Potsdam. (Keweenawan).
Great unconformity.		
AZOIC OR ARCHEAN.	MICHIGAN	Negaunee.
		Holyoke.
	Unconformity.	
	HURONIAN ?	Mesnard.
		Unconformity.
		Republic.
	Unconformity.	
	LAURENTIAN ?	Cascade.

GENERAL TERMS USED BY THE U. S. GEOLOGICAL SURVEY.

PALEOZOIC	UPPER CAMBRIAN.
Unconformity.	
ALGONKIAN	KEWEENAWAN.
	Unconformity.
	UPPER HURONIAN.
	Unconformity.
	Lower Huronian.
Unconformity.	
ARCHEAN OR BASEMENT COMPLEX	MARENISCAN.
	Eruptive unconf.
	LAURENTIAN.

TERMS USED BY THE GEOLOGICAL SURVEY OF CANADA.

PALEOZOIC	CAMBRIAN.	4. Calciferous. ?
		3. Potsdam.
		2. Keweenian.
		2. and 3. Selkirk series.
		1. Animikie, Bow River and Nisconlith series.
		1. St. John group.
Great and universal unconformity.		
ARCHEAN		HURONIAN.
		Local unconformities.
		LAURENTIAN.

[1] The St. Peter has been put in the Cambrian in the reports of the Minnesota Survey already published, but recent developments indicate that it belongs to the Lower Silurian.
[2] Cambrian is regarded as the time equivalent of the Upper Cambrian, as that term is used by the U. S. Geological Survey.
[3] Some parts of the Cambrian are unconformable on the Lower Keweenawan, but there is no evidence to show the exact date or the kind of disturbance that brought about this change.
[4] The two divisions of the Taconic, Keweenawan and Animikie, are regarded as the time equivalents of the Middle and Lower Cambrian, respectively, as these terms are used by the U. S. Geological Survey.
[5] There are some reasons for separating the Sioux quartzyte from the Animikie, making it a distinct formation of equal rank with the Animikie.
[6] In the Minnesota reports this has been considered the true Potsdam, but there is more reason to consider the Hinckley sandstone the true Potsdam. (See the discussion of the Potsdam region in this report).
[7] The term Coutchiching antedates Vermilion, but in the Minnesota reports already published, the latter has been used instead of the former.

II.

THE GEOLOGY OF

KEKEQUABIC LAKE

In Northeastern Minnesota

WITH SPECIAL REFERENCE TO

An Augite Soda-Granite

BY ULYSSES SHERMAN GRANT

A THESIS ACCEPTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE JOHNS HOPKINS UNIVERSITY, JUNE, 1893.

CONTENTS.

ILLUSTRATIONS.

PREFACE.

In this paper an attempt is made to present a description of the geology of a small part of the complex area of northeastern Minnesota in more detail than has been done hitherto. In order to give a connected account of the geology of this area it has been necessary to duplicate in small measure some of the former descriptions; this is true of part of the descriptions of some of the clastic rocks, the argillytes, graywackes and conglomerate. But some of the earlier accounts have been enlarged somewhat, and to the whole has been added a number of petrographical descriptions. The points of special interest in this paper, which have not been presented previously, are: (1) Petrographical description of the anomalous green schists. (2) Notice of a small area of hornblende porphyrite. (3) Investigation of the petrography of the granite, which is shown to be of a rather uncommon and interesting type—*an augite soda granite.* (4) Evidence is brought forward to show that the granite is of truly eruptive origin and that it is not a recrystallized condition of the sediments of the region *in situ*, as it has been considered in most of the previous papers on this region.

All of the field work and part of the laboratory work for the preparation of this article was done while the writer was in the employ of the Geological and Natural History Survey of Minnesota. During the summer of 1891, while studying several granite areas in northeastern Minnesota, several days were devoted to the granite of Kekequabic lake, and again, in the summer of 1892, more time was employed in studying the rocks around this lake. Thanks are due to Prof. N. H. Winchell, State Geologist of Minnesota, for assistance and advice during the prosecution of this work, and for his kindness in allowing part of the investigation to be carried on outside of laboratories of the Survey.

The writer also desires to express his sincere thanks to Prof. George H. Williams of the Johns Hopkins University for kindly aid and numerous suggestions from the beginning to the end of this investigation. To him is due in large measure whatever of merit this paper may possess.

The analyses were made by Profs. J. A. Dodge and C. F. Sidener of the University of Minnesota.

CHAPTER I.

GENERAL DESCRIPTION OF THE AREA STUDIED.

LOCATION.

The area described in this paper is a small portion of the triangle in Minnesota which lies between lake Superior and the Canadian boundary. This part of the state is made up of more or less highly crystalline rocks of pre-Cambrian age. The region described is about the centre of the northern side of this triangle. Kekequabic lake, the geology of whose shores is here presented, lies in the northeastern part of Lake county, in latitude 48° 2′ north and longitude 91° 6′ west of Greenwich. It is less than two miles south of Knife lake, which is one of the narrow bodies of water forming the boundary between Minnesota and Ontario.

The exact position of Kekequabic lake can be seen on Plate XLI, "Geological map of northeastern Minnesota," of Irving's paper "On the classification of the early Cambrian and pre-Cambrian formations."* A larger and more accurate map of the region is that included in the "Fifteenth (1886) Annual Report of the Geological and Natural History Survey of Minnesota"; and a still better one is that found in "The iron ores of Minnesota."†

The accompanying sketch map (Fig. 1) shows the western part of the lake Superior basin and the adjacent territory. A glance at this map will give a general idea as to the location of the region to be described in this paper. The star shows the approximate position of Kekequabic lake.

An area extending five miles in an east and west direction and about the same distance north and south is represented in the geological map (Plate II) and is the area described. It con-

*U. S. Geological Survey, 7th Ann. Rept, pp. 365-454, 1888.

†Geol. and Nat. Hist. Survey of Minn., Bull. No. 6, 1891.

tains sections 29, 30. 31 and 32 of township 65 N., range 6 W. of the 4th Principal meridian; sections 25, 26, 27, 34, 35 and 36 of T.65 N., R. 7 W.; sections 5, 6, 7 and 8 of T. 64 N., R. 6 W.; and sections 1, 2, 3, 10, 11, 12 and the east half of section 4 of T. 64 N., R. 7 W.

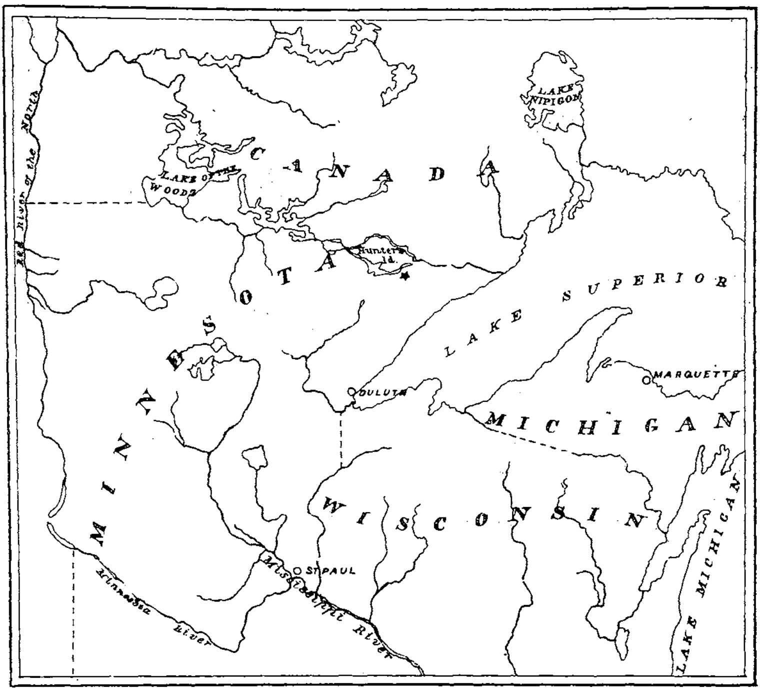

FIG. 1. Sketch map of the western end of lake Superior and adjacent territory showing the location of Kekequabic lake.

TOPOGRAPHY.

The surface is rough and hilly, though not strictly mountainous. The elevations consist of more or less broken parallel hill ranges, which trend a little north of east. The most important of these ridges lies along the south side of Kekequabic lake. In the southwest quarter of section 36, T. 65 N., R. 7 W., this range attains a hight of 240 feet above the lake level; farther east,—in the S. E. $\frac{1}{4}$ section 31, T. 65 N., R. 6 W., —it rises over a hundred feet higher, and two miles farther east, just outside the area of the map, are the twin peaks which are more than 500 feet above the lake or 2,000 feet above sea level. These peaks are visible for many miles in any direction and form the highest land in the northern part of Lake county. Kekequabic lake, as ascertained by level, is 1,498 feet above the sea. On the north shore of the lake is another noticeable ridge attaining an elevation of 260 feet in the N. E. ¼ section 35, T. 65 N., R. 7 W. Mallmann's peak is a continuation of the same ridge in the S. E. ¼ section 30, T. 65 N., R. 7 W.; its summit is some 250 feet above the lake, its southeastern front rising in an almost vertical precipice for 200 feet. The two hill ranges above mentioned are by far the most conspicuous in the area under consideration, but lower elevations of gentler slope are common. The western shores of the lake are comparatively low, and oftentimes the land is swampy for a considerable distance from the water's edge.

By far the larger part of the land surface is rough and hilly. The hills are almost entirely of rock, there being no drift ridges, but some of the elevations have parts of their surfaces covered by a thin mantle of glacial material. Between the hills lie lakes, which constitute about a third of the surface. There are also some low areas, which are swampy, but these are of considerably less extent than the lakes. The surface may be roughly divided into three parts,—hills, lakes and swamps,—in the relative proportions of 3, 2 and 1.

Very noticeable features of the topography are the precipitous cliffs, which rise vertically from the water's edge to the hight of from 10 to 200 feet. The highest of these, Mallmann's peak, has already been mentioned. Others occur on the north and south sides of Stacy island and along the south shore of the lake a short distance east of this island. These cliffs, as a rule, face toward the north or the south and they lie parallel with the hill ranges and the long axes of the lakes. It is quite probable that the cliffs occur along lines of faulting.

LAKES AND DRAINAGE.

The lakes of this region lie in rock bound basins, and a large number of them are elongated in a direction parallel with the hill ranges. From one rocky basin a short, rapid stream carries the water down to the next lower basin; in this way the greater part of the drainage is accomplished. These streams, connecting one lake basin with another, often have a considerable fall in a short distance; for instance the outlet of Epsilon lake, through which the waters from Kekequabic lake flow, descends 80 feet in a distance of about 100 yards. One of the cascades of this stream is shown in Plate I, Fig. 1.

Kekequabic lake, the largest in the area studied, is clear and deep. It is a narrow body of water, some five miles in length; its eastern half never reaches a width of more than half a mile, while its western part is broader, being nearly a mile and a half wide. To the north of Kekequabic lake lie several smaller lakes, more shallow and not surrounded by as noticeable hills.

The streams of the region, excepting those connecting one lake with another, are small and insignificant. They have cut no appreciable channels of their own and have carried very little sediment into the lakes. In no place has a stream begun to build a delta at its mouth. Since the lakes serve as resting places for what little sediment is brought down by these streams, the larger streams flowing from one lake to another are practically free from suspended material and so have little eroding power, even though they are often very rapid. Thus the surface is suffering comparatively little denudation and presents now almost the same contours and depressions which existed when the ice sheet departed. Then, as now, there were hills and deep valleys filled to their edges with water, and since then these lakes have been lowered very little by the wearing down of their outlets. The whole drainage follows the depressions left by the ice sheet and is not dependent on the character of the underlying material, be it drift or crystalline rock. The drainage of the Kekequabic basin is toward the north, through several small lakes lying north of the east end of this lake, to Knife lake,—one of the series of International Boundary lakes belonging to the Rainy Lake system.

SOIL AND FOREST.

The land surface is covered by but a thin layer of soil. This consists in places of glacial material, but where drift deposits are lacking a layer of soil of only a few inches thickness has accumulated. This scanty soil is entirely sufficient, even when but three inches deep, to support a luxuriant forest of conifers;—in fact the surface is usually covered by a thick growth of black pine (*Pinus banksiana* Lambert), red pine (*P. resinosa* Ait.) white pine (*P. strobus L.*), balsam fir (*Abies balsamea* Marshall), black spruce (*Picea nigra* Link.) and arbor vitæ (*Thuya occidentalis L.*); the last two are confined mostly to the lower ground. Considerable areas of the forest were burnt some years ago and these areas are now covered with a thick and tangled second growth, in which the white birch (*Betula* *papyrifera* Marsh) and aspen (*Populus tremuloides* Michx.) play an important part. This dense growth, coupled with thickly strewn fallen logs, renders exploration of such areas unusually difficult.

ROCK EXPOSURES.

Around the lake shores there are rather frequent exposures. The outcrops vary greatly in size, and their frequency and extent do not seem to be conditioned by the character of the rock, the softest and most easily eroded often extending for considerable distances along the lake shore; this is especially noticeable in the case of the soft, fissile, green schist, which is seen in such large development along the north side of the central part of the lake. However, there are stretches of shore a quarter of a mile or more in length where no rock is to be seen *in situ*; this is generally true along the low and swampy shores and in a few other places where there are larger accumulations of drift than is usual. In some cases, as before mentioned, almost vertical cliffs rise directly from the water's edge from 10 to 200 feet above the lake surface. Along these cliffs and elsewhere on the steeper hillsides numerous and extensive exposures are accessible. Along the streams there are fewer outcrops than would be expected, for the streams usually flow in depressions more or less filled with glacial material and they have as yet but infrequently cut down to the underlying rock; in fact their channels are generally boulder filled, and, contrary to a geologist's expectation, he can find little clue to the underlying rocks by following up these stream beds. Many of the hills, especially those of gentle slope, show no outcrops, and it is only on their summits and steep sides that one finds many large exposures away from the actual lake shore. The comparative thinness of the drift and its almost total absence over areas of some extent would seem favorable to the existence of more extensive exposures than are to be found. But in many cases where the drift is almost absent vegetation has gained a foothold, and at present the rock is covered with soil, moss, rock-fragments and decaying sticks and logs, the whole forming a layer two inches to two feet in thickness, firmly bound together by numerous roots, so that with the aid of merely a hammer the subjacent rock is as inaccessible as when buried under several feet of drift.

The weathered and decayed rock of the whole region has been almost completely carried away by glacial action; and since the departure of the ice there has been but little surface decay, such as there is extending but a fraction of an inch below the surface. Thus the exposures, with few exceptions, furnish clean and unweathered specimens. The only rock which shows evidence of post-glacial decay and alteration is the green schist, and this is decaying in but a few places, the most noteworthy being on the extreme western side of the promontory from the north side of the lake, at the northeast corner of section 31, T. 65 N., R. 6 W. From this it is not to be supposed that the rocks are in a perfectly unaltered state, for their minerals have been more or less affected by destructive processes, other than mere surface weathering, acting through long geological ages, but the rocks are now in practically the same condition as at the end of the Glacial period.

OUTLINE OF GEOLOGICAL FEATURES.

The northern edge of Lake county, where Kekequabic lake is situated, is composed entirely of pre-Cambrian rocks, which have suffered more or less metamorphism. Leaving out of consideration their exact stratigraphical positions and designations, we shall proceed to a very brief description of the various rock types. The discussion as to the nomenclature, precise age and relationships of the various formations is reserved for another part of this paper.

By far the larger proportion of the rock masses represented in this area are sedimentary in character, but some of the material is of volcanic origin and some of this was probably deposited in water. These sediments may be divided for convenience into four groups, although this division is arbitrary to some extent, as the different groups are not always sharply separated from one another. The first and by far the most widely developed group is that which may be termed the slate formation. This consists largely of argillytes, with smaller amounts of fine and coarse graywackes and grits. The argillytes, graywackes and grits are closely associated with each other, being oftentimes intimately interbanded, so that it is impossible to map them separately. The coarser facies of the rocks just mentioned often become distinctly conglomeratic in small areas, and in other places there are conglomerates which are composed of very coarse boulders;—these conglomeratic rocks form the second group. The third group is made up of certain peculiar, fissile, green schists, which have usually been called chloritic schists. While the fourth group is composed of more or less marked fragmental volcanic material, which in places shows a banding apparently due to deposition in water. These clastic rocks have been greatly disturbed since their deposition, and they now stand in nearly vertical positions with a strike that is a little north of east.

Sharply marked off from the clastics are four types of igneous rocks, whose age, with perhaps the exception of the first, is later than that of the surrounding clastics. The first of these igneous rocks is a peculiar, purple, hornblende porphyry, more precisely a hornblende porphyryte. The other rocks of igneous origin are granite, diabase and gabbro. The first is divisable into two types,—the ordinary granite and a granite porphyry, the latter of which is seen only in small patches. These two types of granite are of interest from the fact that their ferro-magnesian constituent is almost exclusively pyroxene and that the predominating feldspar is anorthoclase. The diabase is found only in a few small dykes cutting all the other rocks, excepting possibly the gabbro. Unconformably above all the other rock series is a coarse grained gabbro. The country shows no remains of any strata younger than the gabbro, which is of Keweenawan age, and older than the drift.

PREVIOUS LITERATURE.

The descriptions of the rocks of Kekequabic lake are to be found almost wholly in the reports of the Geological and Natural History Survey of Minnesota, and a list of references to this locality is here appended (I). Under each reference are a few words briefly explaining the character of the descriptions; the articles are given in order of date of publication. Following this list is another (II) giving the titles of the more important papers which relate to the rocks of northeastern Minnesota that occur at Kekequabic lake; this second list makes no pretensions to completeness.

I. *Articles relating to Kekequabic Lake.**

1882.—N. H. Winchell. 10th (1881) Ann. Rept., pp. 92-93.
A single specimen (No. 751) of peculiar porphyry (hornblende porphyryte) is reported from Mallmann's peak.

*All the articles in this list, excepting the last, are to be found in the publications of the Geological and Natural History Survey of Minnesota.

1887.—M. E. Wadsworth. Bull. No. 2, Preliminary description of the peridotytes, gabbros, diabases and andesytes of Minnesota, pp. 124-125.
A microscopical description of the above mentioned specimen of hornblende porphyryte is given and sections of it are figured (Pl. X, Figs. 1 and 2).

1887.—A. Winchell. 15th (1886) Ann. Rept, pp. 148–156.
Detailed field descriptions confined mostly to the south shore of the lake.

1887.—N. H. Winchell. 15th (1886) Ann. Rept., pp. 361–369.
Field notes on the rocks of the lake shore. Special attention is given to the structure and origin of the gneiss (granite) and porphyry (granite porphyry).

1888.—N. H. Winchell. 16th (1887) Ann. Rept., pp. 100–108.
A continuation of the last report with some general statements concerning the genesis and relationships of the various rock-series.

1888.—A. Winchell. 16th (1887) Ann. Rept., pp. 321–327.
Field notes about Epsilon lake. An unconformity is noticed between the Animikie and Keewatin and mention is made of several exposures of purple porphyry (hornblende porphyryte).

1893.—U. S. Grant. 20th (1891) Ann. Rept., pp. 69–82.
Field notes on the region about Kekequabic lake, with special reference to the granite. It is stated that the gneiss of the former reports is a fine grained pyroxene granite and that the porphyry is a pyroxene granite porphyry.

1893.—U. S. Grant. Note on an augite soda-granite from Minnesota; Amer. Geologist, vol xi, No. 6, pp. 383–388.
A preliminary petrographical description of the granite of Kekequabic lake is given. It is shown that the rock is an augite soda-granite with a large percentage of soda, which finds expression in the composition of the augite as well as in that of the feldspar.

II. *Articles on northeastern Minnesota and adjacent territory.*

N. H. Winchell.—Geol. and Nat. Hist. Survey of Minn., 7th (1878) Ann. Rept., 1879.—9th (1880) Ann. Rept., 1881.—10th (1881) Ann. Rept., 1882.—11th (1882) Ann. Rept., 1883.—13th (1884) Ann. Rept., 1885. —15th (1886) Ann. Rept., 1887.—16th (1887) Ann. Rept., 1888.—17th (1888) Ann. Rept., 1889.—20th (1891) Ann. Rept., 1893.
The Norian of the Northwest; Geol. and Nat. Hist. Survey of Minn., Bull. No. 2, pp. iii–xxxiv, 1893.

R. D. Irving—The copper-bearing rocks of Lake Superior; U. S. Geol. Survey, Mon. vol. 5, 1884.
Preliminary paper on the investigation of the Archæan formations of the northwestern states; U. S. Geol. Survey, 5th Ann. Rept., pp. 175-242, 1885.
On the classification of the early Cambrian and pre-Cambrian formations; U. S. Geol. Survey, 7th Ann. Rept., pp. 368–454, 1888.

A. C. Lawson.—Report on the geology of the Lake of the Woods region, with special reference to the Keewatin (Huronian?) belt of Archæan rocks; Geol. and Nat. Hist. Survey of Canada, new series, vol.

1, pt. CC, 1885. Report on the geology of the Rainy Lake region; Geol. and Nat. Hist. Survey of Canada, Ann. Rept. 1887, vol. iii, pt. F, 1889.

A. Winchell.—Geol. and Nat. Hist. Survey of Minn., 15th (1886) Ann. Rept., pp. 7-207, 1887.—16th (1887) Ann. Rept., pp. 131-391, 1888. Conglomerates enclosed in gneissic terranes; Amer. Geologist, vol. 3, pp. 153-165, 256-262, 1889.

H. V. Winchell.—Geol. and Nat. Hist. Survey of Minn., 15th, (1886) Ann. Rept., pp. 401-417, 1887.—16th (1887) Ann. Rept., pp. 393-463, 1888. —17th (1888) Ann. Rept., pp. 75-145, 1889.

N. H. and H. V. Winchell.—The iron ores of Minnesota; Geol. and Nat. Hist. Survey of Minn., Bull. No. 6, 1891.

C. R. Van Hise.—An attempt to harmonize some apparently conflicting views of Lake Superior stratigraphy; Amer. Jour. Sci., 3, vol. xli, pp. 117-137, Feb., 1891.

CHAPTER II.

THE ROCK FORMATIONS REPRESENTED.

In this chapter the different rock formations occurring in the area studied are considered in succession, but two of them—the granite and the porphyryte—are reserved for a more detailed treatment in the following chapters. In the first place the different formations, already briefly mentioned in an "Outline of geological features" in Chapter I, are to be considered lithologically and structurally. These will be taken up in the order of their supposed ages, and the discussions as to their comparative ages and relationships are brought together at the end of this chapter. It is fair to state at the outset that the following division of the clastic rocks is partly for convenience in description, and is not wholly due to the fact that they can all be distinctly separated from each other in the field or in hand specimens. Nevertheless, it is possible to recognize more or less distinctly the following rock types:—argillyte, graywacke, grit, conglomerate, green schist and volcanic tuff. The first three are often so intimately interbedded that it is impossible to separate them in mapping and general description; consequently they are grouped together and form what is termed the slate formation. The other types are more easily separated from each other and from the slate formation, and they have therefore each been mapped separately; but the boundaries shown on the geological map (Plate II) are of only approximate correctness for this reason: these rock types often seem to pass by insensible transitions into one another and each occcurs in small amounts interbanded with the others so that separation is not possible. However, there are certain areas where one type covers a large proportion of the surface and such areas have been mapped as though composed of that type. The conglomerates have been included in the rocks to which the above remarks apply, although there is a possibility that the coarse conglomerate is of a later age than the surrounding clastics; this question will be considered in another place.

THE ANCIENT CLASTIC ROCKS.

These form the country rocks of the region; geographically they cover perhaps three fourths of its area. The different parts of this series,—the slate formation, the green schist, the tuff and the conglomerate,—are more or less closely related and have many characters in common.

The strike, with some local exceptions, varies from N. 40° E. to N. 75° E., the average being about N. 60° to 65° E., which is the usual strike of similar rocks in this part of the state. The dip varies a few degrees either side of the vertical, but rarely becomes lower than 70°. This general strike and dip are practically constant over the whole area. There is, however, one noticeable exception to the general strike of the rocks of this region; this is in the west half of section 6, T. 64 N., R. 6 W., where for a considerable distance the strike is almost exactly north and south, the dip being about vertical.

The clastic rocks have been subjected to considerable dynamic action and as a result all except the coarse conglomerate have acquired slaty and schistose structures in many places. This is especially true of the argillytes and green schists, but in most cases where undoubted stratification appears it is practically coincident with the slaty or schistose structure. There are however many outcrops which show one of these secondary structures without exhibiting any distinct lines of sedimentation. And in this connection it should be stated that evidences of sedimentation are lacking over exposures of considerable size; this is especially the case in the conglomerates, tuffs, graywackes and grits, but is also true to a less extent in the argillytes. All of the clastic rocks, excepting the green schists and argillytes, are often seen possessing no evidence either of sedimentary lamination nor of secondary parallel structures; in such cases the graywackes frequently present the appearance of fine-grained massive rocks.

The slate formation.

The larger part of the area described is composed of rocks belonging to this formation. It includes almost all the northern half of the region mapped,—in fact the whole portion of the area north of Kekequabic lake, except small areas of green schist, tuff and hornblende porphyryte, is made up of rocks belonging to this formation. It also occupies the eastern side and all of the southeastern quarter of the map, but does not occur in the southwestern quarter. These rocks reach a greater development outside of the immediate vicinity of Kekequabic lake and form a large proportion of the Keewatin rocks in Minnesota.

Lithologically the slate formation is divisible into three parts:—argillyte, graywacke and grit. The first covers some areas almost exclusively, but the others, while found in large amount, are never entirely free from bands of argillyte. Still there are certain portions of the surface where grit or graywacke is developed to almost the complete exclusion of the argillytes. These three types of rocks are found grading into each other. This is especially noticeable in the case of the graywackes and argillytes, the finer grained slaty facies of the former passing by indistinguishable steps into gray argillytes. In mapping it is of course impossible to separate areas of argillyte from those of grit or graywacke as they are so intimately interbedded, but under the description of each is given its distribution in areas where the two others are largely absent.

Argillyte.—The larger part of the region north of Kekequabic lake and also a considerable part of section 6, T. 64 N., R. 6 W. is occupied by argillytes. They are found in their best development, comparatively free from bands of grit and graywacke, just to the west and northwest of Kekequabic lake and around the shores of Epsilon lake. In color the argillytes are generally rather dark, nearly black or dark gray, but they often vary towards greenish and lighter gray tints and in one place near the corner of the bay, in which is Stacy island, to a reddish shade. Evidences of stratification are quite generally present, being shown by alternating bands of lighter and darker shades, these bands usually being from one quarter of an inch to an inch in width. Rarely there are seen areas of the darker slates where sedimentary lines are obscure or entirely lacking. The darker varieties show the best developed slaty cleavage, but in no place is this continuous and perfect enough to make the beds of economic importance.

The argillytes vary in composition in two general directions. First, by the addition of more and more silicious matter, they grade into silicious schists; variation in this direction is marked by a change in color to lighter and lighter gray. When the silica becomes more abundant and is in distinct grains the rock is approaching the graywackes and grits. Variation in the second direction is due to the addition of a chloritic or hornblendic (actinolite?) constituent often accompanied by an increase of silica; the rock thus assumes a greenish color and a less cleavable character. Such green slates are tough and very hard. In one place near the southeast end of Pickle lake there are narrow bands of red and black jaspilyte interbedded with these green slates. These jaspilyte bands are the nearest approach to iron ore in the immediate vicinity of Kekequabic lake. Another direction of change for the argillytes is toward sericitic schists; this variation is not seen commonly at Kekequabic lake, but is shown to some extent.

Graywacke.—This rock occurs in its best development around the east end of Kekequabic lake. It is seen in especially fine exposures in the S. W. ¼ section 29, T. 65 N., R. 6 W. It varies in grain from quite coarse graywacke, with quartz grains $\frac{1}{16}$ to ⅛ inch in diameter, to a very fine gray slate. The coarser facies occur in massive beds from a few inches to many feet in thickness, and often show no parallel structures, either original or induced. Since this rock has been fully described in the reports on northeastern Minnesota it seems preferable to give a few quotations from the published descriptions of Dr. Alexander Winchell than to attempt any new description.

"The best characterized graywackes are obscurely bedded, dark gray and composed of fine grains of quartz and feldspar mostly but not exclusively monoclinic, all imbedded in a sparse or copious groundmass of a silico-argillaceous character. Disseminated through the rock are generally some black specks of an anthracitic character. Peroxide of iron also, is often present. From the condition thus described the variations are very marked. Often through an excess of quartz and a high silicification of the groundmass, the rock becomes impure-flinty, and under the influence exerted by heat, has acquired a ringing hardness, accompanied by two or three sets of jointage planes, which divide the mass into cuneiform portions. It thus seems to answer the description of *hornfels.* This condition is approximated very frequently. But, far from being persistent, we often see it pass rapidly into a well bedded terrane. In another direction, the feldspathic constituent exists in increased quantity, and the dark aspect of the other ingredients gives the rock a diabasic look, especially when, as is mostly the case, all bedded structure is completely disguised. At times it is almost impossible to decide macroscopically whether the rock is a real diabase, an anamesitic doleryte, or only an altered and aberrant graywacke."*

*Geol. and Nat. Hist. Survey of Minn., 16th (1887) Ann. Rept., p. 339, 1888.

"A very conspicuous feature of the schist belt is the frequent and abrupt transition from a pronounced slaty structure to a massive structure, in which the bedding planes are obscure, and in many cases scarcely discoverable. These massive conditions present the ordinary external appearance of diabase, and sometimes of dolerite; and it requires many observations to convince one's self that none of these are truly eruptive. At times these masses are cut by joints into cuneiform cuboids, ringing and flinty, precisely like rocks of eruptive origin; and if one were to restrict his observations to a few such occurrences, he would feel persuaded that large portions of the region are occupied by true dykes of enormous extent. But with surprising abruptness these rock-masses are seen assuming a more earthy character and losing their eruptive features. Close by, the lines of an ancient stratification come into view, and these always conform to the rule of the region. The rock may now be seen more distinctly to contain an important quartzose constituent. This is sometimes in fine, almost indefinite grains and sometimes a silicious groundmass. A different condition of the rock contains, with more or less quartz, a considerable feldspar—mostly orthoclase, but partly triclinic. This appears sometimes in distinguishable grains imbedded in the silicious or silico-argillaceous groundmass, and sometimes as a feldspathic groundmass holding obscure grains of quartz. Not unfrequently the groundmass appears to be a real petrosilex. In all cases the rock possesses great hardness and toughness. These are the macroscopic characters of a range of rocks which I have called graywacke."*

Grit.—This name is applied to a part of the slate formation which makes up the north side of the high hill in the S. E. ¼ section 31, T. 65 N., R. 6 W. The rock called grit is very intimately interbanded with fine bands of argillyte. The beds of grit vary from a fraction of an inch to fifty feet in width, and, aside from the interbanding of the argillite, show no sedimentary lamination or slaty cleavage.

This rock seems to be somewhat different from anything that has been described in the Minnesota reports; it was mentioned by the writer in one place,† but no special description was given. It is a dark gray to black rather fine grained rock showing numerous macroscopic glistening quartz grains and a few feldspar grains imbedded in a dark ground mass. The

*Ibid., 15th (1886) Ann. Rept., pp. 173-174, 1887.

†Ibid., 20th (1891) Ann. Rept., p. 79, 1893.

grains of quartz and feldspar and rock fragments (to be mentioned below) are usually from one-half to two milimeters in diameter,—often smaller and rarely larger. Under the microscope the rock is seen to be composed of sub-angular fragments of quartz and feldspar imbedded in a groundmass, which is made up almost entirely of green hornblende. The hornblende occurs in fibers and irregular grains. The fibers often are of minute size and penetrate the rock mass in all directions; they even seem to extend for short distances into certain quartz grains. Small fragments of various massive rocks are also present, noticeable among which are a porphyryte and a fine grained granite porphyry very similar to the porphyritic facies of the granite of the region, but showing no augite. The grit thus appears to be a rather impure sandstone with considerable interstitial matter, which has recrystallized as hornblende. This development of hornblende in the clastics of northeastern Minnesota is of interest as it is of so widespread occurrence. It has been noticed in the quartzites of the Animikie* and in the Ogishke conglomerate, and, as will be mentioned below, is very characteristic of the green schists and tuffs.

Green schist.

Within the area under consideration there occur certain green schists of a rather anomalous character. They are of a dull green color and are rather soft, crumbling easily under the hammer. These rocks have been often described in the reports on this region as "soft green schists" and "chloritic schists," but, as is shown below, they are essentially composed of hornblende.

These schists are found well developed in some places. A small belt occurs just north of Kekequabic lake in the E ½ section 34, T. 65 N., R. 7 W.; also at the west end of the lake in the N. E. ¼ section 4, T. 64 N., R. 7 W., along the N. ½ section 11, T. 64 N., R. 7 W., and on the south shore in the N. W. ¼ section 32, T. 65 N., R. 6 W. But by far the largest and most typical exposures are to be seen in a narrow belt along the north side of the lake in sections 35 and 36, T. 65 N., R. 7 W., and the S. W. ¼ section 31, T. 65 N., R. 7 W.; perhaps the best of these exposures occur on the small islands near the center of section 36, T. 65 N., R. 7 W.

*W. S. Bayley. Notes on the petrography and geology of the Akeley Lake region in northeastern Minnesota; Ibid., 19th (1890) Ann. Rept., p. 194, 1892.

These outcrops almost everywhere show a distinct schistose structure, which is more pronounced where the rock has weathered. There are also in many places clearly defined lines of sedimentation; these can be seen in great perfection on a little island in the S. W. ¼ section 35, T. 65 N., R. 7 W. And here, as well as at some other localities, there are numerous rounded green pebbles of about the same composition as the green schist. These pebbles are clearly brought out by weathering and wave action, being slightly more resistant to these agencies of destruction than the rock itself, which decays and crumbles readily. There are also occasionally seen quartz bebbles arranged in parallel lines, thus giving additional traces of original sedimentary planes.

The green schist is usually of rather fine grain and is sometimes so fine that it appears homogeneous. In the coarser varieties it macroscopically seems to be composed of small, glistening flakes in an unindividualized groundmass. Under the microscope the rock is seen to consist of closely crowded green hornblende crystals imbedded in a fine fibrous groundmass. These hornblendes are usually in short stout prisms but little elongated in the direction of the vertical axis. They are rarely more than half a millimeter in length and the average are not more than half this size. They are commonly not completely idiomorphic, although sometimes they are. The prismatic planes are, however, very generally quite distinct, but the terminal faces are not so often well developed and are usually entirely absent. The hornblende is of the usual green variety, although some crystals are inclined to a brownish shade. Its pleochroism is quite distinct, $\mathfrak{a}$ being light greenish yellow, $\mathfrak{b}$ olive green to brownish, and $\mathfrak{c}$ bluish green. The absorption formula is $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$, although the rays vibrating parallel to $\mathfrak{c}$ and $\mathfrak{b}$ are nearly equally absorbed, and the color is frequently almost the same in the direction of both of these axes.

The ends of many of the hornblende crystals, as stated above, show no terminal planes, but they have fibrous prolongations running out into the groundmass. These fibrous ends are commonly not sharply marked off from the crystal proper and no line can be drawn between them, the fringe being of the same color as the rest of the crystal and optically continuous with it. It however happens that some of the hornblendes, especially those of a brownish shade, show sharp terminal planes, beyond which is the fibrous growth optically continuous with the crystal; but this fringe is of a different shade from the crystal proper, being greenish instead of brownish. These fringes are always confined to the ends of the crystals and are not seen on the prismatic planes.

The fringes of hornblende fibers closely resemble the secondary enlargements of hornblende grains and crystals described by C. R. Van Hise* and they also appear very similar to those figured from the Menominee region of Michigan by G. H. Williams, who considers them not to be secondary enlargements but "the result of bleaching and fraying out of originally compact hornblende."† It seems to the writer that the fibrous rims in the green schist under consideration are due to enlargement or a second period of hornblende growth, as the rock is perfectly fresh and shows no evidence that the hornblende has suffered bleaching.

The groundmass of the green schist is quite fine and is composed almost entirely of interlacing fibers of hornblende. There are also small areas of colorless, weakly refracting, substance which is apparently saussurite; the hornblende fibers penetrate this in all directions.

The original nature of the green schist is not very evident. That it is a water deposit is, however, clear. As already mentioned it often shows distinct sedimentary lamination and the laminæ are frequently seen, where the rock has been more or less crumpled, running in wavy lines at various angles to the schistose structure. The difference between the laminæ appears usually only on weathering, as some are more resistant than others. One thin section cut across the lamination and schistosity, where these are parallel, shows many cross sections of hornblende, thus proving that a considerable number of the hornblende crystals have their vertical axes lying approximately parallel to the schistose planes of the rock. To the cleavage of these crystals is due, at least in some measure, the schistose structure of the green schists. This section also shows two laminæ, the only difference between them being that in one the hornblendes are noticeably larger and that there is a small amount more of the saussurite substance than in the other. It seems improbable that the fresh and sharply outlined crystals of hornblende should have been deposited in that state, and so the rock appears to have been entirely recrystallized from its original condition. If such is the case there would

*Enlargements of hornblende fragments; Amer. Jour Sci., 3, vol. xxx, pp. 231-235, Sept., 1885.

†The greenstone schist areas of the Menominee and Marquette regions of Michigan; U. S. Geol. Survey, Bull. No. 62, p. 126, fig. 19, 1890.

seem to have been two periods of hornblende formation, to the second of which belong the fibrous enlargements of the crystals and very likely the fibrous groundmass.

The occurrence of sharply outlined crystals of hornblende of secondary origin in a clastic rock has already been mentioned. Reusch* has described a conglomerate from Norway in which there are hornblende needles ("epigenetic hornblende") lying in the matrix of the conglomerate, and also running from the matrix into the pebbles, thus proving the secondary origin of the hornblende.

As to just what was the nature of the original sediment which formed the green schist it is impossible to decide, but it seems probable that it was a fine water deposited volcanic ash, now entirely recrystallized. This idea is strengthened by the fact that these green schists are rather intimately connected with the next rock type,—an undoubted tuff,—and the two grade together; and in the latter are also found similar crystallizations of hornblende.

Volcanic tuff.

Extending along the central part of the north shore of Kekequabic lake and separated from the water by a narrow belt of green schist, is a prominent ridge ending on the east in Mallmann's peak. This ridge is made of hard tough rock, which, excepting at its eastern end, is different from any rock in the vicinity. It varies much in general appearance but is usually of a greenish color with an aphanitic base in which are seen numerous lighter blotches and changes of color. Between these blotches, and sometimes in them, are black crystals of hornblende. Pyrite is also quite commonly seen. In certain places rounded and subangular pieces of quartz and argillyte are embraced in the rock, and it is also seen gradingin to the green schists. Parallel bandings similar to sedimentary laminæ also occur, sometimes quite abundantly, but usually the rock shows no structural planes of any kind, nor any schistose or slaty cleavage.

In thin section this rock varies much, but its fragmental character is easily discernible. The original nature of the fragments, which are usually angular, is, however, not very evident owing to alteration and the development of second-

* Die Fossilien fuehrenden krystallinischen Schiefer von Bergen in Norwegen, p. 50, Leipsic, 1883.

ary minerals in the rock, but it seems that a porphyryte forms most of these fragments. Between the fragments and forming the groundmass of the rock, and often in the fragments themselves, are many hornblendes similar to those in the green schist. And there are also areas of secondary hornblende filling in old crystal outlines; what these crystals originally were is not clear, although they probably were pyroxenes.

That the Keewatin rocks northwest of lake Superior are to a considerable extent composed of volcanic (effusive) material has been stated already by G. M. Dawson,* A. C. Lawson† and N. H. Winchell. Although the material of much of the Keewatin in Minnesota has been assumed to be volcanic tuff and finely divided, water-deposited ash, still the actual number of places where the rocks have been shown to be composed of such volcanic matter is very small. M. E. Wadsworth has described a few sections of fragmental volcanic rocks—porodytes‡—, and N. H. Winchell has given an account of an agglomerate from Ely.§ Aside from these the writer knows of no descriptions of rocks from the Keewatin of Minnesota that are clearly shown to be of volcanic origin. That some of the rocks about Kekequabic lake, especially the green schists, were composed of fragmental volcanic material has been suggested before.‖

Conglomerate.

While conglomeratic patches of very limited extent, holding only small pebbles, are found at various places in the rocks already described, especially in the green schists, still these areas have never been large enough or common enough to entitle the rock to be designated as a conglomerate. However, a conglomerate containing numerous rounded and closely crowded pebbles, which often reach a size of over a foot in diameter, occurs near the south shore of Kekequabic lake at its narrowest point. There has been no unconformity found between this rock and the finer grained non-conglomeratic rocks near it, although the bedding in the conglomerate is obscure; and it seems to grade into the other rocks by simple loss of its peb-

* British N. A. Boundary Commission, 1875.

† Geol. Surv. of Canada, vol. iii, pt. i, 1888.

‡ Ibid., Bull. No. 2, 1887.

§ Amer. Geol., vol. ix, pp. 359-368, June, 1892.

‖ N. H. Winchell. Geol. and Nat. Hist. Surv. of Minn., 16th (1887) Ann. Rept., p. 108, 1888.

bles. This conglomerate is part of what has been termed the Ogishke Muncie or simply the Ogishke conglomerate. It has been frequently described and discussed as far as our present knowledge of it will allow, and consequently it need not be further spoken of here. The reader is referred to a paper by the writer where full references are given to the descriptions of this conglomerate and to the ideas that have been advanced concerning its stratigraphic relationships.*

THE IGNEOUS ROCKS.

There are four distinct types of igneous rocks represented within the area treated in this paper. In order of their probable ages they are: porphyryte, granite, diabase and gabbro. Of these the first two have been made subjects of somewhat detailed investigation, the results of which are contained in the two following chapters. The other two types of igneous rocks are developed within the area studied only to a small extent, and they are therefore given but a brief description in this place.

Diabase.

Diabase is found in this area only in vertical dykes which do not form any very prominent features of the country. These dykes are of later age than, and cut all the other rocks of this region, with the possible exception of the gabbro. The most westerly occurrence of diabase is at the base of the small promontory in Kekequabic lake in the S. W. ¼ section 3, T. 64 N., R. 4 W. Here this rock was seen only in one place and the direction of the dyke is not known. A dyke thirty feet in width is found along the south shore of Spoon lake in the S. E. ¼ section 26, T. 65 N., R. 7 W.; its direction is N. 40° E., and it is again seen a short distance to the northeast cutting across a point on the north shore and forming the center of a low ridge. Just to the west of this place and on the north side of the same lake is a fine grained dyke three feet wide; this runs almost at right angles to the other. On the eastern half of Kekequabic lake are three dykes with a nearly north and south direction; each is seen on both sides of the lake. The most westerly is in the N. W. ¼ section 31, T. 65 N., R. 6 W., and the most easterly is seen on the north shore in the

* The stratigraphic position of the Ogishke conglomerate of northeastern Minnesota; Amer. Geologist, vol. x, no. 1, pp. 4-10, July, 1892.

S. W. ¼ section 29 and on the south shore in the N. W. ¼ section 32, T. 65 N., R. 6 W. The other crosses the lake just east of Mallmann's peak; it appears above the water twice in its course across the lake and forms two small islands; this dyke has been described by N. H. Winchell* and by A. Winchell.‡

Just east of the centre of section 32, T. 65 N., R. 6 W., is another dyke running north and south, which has been traced but a short distance. Near the southwestern end of Epsilon lake are two more dykes; the smaller one, fifteen feet wide, runs in a northwesterly direction and is seen on both sides of the lake. The other is the largest seen in this region, being over 150 yards in width. It is very coarse grained in the centre, and sends off small branching dykes into the surrounding rock.

A thin section of the diabase from the most easterly of the dykes that cross Kekequabic lake shows the rock to be a coarse ophitic aggregate of plagioclase and a pinkish augite. There is considerable iron ore, probably magnetite, present and large amounts of secondary hornblende have been developed, not only as replacements of part of the augite but also in numerous films all through the section. The plagioclase is in places undergoing alteration to sericite. A section from the larger of the two dykes on Spoon lake is of medium grain and contains a very large proportion of augite, which however does not show as pronounced a pinkish tinge as that in the other section. Much of the plagioclase appears cloudy in ordinary light and under crossed nicols is seen to have largely altered to sericite. Secondary hornblende is not as common as in the other dyke.

Gabbro.

This type of igneous rock occurs only along the southern side of the area studied. The gabbro is quite coarse grained and shows many variations, which have been described already quite fully, and no further mention of it need be made here except to refer to Irving's description§ and to those in the reports of the Geological and Natural History Survey of Minnesota.†

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* Geol. and Nat. Hist. Survey of Minn., 15th (1886) Ann. Rept., p. 368, 1887. 16th (1887) Ann, Rept., p. 101, 1888.

‡ Ibid., 15th (1886) Ann. Rept., p. 153, 1887.

§ The copper-bearing rocks of Lake Superior; U. S. Geol. Survey, Mon. V, pp. 37-61, 1884.

† Especially Bulletins Nos. 2 and 6; also some of the Annual Reports.

However, it will be of interest to speak briefly of a peculiar rock, which is mapped as a contact rock of the gabbro. This has been mentioned many times in the reports of the Minnesota Survey as "muscovado." It is, as usually seen, a brownish, fine grained, granular, rock which easily crumbles under the hammer; this is, however, only the weather parts of the rock, and in fresh exposures it is dark gray, of granitic texture and rather fine grain. This rock is confined to the northern limits of the gabbro and is seen in many places along this line and to the south of it. It is now known that part of the rocks included under the term "muscovado" are altered portions of the Keewatin sediments, probably metamorphosed by the action of the gabbro. Such rocks can be especially well seen on the east shore of Gabimichigama lake in section 32, T. 65 N., R. 5 W. On the other hand it seems very probable that large parts of the so-called "muscovado" will be found to be fine grained gabbros;—perhaps a facies of the gabbro presented near its contact with the underlying rocks, or fine grained gabbros of a little earlier date than the main coarse grained gabbro mass. Sections of such rocks show them to be nothing but fine grained gabbros.

DRIFT DEPOSITS.

From the gabbro, which is of Keweenawan age, there are no evidences of any other geological formations having been deposited in this region until coming to the drift. However, near the northern edge of the gabbro and considerably farther west Cretaceous strata have been recently found and it is possible that these deposits once existed much farther east in northeastern Minnesota than they are now known.* Traces of glacial action are very evident in many rounded knobs of ice-scored rock and in scanty deposits of sand, gravel and boulders. The tops of the highest hills show glacial striæ and often are more or less strewn with foreign boulders. There are, however, no recognized moraines about Kekequabic lake, and wherever the drift is present it is at most of only a few feet in thickness.

*H. V. Winchell. Note on Cretaceous in northern Minnesota; Amer. Geologist, vol. xii, no. 4, pp. 220-223, Oct., 1893.

AGES OF THE DIFFERENT ROCKS.

The rocks around Kekequabic lake, excepting the gabbro and diabase, have been considered in the reports of the Minnesota Survey as belonging to the Keewatin; this is the Minnesota equivalent of the Lower Huronian, as that term is used by the United States Geological Survey.* To this series would be referred the slate formation, the green schist and the volcanic tuff, which seem intimately connected with each other and are probably the oldest rocks in the area studied. The conglomerate contains numerous well rounded pebbles, many of which are similar to some of the Keewatin rocks, and it seems to belong to a newer series, although as yet no unconformity has been seen between this conglomerate and the other rocks.

That this conglomerate is a conformable part of the Keewatin is the view of N. H. and A. Winchell, while Lawson holds the same view, but regards it as representing a newer infolded part of this series, probably separated from the rest of the Keewatin rocks by an unconformity. Van Hise considers the conglomerate to belonging to a newer series,—the Animikie (Upper Huronian),—which is separated from the Keewatin (Lower Huronian) by a marked unconformity. The writer is inclined to the view of Lawson, *i. e.* that the conglomerate is part of the Keewatin, probably separated from the lower part of that series by an unconformity, and that it is much older than the Animikie.†

An unconformity, considered to exist between Keewatin schist and Animikie slate, has been described by A. Winchell on the northeastern shore of Epsilon lake,‡ just outside the area mapped in this paper. This unconformity has not been recognized about Kekequabic lake.

From our present knowledge we have no positive proof that there is more than one series of clastic rocks in the Kekequabic lake area, but there are certain facts which suggest the possibility of two unconformable series being here represented. The clastic rocks of the whole region have been subjected to severe folding and have in many places acquired secondary structures, so that the exact structure and sequence can be determined

*Cf. C. R. Van Hise. Correlation Papers—Archaen and Algonkian; U. S. Geol. Survey, Bull. No. 86, 1892.

† References to the views concerning the age of the Ogishke conglomerate will be found in the writer's paper "The stratigraphic position of the Ogishke conglomerate of northeastern Minnesota;" Amer. Geologist, vol, x, no. 2, pp, 4-10, July, 1892.

‡ Geol, and Nat. Hist. Survey of Minn,, 16th (1887) Ann. Rept., p. 323, 1888.

only by careful and detailed work. Future investigations may show that the whole is one conformable series, or that there are two unconformable series, to the younger of which belongs the conglomerate, and perhaps some of the other rocks.

The porphyryte has been regarded as of Keewatin age and there is nothing to show that the granite cut rocks of a more recent age than the Keewatin. The gabbro is usually regarded as of early Keweenawan age. The age of the diabase dykes is not known; they were perhaps cotemporaneous with the great diabase intrusions in the Animikie, which have been referred to Animikie, Keweenawan, and perhaps even to Silurian* time.

The porphyrite and granite do not show the results of having been subjected to intense dynamic action, like periferal granulation of the grains or the production of a schistose structure, except that the quartz sometimes shows undulatory extinction. However, the harder and more resisting parts of the clastics,—the graywacke, volcanic tuff and conglomerate,—also often show no structures produced by dynamic agencies, but they were certainly present during the folding of the region. So the two igneous rocks just mentioned may be of earlier date than the folding. From his present knowledge the writer regards the porphyryte as cotemporaneous with the deposition of the volcanic tuff and the green schist, and the granite as dating from the folding. The diabase dykes are clearly later than both the porphyryte and the granite, and are also certainly of more recent date than the folding.

The following table gives the ages of the rocks represented around Kekequabic lake. On the left are given the age terms used by the Geological and Natural History Survey of Minnesota, and on the right those of the United States Geological Survey. However, as before stated, the diabase may not belong where it is placed, and the conglomerate, with perhaps some of its associated rocks, may prove to be later than the Keewatin (Lower Huronian). If the latter is the case, there were probably two periods of folding.†

Taconic	Keweenawan	Diabase	Keweenawan	Algonkian
		Gabbro		
Archean	Keewatin	Conglomerate	Lower Huronian	
		Slate formation		
		Volcanic tuff		
		Green schist		
		Porphpryte		
		Granite		

*A. C. Lawson. The laccolitic sills of the northwest coast of lake Superior; Geol. and Nat. Hist. Survey of Minn., Bull. No. 8, p. 48, 1893.

†See also the table of Pre-Silurian rocks of Minnesota published elsewhere in this volume.

CHAPTER III.

THE GRANITE.

The granite, which forms the principal object of this investigation is of an unusual and interesting type, being an augite granite containing sufficient alkali to impart an acmite-like habit to the pyroxene, but not enough to prevent the crystallization of free silica. The author has already published a preliminary description of this granite, which description, however, is devoted only to the petrography of the rock.*

OCCURRENCE.

The granite, with the two exceptions mentioned below, is confined to a roughly oval area, whose major axis (east and west) is about three and a half miles; the minor axis being less than two. It occupies most of the S. W. ¼ section 31, T. 65 N. R. 6 W., the S. ½ of S. ½ section 36, T. 65 N., R. 7 W., nearly all of section 1, all the land in section 2 and most of the land in section 3, T. 64 N., R. 7 W. The only exceptions to the oval outline of the area occupied by the granite are: (1.) A narrow band of granite, or what appears to be such, running out from the main mass along the south shore of Kekequabic lake, in section 31, T. 65 N., R. 6 W. (2.) Small isolated granitic bosses found in the clastic rocks, mostly to the north of the main mass of the granite. The rock of these areas makes up the porphyritic facies of the granite. In this connection, and before proceeding farther, it might be well to state that the granite is separated into two principal facies,—a granitic and a porphyritic,—which are rather distinct in the field.

On all sides, except at the southwest, the outlines of the granite area can be pretty definitely traced, and we can feel sure that its surface area is about all exposed. But at the southwest the gabbro contact rocks come up to the granite. If

*Note on an augite soda-granite from Minnesota; Amer. Geologist, vol, xi, no. 6, pp. 383-388, June, 1893.

these rocks are part of the gabbro which extends over the old granite surface, it is possible that there is an area of granite now concealed under the gabbro and its contact rocks to the southwest. But this is rendered rather improbable for two reasons: (1.) The general outline of the granite area and the fact that the clastic rocks of the region are found both on the south and west would seem to indicate that they were continuous around the southwestern edge of the granite boundary. (2.) It is not yet certain that the gabbro contact rocks which here come up to the granite are not the clastics of the region metamorphosed. There are no other known exposures of granitic rocks within several miles of the Kekequabic lake granite, excepting one small outcrop (syenite) in the midst of the gabbro near the center of the S. W. ¼ of section 11, T. 64 N., R. 7 W.*

PARALLEL STRUCTURES.

One of the first features of the granite which attracts attention is its separation along roughly parallel planes. The layers thus formed vary from an inch to ten or more inches in thickness, and the same layer varies in thickness within a short distance. No difference in petrographical character between the different layers can be made out, nor is there any arrangement, macroscopically visible, of the constituent minerals of such a kind as to cause splitting along these planes. And there seems to be no tendency toward an indefinite separation into finer and finer layers. In some cases small quartz veins are to be seen between the different layers, but usually there is nothing visible except a simple undulating crack. Thin sections of the rock cut at right angles to this cleavage show no evidence of any parallel arrangement of the minerals nor of any microscopical faults or fault breccias, to which cause the rifting of certain granites is due.†

The cleavage of the granite of Kekequabic lake has been described and figured‡ but no explanation of its origin was given. It was provisionally called flowage structure, but there is no evidence of such a structure in the rock. It seems to

*Geol. and Nat. Hist. Survey of Minn., 20th (1891) Ann. Rept., p. 69, 1893.

†R. S. Tarr. The phenomenon of rifting in granite; Amer. Jour. Sci., 3, vol. xli, pp. 267-272, Apr. 1891.

‡Geol. and Nat. Hist. Survey of Minn., 15th (1886) Ann. Rept., pp. 361-362, figs. 51 and 52, 1887. 20th (1891) Ann. Rept., pp. 70-71, fig. 5, 1893.

the writer this separation into sheets is probably due to jointage caused by contraction in cooling. While this cleavage is in places very pronounced, it is still not to be seen over most of the granite area. It is found in its best development on some of the smaller islands in the western part of Kekequabic lake in section 3, T. 64 N., R. 7 W. Here the parallel layers dip toward the north at angles varying in different outcrops from 10° to 40°, but on the little point in the S. E. ¼ of S. W. ¼ section 2, T. 64 N., R. 7 W., the dip is toward the south 10° to 15°. No general direction nor regularity in this dip has been seen.

It will be noticed that in the previous descriptions of this granite it has been frequently called "fine syenitic gneiss," "chlorite gneiss" or simply "gneiss,"* thus implying that there was some evident gneissic structure in the rock. However, aside from that described above, the writer has been able to detect no evidence of any parallel structures in the rock; there are no alternating bands of different mineral composition, nor are the mineral grains uniformly elongated in a common direction. Wherever examined the rock presents a truly massive aspect. The only thing to suggest a parallel arrangement of the minerals is in small areas of the porphyritic facies of the granite, where some of the feldspar phenocrysts are arranged with their long axes roughly parallel, due to movement in the mass before solidification and after the formation of the phenocrysts. In support of the above statements concerning the absence of gnessic structure in the granite it may be well to quote the following from N. H. Winchell's second report on Kekequabic lake: "This [the granite] has been called *gneiss* this year and last, but it needs a word of qualification. It is not the real gneissic structure, or foliation supposed to be due to original sedimentary bedding. It has acquired a sheeted structure, but in general it is a massive rock, showing variations due to the original conglomeritic state of its materials, as already described. Where it passes into the porphyry it is more compact and more firm than when it is not porphyritic."†

The only other parallel structure heretofore noted in the granite is that due to traces of an original sedimentary banding —considering the granite as a highly metamorphosed conglom-

*N. H. Winchell. Ibid., 15th (1886) Ann, Rept., pp. 361-369,1887. 16th (1887) Ann. Rept., pp. 149-156, 1888.

A. Winchell. Ibid., 15th (1886) Ann. Rept., pp, 69-82, 1887.

†Ibid. 16th (1887) Ann. Rept., p, 104, 1888.

erate. The remains of this structure were noted in one place, as follows: "There is visible sometimes not only a conglomeritic, but a sedimentary banded structure, dipping 80° from the horizon, south 10° west."* The writer can only say that he has been unable to find any traces of an original sedimentary banding, or anything that would suggest it, in the granite.

FIELD RELATIONS OF THE GRANITE.

In this section it is proposed to briefly outline the general relations of the granite, as seen in the field, to its own facies and to the other rocks by which it is surrounded.

Field relations of the granite to its own facies.

As already stated there are two important facies of the granite,—a normal granitic and a porphyritic. The porphyritic facies occurs in isolated bosses without the limits of the granite proper and is usually separated from it by the country rock. In a few places the two facies approach near to each other, but are not seen in actual contact. Here no evidence of a transition between the two is seen, each retaining its own characters as near together as they were exposed. Only one contact has been seen between these two facies of the granite; here in a small exposure branching vein-like forms of the granite porphyry cut the granitic facies. From this it would appear that the porphyritic facies is of some later date than the main mass of the granite. The two rocks agree so well in chemical and mineralogical composition, which will be mentioned later, that it seems impossible to consider them as anything but parts of the same magma. The writer is inclined to think that the porphyritic facies is of but little later date than the granitic facies and perhaps was erupted before the complete cooling of the latter.

In the N. W. ¼ section 2, T. 64 N., R. 7 W., is a small island made up mostly of the normal granite, but with a porphyritic aspect. At the north end of the island is a dark gray to greenish rock, which is called the poikilitic facies of the granite. This is cut in all directions by vein-like forms of the granite and angular fragments of the dark rock are found imbedded in the granite mass. The granite where it cuts the other rock is

*Ibid., 15th (1886) Ann. Rept., p. 362, 1887.

somewhat finer grain than at a short distance from this place.

A peculiar facies of the granite is found in the narrow strip, which runs along the south shore of Kekequabic lake in the east half of section 31, T.65 N., R.6 W. This is somewhat different from the normal granite, but nevertheless seems to grade into it. This facies of the granite is called the hornblendic facies.

Aside from the four phases of the granite already mentioned, there is another,—the syenitic facies. This is not as distinctly separated from the normal granite as are the others, but it forms an important part of the granite mass. In many places by a simple gradual loss of the quartz, the granite passes into an augite syenite. These areas of syenite occur most frequently on the hills in sections 1 and 2, T. 64 N., R. 7 W.

Field relations of the granite to the surrounding rocks.

Transitions.—In former descriptions it has been supposed that this granite in places passes gradually into the graywackes and conglomerates of the region. At two localities there has been found a gradual passage from the granite to rocks macroscopically resembling fine graywacke or graywacke slate. The first of these is on the northern side of the narrow point which projects from the west shore of Kekequabic lake in the S. W. ¼ of N. W. ¼ section 3, T. 64 N., R, 7 W. Here within a distance of 30 feet there is a gradual transition from distinct fine grained granite into a rock which resembles the graywacke slates of the region, but it shows no lamination and the slaty structure is not well developed. Near the base of the promontory in the S. W. ¼ of S. W. ¼ section 29, T. 65 N., R. 6 W., is an apparent transition in a distance of a foot or two from the phorphyritic granite to a graywacke-like rock. A series of specimens has been collected from both of these places and mention of them is made in the section on the origin of the granite, but it may be well to state here that the microscopical examination in no way confirms the idea of a passage from a clastic rock to the granite.

Contacts.—Around the edge of the main mass of granite several exposures have been found showing contacts of this rock with the surrounding sediments. Perhaps the one best suited for the determination of the relations of the granite to the country rock is near the center of the W. ½ of S. E. ¼ section

1, T. 64 N., R. 7 W. The plan of this exposure is shown in the accompanying sketch (Fig. 2), which makes the relations of the

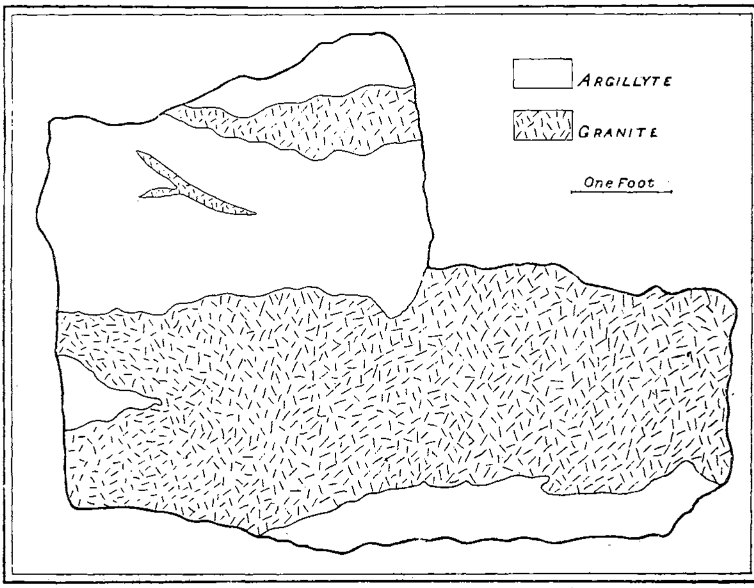

FIG. 2. Contact of granite and argillyte; W. ½ of S. E. ¼ section 1, T. 64 N., R. 7 W.

two rocks sufficiently plain. The granite is quite sharply marked off from the country rock, which is here a dark argillyte in which the bedding is obscure, although approximately parallel with the main line of contact. In the other contacts the eruptive character of the granite in the country rock is not so clearly shown, but the line between the two rocks is quite distinct and the granite is of a finer grain at the contact than at a distance of a few feet from it. In the southwest quarter of section 31, T. 65 N., R. 6 W., a mass of argillyte, more or less altered. is seen included in the granite, but sharply marked off from it.

The porphyritic facies of the granite is found in contact with the green schist and conglomerate in several places. It usually sends no apophyses into these rocks, but its later age is shown by its uniformly finer grain at the contact lines.*

On a little point on the north shore of Kekequabic lake (S. W. ¼ section 34, T. 65 N., R. 7 W.), the dark argillyte is cut by a small irregular dyke of granite porphyry, which sends many stringers into the argillyte and also includes fragments of it.

*Two of these contacts have been figured in the 15th (1886 Ann. Rept., Geol. and Nat. Hist. Survey of Minn., pp. 154, 367, 1887.

PETROGRAPHICAL DESCRIPTION OF THE GRANITE.

Macroscopical.

In the field there are seen to be two quite distinct facies of the granite—the normal granite andthe granite porphyry. These present some microscopical differences, but they have many characters in common. The normal granite is of a medium or fine grain and a dull pinkish color. This color is quite characteristic of the rock as seen in most of the outcrops; it is due to the color of the feldspar which is the predominating mineral. The texture is firm and compact. In some of the finer grained phases it is almost impossible to distinguish any mineral other than feldspar, but in the coarser phases are also seen grains of a darker mineral, which proves to be augite, and quartz. However the last is not very evident in hand specimens. In some places, noticeably in the N. W. ¼ of N. W. ¼ section 2, and the promontory in the S. W. ¼ of S. W. ¼ section 3, T. 64 N., R. 7 W., the granite is sub-porphyritic with feldspar crystals. These phenocrysts are often, especially at their centres, of a little lighter color than the non-porphyritic feldspar. This granitic facies makes up the main mass of the granite; it varies little in different exposures.

The granite porphyry is found only in small isolated areas in the clastic rocks and near the edge of the area of normal granite. It is distinguished by its fine, usually aphanitic, groundmass and its decidedly porphyritic aspect, which is due to numerous white or flesh colored feldspar phenocrysts scattered indiscriminately through the rock mass. There are also minute short stout augite prisms and occasional brilliant black biotite scales to be seen in the groundmass. The feldspar phenocrysts vary in size in the same hand specimen from almost microscopic dimensions to those ten or fifteen millimeters in length. The smaller ones are often very closely crowded together and are sometimes arranged more or less in lines of flow. At one locality these feldspars are very large and conspicuous, sometimes reaching a length of over twenty millimeters. The only exception to the white or flesh color of these phenocrysts is on the northern side of the small island in the S. W. ¼ of N. W. ¼ section 3, T. 64 N., R. 7 W., where the feldspars are of a reddish color. Plate I, Fig. 2, shows the appearance of a pronounced phase of the granite porphyry.

What is termed the hornblendic facies of the granite is found only in a narrow strip along the south shore of Kekequabic lake in section 31, T. 65 N., R. 6 W. It has a fine grained gray groundmass whose constituent minerals are not readily distinguishable. In this are usually scattered small whitish subporphyritic feldspars and less evident black prisms of hornblende. This rock is different from the main mass of the granite in several respects, and the writer does not feel entirely satisfied that it is part of the granite, but it seems to be such and is placed here as a hornblende facies of the granite.

As already mentioned (pp. 40-41) the normal granite is seen cutting a dark gray to greenish rock on the small island in the N. W. ¼ of N. W. ¼ section 2, T. 64 N., R. 7 W. This rock has a dull greenish groundmass in which are imbebbed noticeable flakes of biotite and less evident augite prisms. Even in hand specimens there are seen to be certain areas of the groundmass, each of which reflects the light and in which are biotite and augite individuals. The rock is consequently called the poikilitic* facies of the granite, but it is possible that this is not part of the granite mass. It is known only from the northwest side of this small island.

A noticeable feature of the granite in all its facies is the occurrence of small rounded, subangular and angular areas, which are sharply marked off from the rest of the rock. They vary from half an inch to two inches in diameter, rarely being larger. They are composed usually of aggregations of rather coarsely crystallized hornblende, or augite. Frequently, however, these dark areas are fragments similar to the country rocks—argillyte and green schist. These more or less rounded form are very abundant in certain parts of the hornblende granite. In fact in one exposure it is almost impossible to find any surface a foot square which does not contain one or more of them, and some areas of this size include as many as twenty.† In the granite proper and the porphyritic facies these rounded forms are not so abundant, still they are seen rather frequently. In the former reports on this granite these forms have been regarded as the remains of pebbles in a conglomerate, which was considered to be the original character of the rock now a granite.‡ It also seems very possible to refer some of these forms to basic secretions, which are common to

*See G. H. Williams. On the use of the terms poikilitic and micropoikilitic in petrography; Journal of Geology, vol. 1, no. 2, pp. 176-179, 1893.

†Geol. and Nat. History Survey of Minn., 20th (1891) Ann. Rept., p. 79, 1893.

‡N. H. Winchell. Ibid., 15th (1886) Ann. Rept., pp. 362, 368, 1887.

very many granites, while others, on account of their petro graphical character, can be regarded as inclusions of fragments of the surrounding rocks.

Chemical.

Two analyses have been made—one of the normal granite (I in the table of analyses) and the other of the granite porphyry (II). It will be seen that the two facies agree quite closely in chemical composition and that in each the proportion of soda is much larger than that of potash; in the granite proper the ratio of soda to potash is 1.8:1 and in the granite porphyry 2.4:1. Using the term "soda-granite" as a true granite which contains a larger amount of soda than potash, this rock would belong to the series of soda-granites. These have been reported from several localities in Europe, but as yet have been rarely found in America. W. S. Bayley* has described a granite which contains large amounts of anorthoclase from Pigeon Point, Minnesota, on the north shore of Lake Superior; this was found in connection with a quartz-keratophyre. And N. H. Winchell has recently published (see VI in the table of analyses) an analysis of a red granite from Rice Point, Duluth, in which the proportion of soda is very

ANALYSES OF SODA-GRANITES.

	I.	II.	III.	IV.	V.	VI.
SiO_2	66.84	67.42	68.00	70.69	72.42	75.78
TiO_2	.....	.....	.....	.....	0.40	.....
P_2O_5	tr.	0.07	.....	.....	0.20	.....
Al_2O_3	18.22	15.88	16.18	15.20	13.04	11.09
Fe_2O_3	2.27	1.37	3.68	3.76	0.68	2.09
FeO	0.20	1.14	0.65	.....	2.47	.....
MnO	.....	tr.	.....	.....	0.09	.....
CaO	3.31	3.49	4.05	3.31	0.66	0.86
MgO	0.81	1.43	0.95	0.45	0.58	0.65
K_2O	2.80	2.65	2.04	2.31	4.97	1.06
Na_2O	5.14	6.42	4.32	4.69	3.44	6.43
H_2O	0.46	0.05	.....	0.56	1.21	1.82
Totals	100.05	99.92	100.49	101.07	100.37†	99.78

large; this rock is a hornblende granite of medium grain. These two soda-granites are from the Keweenawan. A soda-granite

*A quartz-keratophyre from Pigeon Point and Irving's augite syenites; Amer. Jour. Sci., 3, vol. xxxvii, pp. 54-62, Jan., 1889.

†Including traces of Li_2O and Cl and 0.15 per cent of BaO.

from Westchester county, N. Y., has been mentioned by J. D. Dana*, but G. H. Williams† has shown that this is properly a mica diorite.

The analyses of both facies of the granite under discussion and of several other soda-granites are given in the accompanying table. I is the normal granite from Kekequabic lake, Minnesota; No. 551G of the Minnesota Survey series. II is the porphyritic facies of the same; No. 86G. III is a soda-granite from Donegal, Ireland.‡ IV is the Aughrim (Ireland) soda-granite.§ V is the rock from Pigeon Point, Minnesota.‖ VI is the red granite from Rice Point, Duluth.**

In comparison with the last four analyses given in the above table and other published analyses of soda-granites,†† the rock from Kekequabic lake is seen to be lower in the amount of silica and usually higher in soda than other granites of this series. The large proportion of soda finds expression in the composition of the augite, as well as in that of the feldspar, as will be seen in the analyses of these minerals.

There is reason to think that soda-granites will be found more extensively developed in the Lake Superior region than has been supposed heretofore. It seems that some of the augite syenites from the Keweenawan, as already suggested by W. S. Bayley‡‡, may fall into this class, and there are numerous dykes in the Keewatin of northeastern Minnesota, described as quartz porphyries and syenite porphyries§§, a careful study of which will probably show that their feldspar is largely anorthoclase.

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*Geological relations of the limestone belts of Westchester county, New York; Amer. Jour. Sci., 3, vol. xx, p. 198, Sept., 1880.

†The gabbros and diorites of the "Cortlandt series" on the Hudson river near Peeksville, N. Y.; Amer. Jour. Sci., 3, vol. xxxv, pp. 443-444, June, 1888.

‡S. Haughton. Experimental researches on the granite of Ireland. Pt. iv. On the granites and syenites of Donegal; with some remarks on those of Scotland and Sweden; Quar. Jour. Geol. Soc., vol. xx, p. 269.

§W. J. Sollas. Contributions to a knowledge of the granites of Leinster; Trans. Royal Irish Acad., vol. xxix, pt. 14, p. 471, 1891.

‖W. S. Bayley. *Op. cit.*, p. 59.

**N. H. Winchell. The Norian of the Northwest; Geol. and Nat. Hist. Survey of Minn., Bull. No. 8, p. xxxiii, 1893.

††A. Gerhard. Neues Jahrbuch f. Min., Pet. u. Pal., 1887, II, pp. 267-275.

‡‡ *Op. cit.*

§§ U. S. Grant. Geol. and Nat. Hist. Survey of Minn., 20th (1891) Ann. Rept., pp. 45, 48, 49, 51, 57, 58, 1893.

As this paper is going to press two analyses of acid igneous rocks from northeastern Minnesota have been completed by Mr. A. D. Meeds, Instructor in Chemistry in the University of Minnesota. Both of these show a considerable excess of soda over potash. The analyses are as follows:

Mineralogical.

The minerals of granite have been described so frequently and so exhaustively that it is not necessary nor advisable to attempt any complete description of all the minerals composing this granite. Consequently only one of them,—the augite,—will be spoken of in any detail, but an analysis and specific gravity determinations of the feldspar are given. The minerals comprising the rock can be divided into two classes, essential and secondary. In the order of their importance and abundance they are:

Essential	Feldspar (largely anorthoclase.) Augite. Quartz. Hornblende.	Accessory	Biotite. Apatite. Sphene.

As to the time of crystallization they are as follows: (1) Sphene and apatite. These are not found in contact so that nothing can be said as to their relative ages; they are both older than the other minerals. (2) Biotite, hornblende and augite. The relative ages of these are not clearly shown, but the biotite seems to be the oldest. (3) Feldspar. The only case where this is of as late a crystallization as the quartz is in the groundmass of the granite porphyry. (4) Quartz. Later than all the others, excepting the feldspar in the case just mentioned.

Feldspar.—The feldspar is much more abundant than any of the other minerals; it makes up half and sometimes at least three fourths of the rock mass; in the more basic (syenitic) parts of the granite it reaches its fullest development as regards amount.

Orthoclase is seen frequently in the normal granite and is very abundant in the hornblendic facies, but it never forms phenocrysts. Over two thirds of the feldspar is triclinic; it

	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	H_2O	Totals.
I.	69.70	18.72	0.65	0.79	2.25	0.45	1.68	5.01	0.71	99.96
II.	69.34	17.25	2.46		3.43	1.18	0.71	4.33	1.17	99.87

I is a quartz porphyry (No. 417G; 20th Ann. Rept., p. 57) from a dyke in the "greenstone" of the Kawishiwi river, N. ½ N. E. ¼ sec. 21, T. 63—10 W. This rock has a microgranitic groundmass in which are large phenocrysts of feldspar and quartz; a few small areas filled with chlorite and epidote are present, but what the original ferro-magnesian constituent was is not clear.

II is a characteristic specimen of the Saganaga granite (No. 686 G; 20th Ann. Rept., p. 88) from Saganaga lake, S. W. ¼ N. E. ¼ sec. 22, T. 66—5 W. This rock is a coarse grained hornblende granite.

shows the usual polysynthetic twinning according to the albite law, and in some cases the microcline structure is developed to a small extent. Zonal structure in the plagioclase is quite common, especially in the porphyritic crystals. The feldspar is always more or less cloudy due to incipient alteration, but the resulting minerals are not usually discernible, the cloudiness being due to amorphous opaque white areas; in the orthoclase alteration to sericite is common.

On separating the powder of a fresh specimen of the normal granite (No. 551 G.) by means of Thoulet's solution the larger proportion of the feldspar fell between a specific gravity of 2.58 and 2.62, which would indicate that the mineral was a mixture of the orthoclase and albite molecules; and the analysis, as here given, shows that it belongs to the anorthoclase series.

ANALYSIS OF FELDSPAR.

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	H_2O	Total
67.99	19.27	0.82	0.75	0.02	3.05	6.23	0.90	99.03

It is to be noticed that the silica percentage is larger than is required by the amount of soda, potash and lime present. This is probably due to the fact that a small amount of quartz was so intimately intergrown with the feldspar that certain grains of the feldspar powder contained some quartz. From the analysis it is calculated that this feldspar is an *anorthoclase* with approximately the composition $Or_5\ Ab_{14}\ An_1$.

The specific gravity of several of the feldspar phenocrysts of the granite porphyry was determined; it ranges from 2.59 to 2.60. This, together with the analysis of the whole rock (II in the table of soda granite analyses), is sufficient proof that these phenocrysts, which make up about half the rock mass, are also *anorthoclase.*

Augite.—The augite is the most interesting mineral in the rock, as granites in which this is the chief ferro-magnesian constituent are comparatively rare. Augite makes up from five to twenty per cent of the whole rock and in the majority of sections is, besides the feldspar and quartz, about the only mineral present. It reaches its best development and is found in the least altered condition in the granite porphyry; accordingly the description of this mineral will be confined mostly to that occurring in this porphyry on the promontory at the southwest corner of section 29, T. 65 N., R 6 W., where this facies of the granite is seen in its best and most characteristic development. (Nos. 86G and 1094 of the Minnesota Survey series.)

The augite occurs in short stout prisms, whose length is half a millimeter or less; rarely larger crystals, one to three millimeters in length are seen. The crystals are generally completely idiomorphic, but occasionally the terminal planes are lacking, or are very poorly developed. The prismatic planes are the unit prism, the orthopinacoid and the clinopinacoid. The terminal faces, which are usually present, are the basal plane and the orthodone $P\bar{\infty}$ while the unit pyramid and a clinodome can sometimes be recognized, but usually there is a tendency to a rounding off of the edges basal plane and the orthodome $P\bar{\infty}$. The cleavage is well developed in thin sections and parting is usually not seen, but in one case (see Fig. 4) it is quite noticeable. An attempt was made to measure the angles on some of the larger augite crystals detached from the rock, but the faces gave such imperfect reflections that no satisfactory results were obtained.

In transmitted light the augite is of a bottle green color, but there are parts of some crystals which are colorless and entire colorless individuals are sometimes seen. A slight pleochroism is to be noticed in many sections, $\mathfrak{a}$ and $\mathfrak{b}$ being bottle green and not distinguishable from each other, while $\mathfrak{c}$ is a yellowish green. The absorption is $\mathfrak{a}=\mathfrak{b}>\mathfrak{c}$.

Zonal structure is rather common; in such cases the core of the crystal is usually colorless, or of a lighter green than the outer rim. The colorless centres occasionally pass gradually into the colored rims, but generally the two are separated by a pretty distinct line. The outlines of these colorless cores are irregular and are seldom parallel to any crystallographic planes. The cleavage lines run uninterruptedly from one part of the crystal to another, and in sections cut parallel to the zone of the ortho-axis the extinction direction of both parts of the crystal are parallel, but in sections which are inclined to the ortho-axis, the extinction directions are differedt in the two parts of the crystal. Moreover, in one section, cut parallel to the clinopinacoid, parting parallel to the basal plane is seen, and this runs straight through the colored rim and the colorless core. From these facts it is seen that the two parts of the crystal have the same crystallographic axes, *i. e.* are parallel growths, but that the axes of optical elasticity, excepting the one coincident in direction with the ortho-axis, do not have the same directions in the two parts of the crystal.

The green crystals and rims have a lower index of refraction, lower double refraction and a smaller extinction angle than the colorless augite, (the extinction angle measured being that between 𝔞 and *c* in acute angle *b*). The dark green crystals are more pleochroic than the lighter ones, and the colorless ones show no pleochroism. These facts indicate that the green crystals and rims contain more of the acmite molecule than the colorless parts. (That the augite contains a considerable amount of the acmite molecule is shown by the analysis given below.)

The extinction angle of the colorless augite in sections parallel to the clinopinacoid runs as low as 37°, although usually higher than this; this is an angle of 53° as the extinction of augite is usually measured, *i. e.* 𝔠 to *c* in obtuse angle *b*. In

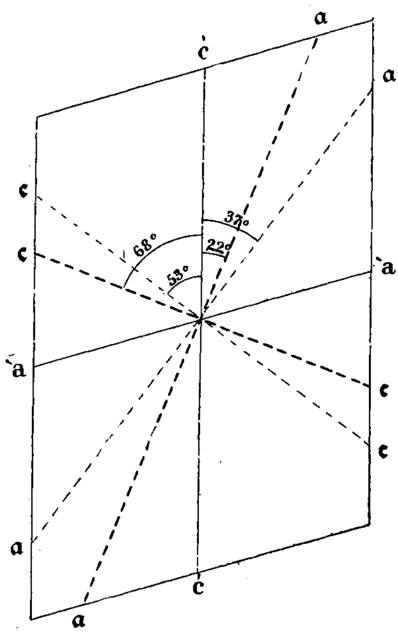

Fig. 3. Diagram showing the relative positions of the crystallographic and optical axes in the green and colorless augite.

the green crystals and rims 𝔞 is inclined about 22° to *c*, but in one section it is as low as 18°. The positions of the axes of elasticity with reference to the crystallographic axes are shown in the accompanying figure; the axes of elasticity of the colorless variety being represented by the lighter dotted lines.

While in the zonal crystals there are usually only two parts, which are of different optical orientation, in a few there are more than two such areas. To illustrate parallel growths of this kind the following figure (4) is introduced. It shows part

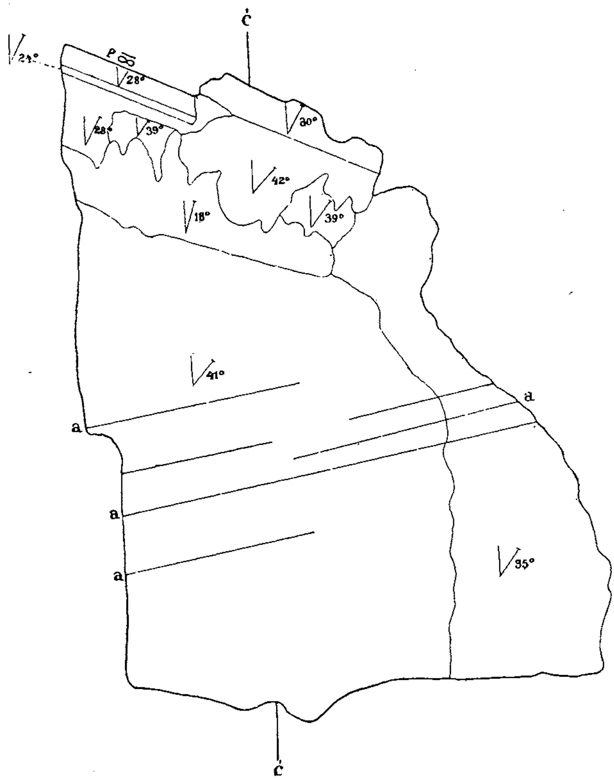

Fig. 4. Section of augite crystal showing areas of different optical orientation.

of a large crystal of augite cut parallel to the clinopinacoid. The extinction and outlines of the different parts are represented rather diagrammatically, as the different zones are not always separated by a sharp line. The lines *a a* represent the parting parallel to the basal plane. The extinction angles given are those of α against c. The large central part of the crystal is colorless and the rest is greenish; the small irregular area with an extinction of 18° is yellowish green and distinctly pleochroic.

A typical fresh specimen of the porphyritic granite was powdered and the augite separated and analyzed. This augite is fresh and unaltered and the powder used (which has a higher specific gravity than 3) is quite pure, as in this specimen of the granite the only other minerals present were feldspar and quartz with a few minute fibers of secondary hornblende. The analysis is here given. Assuming that this represents an isomorphous mixture of the diopside, heddenbergite, acmite and

ANALYSIS OF AUGITE.

SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	H_2O	Total.
53.19	2.38	9.25	5.15	17.81	9.43	0.38	2.63	0.01	100.23

fassaite molecules and calculating their relative proportions we get approximately the following result:

Diopside, Mg Ca Si_2O_6	47 per cent.
Heddenbergite, Ca Fe Si_2O_6	27 " "
Acmite, $\dddot{Na}$ Fe Si_2O_6	21 " "
Fassaite, Mg Al_2 SiO_6	5 " "

In the considerable percentage of the acmite molecule this augite approaches in composition the pyroxene of the more alkaline rocks, the eleolite syenites.* This analysis very probably represents quite well the usual composition of the green augite, as the proportion of zonal crystals, with colorless centres, and entire colorless crystals is small. The colorless augite is very similar to that of the well known augite granite from Laveline in the Voges.

Quartz.—This mineral does not play as important a part in the rock under consideration as it does in most granites. It rarely forms more than a fourth of the rock mass, and, while usually more abundant than the augite in the normal granite, it is not always so. Quartz occurs in small irregular areas in the granitic facies of the rock, and often shows undulatory extinction and sometimes has been slightly fissured. It is never found in phenocrysts in either facies of the granite, and in the granite porphyry is only in minute grains in the groundmass.

Hornblende.—Original hornblende is found only in the hornblendic facies of the granite and in one exposure of the granite porphyry. Here there are some cross sections which show the characteristic planes of a hornblende cross section, but in some cases it seems to be secondary. The hornblende is of the usual green variety.

* Cf. A. Merian. Studien an gesteinsbildenden Pyroxenen; Neues Jahrbuch f. Min., Pet. u. Pal., B.B. III. pp. 252-315, 1885.

Secondary hornblende is of quite universal occurrence in all facies of the granite. It has usually developed in small green fibers, which penetrate the rock in all directions, and is frequently seen in fibrous growths around the ends of the augites and sometimes replaces whole crystals of this mineral with a fibrous aggregate. Where the rock has been much altered the hornblende often occurs in delicate sheaths of fibers much resembling those figured by G. H. Williams* in certain altered greenstones.

Accessory minerals.—Sphene and apatite occur in small amounts in the normal granite and in the granite porphyry; the apatite is in short stout prisms rather than in elongated ones. Biotite occurs in some sections of the granite porphyry and in a few cases is quite abundant; it is in small flakes usually surrounded by magnetite grains. Biotite is very common in the poikilititic facies of the granite.

Structural.

The different facies of the granite already spoken of,—the normal granitic, the porphyritic, the hornblendic and the poikilitic,—are characterized by structural differences.

The normal granite is usually of a truly granitic texture, but in some cases there are two generations of feldspars, the first being mostly idiomorphic, although not generally very sharply separated from the second generation as regards size. Occasionally there is a slight tendency for the fieldspars, when in only one generation, to assume a partially idiomorphic form.

The porphyritic facies has already been mentioned as characterized by numerous large and small phenocrysts of feldspar and smaller ones of augite. The groundmass as a rule makes up much less than half of the rock and is composed of a microgranitic aggregate of quartz and feldspar. The latter mineral is not usually polysynthetically twinned and thus would seem to be orthoclase.

The hornblendic facies is characterized not only by the presence of original hornblende, but also by the almost universal tendency of the feldspars to assume an idiomorphic development. This latter character is perhaps more striking than the presence of hornblende.

*U. S. Geol. Survey, Bull. No, 62, pl. XVI, fig. 1, 1890.

The poikilitic facies of the granite is strictly an augite-biotite syenite, as no quartz is present. The rock is composed of large, irregular, interlocking areas of feldspar, in which are imbedded numerous biotite scales and colorless to greenish augite prisms, thus forming a very beautiful example of the poikilitic structure. In this case it is noticeable that the grains and crystals of varying optical orientation included in an optically continuous area of feldspar are of two species instead of one, as is usually the case in rocks which show the poikilitic structure. The feldspar areas are often a quarter of a inch across and can be distinctly seen in hand specimens. A more careful and detailed study of this peculiar rock would probably bring out facts of interest.

THE ORIGIN OF THE GRANITE.

In the reports on the geology of the region about Kekequabic lake the granite has been regarded as of metamorphic origin. This has been maintained by N. H. and A. Winchell, and from their reports it would seem that their ideas are as follows: The granite is a result of the recrystallization *in situ*, under conditions of partial or complete aqueo-igneous fusion, of the sedimentaries of the region,—the graywackes and conglomerates. The more or less rounded foreign pieces in the granite are the original pebbles of the conglomerate. The granite was in some places plastic enough to allow it to be intruded into the surrounding rocks, but this intrusion was only very local and limited in extent, and the intrusive rock was not moved far from its original place. The main mass of the rock has not been moved at all, but is simply portions of the graywackes and conglomerates altered *in situ*. There are gradations from the granite to these clearly clastic sediments and the granite is not sharply marked off from the surrounding rocks, except in the few places where it has been intruded into them.

The facts, which are urged as sustaining the above idea as to the origin of the granite, seem to be four in number, as follows: (1) Presence of ancient but partially obliterated lines of sedimentation in the granite. (2) Presence of pebble forms in the granite. (3) Transitions from the granite to the clastic rocks. (4) Presence, in the immediate vicinity, of altered clastic rocks resembling the granite.

In regard to the presence of old lines of sedimentation in the granite, or anything to suggest such lines, the writer can only say that he has been unable to see any such, although he has carefully searched for them. In fact he has seen no structures in the granite which could be referred in any way to old lines of sedimentation.

That there are numerous rounded, sub-angular and angular pebble-like forms in the granite has already been stated. These are more abundant near the edge of the granite mass and in the small bosses of granite porphyry; this is a significant fact and agrees well with the explanation that many of these foreign pieces are inclusions of the country rock. In fact there is just as much reason, (to the writer there seems more,) for assuming that these pebble-like form are basic secretions in the granite, or are inclusions of the country rock, as there is for assuming them to be the remains of pebbles in an altered conglomerate.

Two apparent transitions from the granite to a seemingly sedimentary rock have already been mentioned (page 37). In the field these transitions could be traced quite well, but the rock into which the granite graded, while resembling the sediments of the region, still could not be proved to be a clastic rock. A microscopical examination of thin sections of a series of specimens taken to illustrate these transitions shows that the apparent sedimentary end of the series and also all parts of it reveal no evidence of an original clastic nature, in fact their characters are those of fine grained portions of the granite. The conglomerate and graywacke, into which the granite has been supposed to grade, show in thin section undoubted clastic characters, and in all the sections examined there is no occasion to confuse these rocks with the granite.

A mile to the east of Kekequabic lake are found small areas of altered clastics, which, in some characters, resemble the granite. Here the remains of sedimentary planes are visible, and the rock in hand specimens and in sections is seen to be somewhat similar to the granite, especially as regards degree of crystallization. Rock like this is, however, not found in a position intermediate between the clastics, from which it is derived, and the granite, as would be expected to be the case And it is well known that beds of certain altered clastics (gneisses) often closely resemble in hand specimens and in sections the granites which cut them, but this resemblance is no proof that the two rocks are of like origin and are parts of the same mass.

From the above it will be seen that the arguments for the derivation of the granite from the clastics of the region are, to say the least, rather unsatisfactory. Indeed the facts seem as susceptible of explanation on the idea that the granite is eruptive as that it is a part of the altered clastics. Moreover, there are other facts which point very strongly toward the eruptive origin of the granite.

Contacts have been described (page 37) which show that, at least at these localities, the granite plays an eruptive role. Here the granite has come into its present position in relation to the country rocks since their deposition, and it penetrates them in irregular dykes, and in one place includes undoubted fragments of the rock with which it comes in contact. Where contacts of the granite with the surrounding rocks occur the latter have been somewhat altered, although not very greatly, and a mass of the argillite enclosed in the granite is rendered gneissoid near its edges. Contact metamorphism is, however, not very marked. At these contacts the grain of the granite is finer than at a short distance from the contract line.

That the granite is of a different character from the surrounding rocks is well shown by the ease with which it is separated from them. In no place has a gradation from any of the sedimentary rocks to the granite been established. In the field it has been possible to map the limits of the granite much more accurately and easily than any of the sedimentary rocks, the accuracy of the outlines of the granite depending only on the number of exposures to be found. No rocks intermediate in position or character between the granite and the clastics have been observed in the area mapped. The sharpness with which the granite is everywhere separated from the surrounding rocks is best seen where the porphyritic facies comes in contact with or is seen near the dark argillytes. This fact that the granite is everywhere so sharply and so distinctly separated from the surrounding clastics is a very weighty proof that it is not a part of these clastics.

It is easy to imagine sediments buried so deeply and under such conditions of pressure and temperature in the presence of water that they would be converted into completely crystalline aggregates. We have many such instances, and it is undoubtedly true that many gneisses were formed in this way, but here it is to be noticed that a degree of crystallization, as complete as in granites, is often attained without the obliteration of certain structural planes in the rock,—i. e. there are rapid alternations of bands of different chemical and mineralogical composition which are very distinctly separated from each other. Here there seems to have been practically no interchange between different parts of the mass. But if we assume that the granite under consideration, in which there are no alternation of bands of different composition, is of like origin, it seems necessary to assume that the fusion (if this word may be used) was so complete that the mass took on a uniform composition throughout, for it is hardly conceivable that a mass of sediments which shows a section three and a half miles long by two wide should be of a uniform composition throughout and that this mass should be sharply separated, both along and across the strike, from sediments which do show this variation in composition. Moreover it seems impossible that a mass which has been so complete altered *in situ* should be so sharply separated from the rocks from which it is supposed to have been formed and which still show their original clastic characters. Again, it seems impossible that the pebbles in a mass, which has been so profoundly altered and in which there has been so complete an interchange between its different parts, should not have been entirely obliterated, instead of still retaining their own individuality. (It is to be noticed that the presence of so-called pebble forms is the chief point urged for considering the granite as altered sediments.) When fusion has gone so far as to allow a complete interchange of material between the various parts of the rock and an entire obliteration of all differences in composition between its various parts, and when such a rock is allowed to cool and crystallize as a holocrystalline mass, it is but a simple disagreement in terms that cause such a mass to be called anything but a truly igneous rock; and if such a mass is moved from its original position and forced into other rock it is truly eruptive in its nature and origin.

It is not necessary here to consider the question concerning the origin of granites in general; that question is almost as old as geology itself; it dates from the times of Werner and Hutton, and the writer can not presume to discuss it. Nor is it necessary to say anything for or against the idea that some of the pre-Cambrian granites and granitoid gneisses may represent fused portions of ancient and very deeply buried rocks. But it can be stated that there seems to be abundant evidence that the Kekequabic granite shows no indication that it is an altered sediment, that it is not part of the clastics of the region altered *in situ*, but that it is truly eruptive in its origin and nature, that it has broken through the surrounding rocks in a truly eruptive manner, and that throughout its whole extent now exposed to us it is sharply separated from the surrounding clastics and is of later date than these.

It might be well to state that when the writer began the study of this granite area and two others in northeastern Minnesota he was inclined to the view that these granites were the altered clastics of the region, but even before the field work was completed and before the microscopic study of the rocks was begun, he was forced to abandon this idea.

CHAPTER IV.

THE HORNBLENDE PORPHYRYTE.

The field relations of this rock have as yet been only partially studied, and the extent of the surface occupied by it has not been very accurately defined. For these reasons no complete discussion of this rock is now possible, and the time available in the preparation of this paper does not allow of a very detailed petrographical description, although quite a complete set of specimens showing the different phases of the rock have been collected.

The porphyryte is known from only one locality in the area studied, and is confined to a belt of not more than a quarter of a mile in width which curves around the southwestern end of Epsilon lake. The surface covered by this rock is about one-fourth of a square mile in extent; it is confined, with the exception of a few acres in the S. W. ¼ of S. E. ¼ section 20, to the N. ½ section 29, T. 65 N., R. 6 W. However a sample of this rock is noted by N. H. Winchell from Mallmann's peak*, which is on the north side of Kekequabic lake in the S. E. ¼ of section 30, T. 65 N., R. 6 W. The writer has been unable to find any porphyryte *in situ* at this place, and has since learned that Prof. Winchell did not visit Mallmann's peak personally, but that the specimen was brought to him by one of his guides. It is, however, quite possible that other areas of porphyryite will be found in sections 29 and 30, T. 65 N., R. 6 W., between Kekequabic and Knife lakes. The single specimen noted by Prof. Winchell has been figured and described microscopically by M. E. Wadsworth†.

The porphyryte has also been briefly described by A. Winchell,‡ who called it a purple porphyry, in his account of the geology of Epsilon lake.

*Geol. and Nat. Hist. Surv. of Minn, 10th (1881) Ann. Rept., pp. 92-93, 1882. Rock No. 751.

†Ibid., Bull. No. 2, pp. 124-125, pl. x, figs. 1 and 2, 1887.

‡Ibid., 16th (1887) Ann. Rept., pp. 321-327, 1888.

Dr. Wadsworth's description is as follows: "The section has a greenish gray groundmass, holding yellowish brown crystals of hornblende, epidote and greenish pseudomorphs of chlorite. The hornblende is of the usual foreign character in the andesitic rocks, having been attacked by the molten magma, which has torn and eaten into the hornblende, that has its edges blackened and rendered magnetic by the heating and corroding effects. Some of the hornblendes here have been broken and faulted, and blackened on the broken sides, others retain only a small portion of hornblende in the interior, while others are reduced to a heap of opacite or magnetite grains. The chlorite pseudomorphs are composed of plates and scales of chlorite with some epidote, but whether they are pseudomorphs after hornblende or augite the writer can not determine. The epidote is in small crystals and crystal aggregations of a pale yellowish color, with pleochroism varying from colorless to a pale yellow and to a deeper yellow. The epidote is here an alteration product, and is commonly associated with the chlorite. The groundmass is altered and is now composed of chlorite scales, partially altered augite microlites and granules, magnitite grains (disseminated through the entire groundmass), feldspar, microlites, fibrous material, etc., all replacing the usual felty base of the andesytes with its inclosed materials. Here the augite, feldspar and magnetite are original, and the rest secondary. * * * The rock itself is an altered and old andesyte of the variety known as porphyryte or hornblende-porphyryte amongst lithologists. This andesyte, in its original condition, would be called by most lithologists a hornblende andesyte." *

The single section, which was accessible to Dr. Wadsworth when his description was written, is more or less altered and does not clearly show the original nature of the groundmass. Other sections of the less altered rock show that the groundmass is composed of interlocking laths of feldspar,—sometimes the feldspar has a tendency towards a granular development,—as stated below.

Macroscopically the porphyryte is seen to have an aphanitic groundmass, which varies in color from a reddish purple to a dull olive green; the freshest and more abundant phases show the purple color. In this groundmass are sharply outlined shining black crystals of hornblende and also irregular greenish areas, in and around which are frequently small bright yel-

*Ibid., Bull. No. 2, pp. 124-125.

low spots and small white spots. Under the microscope the groundmass is seen to be made up entirely of small short interlacing laths of feldspar. In some sections the groundmass becomes coarser and there is a decided tendency towards a granular development of the feldspar. Although polysynthetic trimming is common, still some of the feldspar does not show it and seems to be monoclinic in character; that there is considerable orthoclase in the rock is also indicated by the percentage of potash in the analysis.* The feldspar is undergoing alteration and is filled with small inclusions and minute fibers which sometimes appear to be sericite. The rock is crowded with dust-like particles, to which perhaps is due its purple color. There seems to have been but one period of crystallization for the feldspar, phenocrysts of this mineral being entirely absent. In all the slides examined there is no unindividualized glassy matter to be seen.

The hornblende is of the usual brown basaltic variety, but the pleochroism is not as intense as in most basaltic hornblendes; $\mathfrak{a}$ is light straw colored, $\mathfrak{b}$ is yellowish brown and $\mathfrak{c}$ is olive brown. The rays vibrating parallel to $\mathfrak{b}$ and $\mathfrak{c}$ are not very unlike. The absorption formula is $\mathfrak{c}=\mathfrak{b}>>\mathfrak{a}$ or $\mathfrak{c}>\mathfrak{b}>>\mathfrak{a}$. The hornblende is all porphyritic in character, the individual crystals being from one to five millimeters in length. Each phenocryst is usually surrounded by a dark corrosion rim.

The dull greenish areas seen in hand specimens are found to be aggregates of chlorite scales, sometimes with a radial arrangment. It is evident that some of this chlorite is an alteration product of the hornblende. But most of the chlorite areas give no evidence as to their origin. In one section a core of pyroxene was seen in a chlorite area, and it is possible that many of these chlorite areas represent old augite phenocrysts; however, they do not show the characteristic outlines of augite crystals, but are usually irregular. Even if all of these chlorite areas, which are not clearly alteration products of hornblende crystals, represent original augite individuals, the hornblende would still be in excess of the augite. So the rock is called a hornblende porphyryte, although it perhaps originally was an augite-hornblende porphyryte.

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*Dr. Whitman Cross, who kindly examined slides of this rock for the writer, also thinks that considerable orthoclase is present.

The yellow spots in and around the chlorite areas are secondary epidote, often in the form of minute spheres. And small white spots of calcite are also seen.

The analysis of the porphyryte is as follows:

SiO_2	Al_2O_3	P_2O_5	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	H_2O	Total.
60.32	15.80	0.12	5.42	0.89	4.65	5.08	1.82	4.09	1.67	99.86.

In the porphyryte have been seen a few fragments of rock similar to the graywacke of the region, and at its contact with the surrounding rock the former is finer grained than is usual, but it does not seem to have altered the rocks with which it comes in contact. It seems very probable that this mass of porphyryte is a part of the same magma which produced the volcanic tuff about Kekequabic lake, but that it solidified before reaching the surface, and at present we have no knowledge in this region of a surface flow of rock similar to the tuff.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Cascade between Epsilon and Knife lakes.
Fig. 2. Pyroxene granite porphyry, with unusually large phenocrysts of feldspar. (No. 776 G.) Three-fourths natural size.

PLATE II.

Geological map of Kekequabic lake and vicinity, Lake Co., Minn. The figures in the lakes show their hight above sea level.

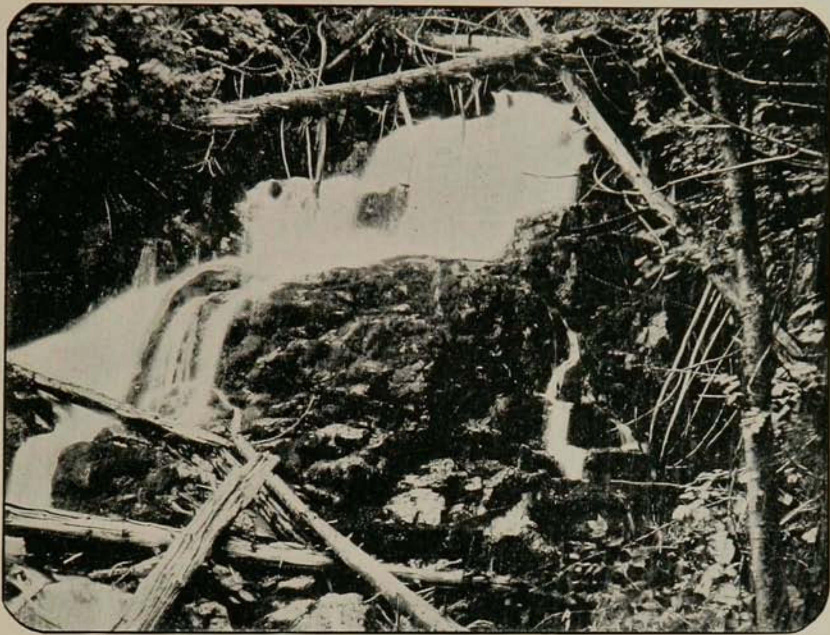


Fig. 1.

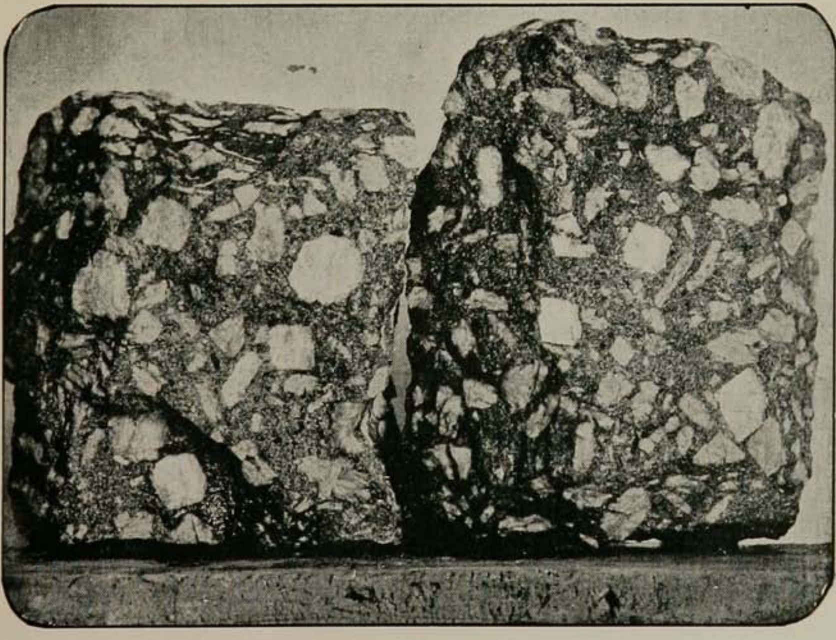
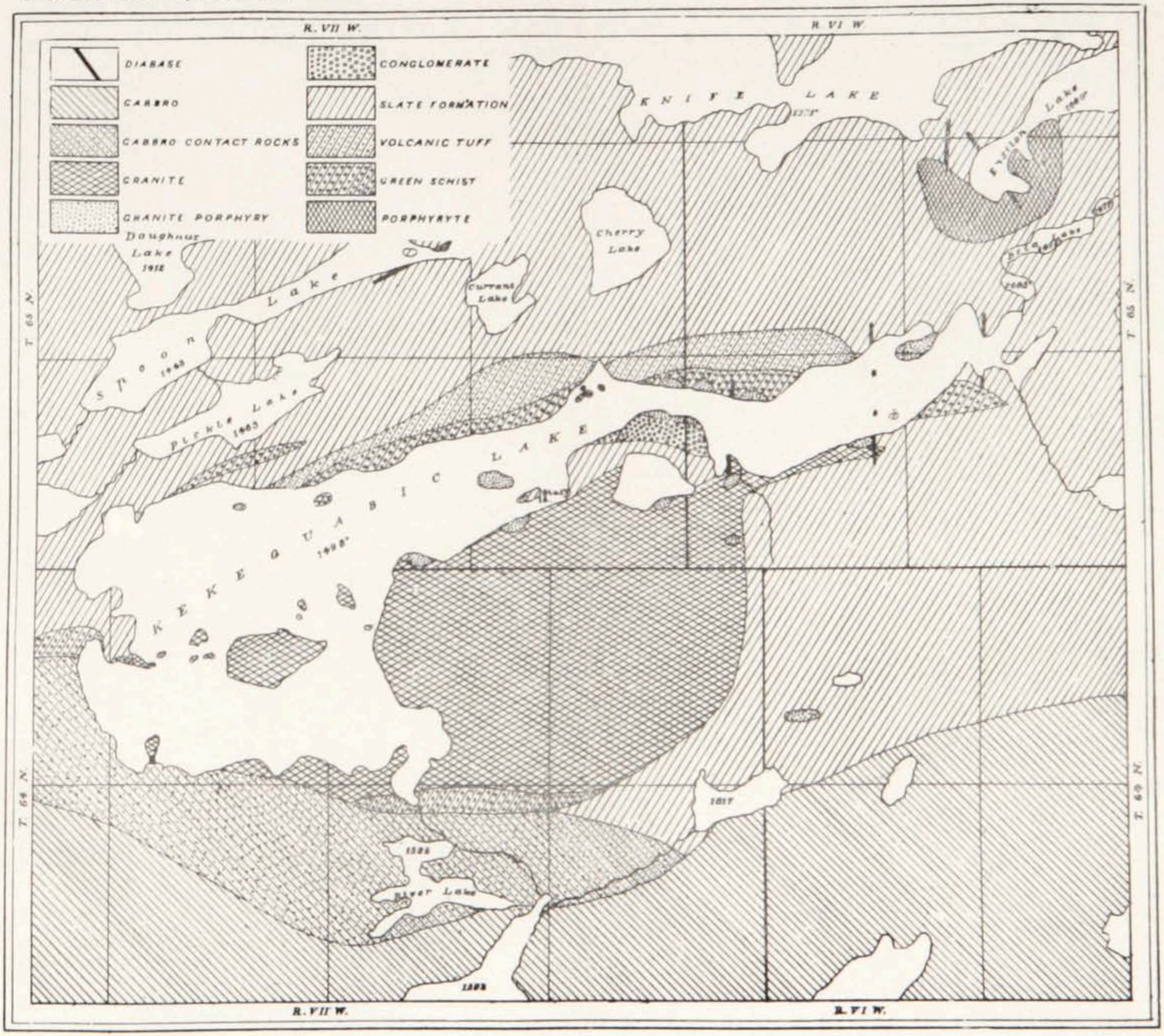


Fig. 2.


R. VII W.
R. VI W.
DIABASE
GABBRO
GABBRO CONTACT ROCKS
GRANITE
GRANITE PORPHYRY
CONGLOMERATE
SLATE FORMATION
VOLCANIC TUFF
GREEN SCHIST
PORPHYRYTE
KNIFE LAKE
Doughnut Lake 1912
Cherry Lake
Current Lake
Spoon Lake
Pickle Lake
KEKEQUABIC LAKE
T. 65 N.
T. 64 N.
1817
R. VII W.
R. VI W.

III

CATALOGUE OF ROCK SPECIMENS COLLECTED IN NORTHEASTERN MINNESOTA IN 1892

BY ULYSSES SHERMAN GRANT

This list is a continuation of that ending on page 110 of the 20th (1891) Annual Report. Most of the specimens have not been examined since they were collected, so the designations may not always be correct. The terms "greenstone" and "muscovado" are applied, according to the field usage of the Survey, to certain rocks which have not as yet been closely studied. In giving localities the township is always *north*, and the range is always *west* of the Fourth Principal meridian.

735. Muscovado near gabbro contact. S. E. ¼ S. E. ¼ S. W. ¼ sec. 32, T. 64–7, island in Thomas lake.

736. Coarse biotitic gabbro. S. ½ sec. 18, T. 64–6, north shore of Marble lake.

737. Muscovado. N. ½ N. W. ¼ sec. 7, T. 64–6.

738. Altered conglomerate. S. ½ S. W. ¼ sec. 6, T. 64–6.

739. Matrix of altered conglomerate. S. W. ¼ S. E. ¼ sec. 1, T. 64–7.

740. Matrix of altered conglomerate. N. W. ¼ N. E. ¼ sec. 12, T. 64–7.

741. Fine gabbro. N. ½ N. E. ¼ sec. 12, T. 64–7.

742. Metamorphosed matrix of altered conglomerate. N. W. ¼ N. W. ¼ sec. 7, T. 64–6.

743. Compact gray argillyte. E. ½ S. E. ¼ sec. 1, T. 64–7.

744. Greenstone band in altered slate. N. W. ¼ S. E ¼ sec. 1, T. 64-7.

745. Altered slate. Same locality.

746. Pyroxene granite near contact with slate. N. W. ¼ S. E ¼ sec, 1, T. 64-7.

747. Gray slate near granite contact. Same locality.

748. Pyroxene granite. N. W. ¼ S. E. ¼ sec. 1, T. 64-7.

749. Pyroxene granite near contact with slate. N. E. ¼ S. E. ¼ sec. 1, T. 64-7.

750. Feldspathic vein rock in slate. N. E. ¼ S. E. ¼ sec. 1, T. 64-7.

751. Hardened slate. Same locality.

752. Fine biotite rock. S. ½ N. W. ¼ sec. 12, T. 64-7, portage running northeast from Shoofly lake.

753. Vitreous quartzyte carrying more or less magnetite, near gabbro contact. N. ½ N. W. ¼ sec. 20, T. 64-6.

754. Gabbro near contact with quartzyte. Same locality.

755. Purple syenite. S. W. ¼ N. E. ¼ sec. 34, T. 63-6.

756. Diorite. Probably in the N. W. ¼ N. W. ¼ sec. 12, T. 62-6.

757. Very coarse gabbro. Probably in the N. E. ¼ S. W. ¼ sec. 12, T. 62-6, bay on north side of Syenite lake.

758. Brick red syenite. Probably in the S. W. ¼ sec. 12, T. 62-6, north side of Syenite lake.

759. Fine grained dark syenite. Probably near the centre of the N. ½ sec. 13, T. 62-6, east shore of Syenite lake.

760. Fine grained pinkish syenite. Probably near the centre of sec. 13, T. 62-6, east shore of Syenite lake.

761. Fine grained pinkish syenite. Probably in the N. W. ¼ sec. 24, T. 62-6, southeast shore of Syenite lake.

762. Fine grained gray syenite. Probably in the S. W. ¼ sec. 24, T. 62-6, southeast shore of Syenite lake.

763. Fine grained gray syenite. Probably in the S. W. ¼ sec. 12, T. 62-6, island in north part of Syenite lake.

764. Volcanic tuff. N. E. ¼ S. E. ¼ sec. 34, T. 65-7, island in Kekequabic lake.

765. Dark slate near contact with pyroxene granite porphyry. E. ½ S. W. ¼ sec. 34, T. 65-7, point on north side of Kekequabic lake.

766. Dark slate and pyroxene granite porphyry in contact. Same locality.

767. Green schist. N. E. ¼ S. W. ¼ sec. 35, T. 65-7, island near north shore of Kekequabic lake.

768. Greenish graywacke. S. W. ¼ N. E. ¼ sec. 33, T. 65-7, bay on north side of Plum lake.

769. Compact carbonate rock. N. E. ¼ S. W. ¼ sec. 33, T. 65-7, west end of Plum lake.

770. Volcanic tuff. N. E. ¼ sec. 35, T. 65-7, top of hill on north side of Kekequabic lake.

771A to 771F. Pyroxene granite from an exposure which is broken into parallel sheets. S. E. ¼ S. W. ¼ sec. 2, T. 64-7, west side of point on south shore of Kekequabic lake.

772. Interbanded green slate and dark red jaspilyte. Near center of N. W. ¼ sec. 35, T. 65-7, southeast corner of Pickle lake.

773. Medium grained diabase. N. W. ¼ S. E. ¼ sec. 26, T. 65-7, south shore of Spoon lake.

774. Pyroxene granite. N. E. ¼ sec. 1, T. 64-7, summit of ridge south of Kekequabic lake.

775. Coarse diabase. S. E. ¼ S. W. ¼ sec. 29, T. 65-6, top of hill on north shore of Kekequabic lake.

776. Pyroxene granite porphyry with large feldspar phenocrysts. N. W. ¼ S. W. ¼ sec. 31, T. 65-7, just south of Kekequabic lake.

776A. Pyroxene granite within three inches of porphyry contact. Same locality.

777. Pyroxene granite. Same locality.

777A. Pyroxene granite porphyry within six inches of granite contact. Same locality.

778. Granite and granite porphyry in contact. Same locality.

778A. Altered argillyte. S. E. ¼ S. W. ¼ sec. 31, T. 65-6, south of Kekequabic lake.

778B. Argillyte. Same locality.

779. Pyroxene granite. Same locality.

779A. Pyroxene granite with dark feldspars. Same locality.

780. Sericitic argillyte. Same locality.

781. Hornblende granite (?). N. E. ¼ S. W. ¼ section 31, T. 65-6, just south of Kekequabic lake.

782. Pyroxene granite. Same locality.

783. Hornblende granite (?). Near center of section 31, T. 65-6, just south of Kekequabic lake.

783A. Rock fragments from same. Same locality.

784A and 784B. Altered grit. Probably near center of E. ½ section 32, T. 65-6.

785. Altered grit with red jaspilyte fragments. Probably in S. E. ¼ section 32, T. 65–7, east shore of small lake.

786. Pyroxene granite porphyry. Same locality.

787. Conglomerate. S. W. ¼ N. W. ¼ section 31, T. 65–6, south shore of Kekequabic lake.

788. Pyroxene granite porphyry near graywacke (?). S. W. ¼ S. W. ¼ section 29, T. 65–6, north shore of Kekequabic lake.

788A to 788C. Rock intermediate between 788 and 788D. Same locality.

788D. Graywacke (?). Same locality.

789. Porphyritic metamorphosed conglomerate. S. W. ¼ N. E. ¼ section 28, T. 65–6, north side of narrows of Zeta lake.

790. Gabbro near contact with quartzyte. N. E. ¼ N. E. ¼ section 34, T. 65–5.

791. Muscovado. N. E. ¼ N. E. ¼ section 34, T. 65–5, north side of stream.

792. Grayish purple hornblende porphyryte. North line of section 29, T. 65–6, south shore of Epsilon lake.

793 and 793A. Purple hornblende porphyryte. N. W. ¼ N. E. ¼ sec. 29, T. 65-6, hill on shore of Epsilon lake.

793B. Decayed dolomyte (?). S. E. ¼ S. W. ¼ sec. 20, T. 65-6, west shore of Epsilon lake.

794. Green porphyryte at contact with slate. S. W. ¼ S. E. ¼ sec. 20, T. 65-6, west side of little bay on south shore of Epsilon lake.

794A. Porphyryte near contact with slate. Same locality.

794B. Greenish slate at porphyryte contact. Same locality.

795. Graywacke from inclusion in porphyryte. S. E. ¼ N. W. ¼ sec. 29, T. 65-6, between Epsilon and Beta lakes.

796. Green porphyryte near contact with slate. Same locality.

797. Typical purple hornblende porphyryte. N. E. ¼ S. E. ¼ N. W. ¼ sec. 29, T. 65-6, south end of Epsilon lake.

798. Coarse diabase from centre of large dyke. Near south line of sec. 20, T. 65–6, between Epsilon and Knife lakes.

798A. Fine diabase from small dyke. Same locality.

799. Coarse diabase. Near centre of N. ½ sec. 7, T. 65-6, northwest corner of Amœba lake, at the portage.

800. Flinty black slate showing lamination. N. W. ¼ S. E. ¼ N. E. ¼ sec. 7, T. 65-6, north shore of Amœba lake.

801. Coarse grit holding black fragments. S. E. ¼ N. E. ¼ sec. 7, T. 65-6, north shore of Amœba lake.

801A. Black fragments from same. Same locality.

802. Fine grained laminated graywacke. N. E. ¼ S. E. ¼ sec. 7, T. 65-6, island in Amœba lake.

803. Flinty slate showing conchoidal fracture. N. E. ¼ N. E. ¼ sec. 18, T. 65-6, west side of bay of Amœba lake.

804. Carbonaceous (?) slate. N. W. ¼ N. E. ¼ sec. 8, T. 65-6, east shore of small bay.

805. Volcanic tuff (?). Near north line of sec. 9, T. 65-6, southeast shore of lake.

806. Greenish tuff (?) graywacke. W. ½ N. E. ¼ sec. 9, T. 65-6, south east shore of lake.

807. Green volcanic ash (?). N. E. ¼ S. W. ¼ sec. 3, T. 65-6, west shore of lake.

808. Greenish slate and graywacke showing lamination. Same locality.

809 A and 809 B. Gray argillyte. N. W. ¼ N. W. ¼ sec. 2, T. 65-6, east side of lake.

810. Coarse graywacke. N. E. ¼ S. E. ¼ sec. 3, T. 65-6, south end of island.

811. Breccia. S. E. ¼ N. W. ¼ sec. 10, T. 65-6, near north end of portage.

812. Green volcanic ash (?). S. E. ¼ S. W. ¼ sec. 3, T. 65-6, west shore of lake.

812 A. Green schist. S. ½ N. E. ¼ sec. 2, T. 65-6, north shore of lake.

813. Grit. S. W. ¼ sec. 1, T. 65-6.

814. Conglomerate. N. W. ¼ N. W. ¼ sec. 1, T. 65-6, west shore of lake.

814 A. Coarse hornblende granite from boulder in the conglomerate. Same locality.

814 B. Various pebbles from the conglomerate. Same locality.

814 C. Green pebbles from the conglomerate. E. ½ S. E. ¼ sec. 35, T. 66-6, west shore of lake.

815. Peculiar light gray graywacke. S. ½ S. W. ¼ sec. 10, T. 65-6, north shore of Knife lake at portage.

816. Breccia. N. W. ¼ S. W. ¼ sec. 10, T. 65-6, top of steep hill.

817. Conglomerate. N. E. ¼ N. E. ¼ sec. 10, T. 65 6.

817 A. Pebbles from conglomerate. Same locality.

817 B. Variolyte (?) pebbles from conglomerate. Same locality.

818. Coarse grit showing sub-porphyrytic white feldspars. E. ½ S. E. ¼ N. E. ¼ sec. 34, T. 66-6, west side of point in lake Avis.

819. The same. S. W. ¼ N. W. ¼ N. W. ¼ sec. 35, T. 66-6, point on west shore of lake Avis.

820. Coarse grit holding elongated gray pebbles. N. W. ¼ N. E. ¼ sec. 34, T. 66-6, point on north shore of lake.

821 and 821A. Contact of Ogishke conglomerate and granite. N. E. ¼ S. E. ¼ sec. 7, T. 65-5, west of West Sea Gull lake.

822. Greenstone. Near centre of S. E. ¼ sec. 7, T. 65-5, west of West Sea Gull lake.

823. Dark green schist. N. line of sec. 22, T. 65-5, a short distance E. of the N. W. corner of the section.

824. Gray porphyrytic rock. A short distance E. of the last.

825. Pink granite. N. line of sec. 22, T. 65-5, ⅛ mi. E. of the N. W. corner of the section.

826. Granite. A short distance E. of the last.

827. Chloritic granite. N. line of sec. 22, T. 65-5, E. of the ¼ post.

827 A and 827 B. Quartz-porphyry (?). Same locality.

828. Granite in contact with greenstone. E. line of sec. 23, T. 65-5, about ¼ mi. N. of the ¼ post.

829 and 829 A. Greenstone near granite contact. Same locality.

829 B. Greenstone holding a few quartz grains. A short distance S. of the last.

829 C. Greenstone. E. line of sec. 23, T. 65-5, about ⅛ mi. N. of the ¼ post; top of high ridge.

829 D. Very coarse greenstone. Same locality.

829 E. Coarse greenstone. E. line of sec. 23, T. 65-5, at the ¼ post.

830. Greenstone containing purple areas. W. line of sec. 23, T. 65-5, S. of the ¼ post.

831. Fine grained syenite. Same locality.

832. Light purplish graywacke. Same locality.

833. Gray porphyritic rock. W. line of sec. 26, T. 65-5, a short distance S. of the N. W. corner of the section.

834. Greenstone with hornblende crystals and pebble forms. W. line of sec. 26, T. 65-5, N. of the ¼ post.

835. Grit. S. line of sec. 21, T. 65-5, W. of the ¼ post.

836. Diabase. N. line of sec. 21, T. 65-5, W. of the ¼ post.

837. Altered camptonyte (?). S. W. ¼ N. W. ¼ sec. 12, T. 65-5, N. W. shore of Cucumber island, Sea Gull lake.

838. Greenstone. N. W. ¼ sec. 20, T. 65-5.

839. Granite with vein of chalcedonic (?) silica. [See: "Geological age of the Saganaga syenite", by H. V. Winchell; Amer.

Jour. Sci., vol. xli., pp. 386–390, May, 1891.] This specimen is from the vein described in this article. N. E. ¼ S. W. ¼ sec. 12, T. 65–4, Granite river, at east end of portage.

840. Greenstone. Sec. 1, T. 64–6, west shore of Gabimichigama lake.

840A. Greenstone holding magnetite. S. W. ¼ S. E. ¼ sec. 1, T. 64–6, west shore of Gabimichigama lake.

841. Coarse gabbro. S. W. ¼ S. W. ¼ sec. 1, T. 64-6, west end of Gabimichigama lake.

841A. Coarse biotite muscovado. S ½ S. W. ¼ sec. 1, T. 64–6, north side of bay of Gabimichigama lake.

842. Diabase from centre of dyke. N. ½ N. ½ sec 12, T. 64–6, north side of point in Gabimichigama lake.

842A. Fine diabase from edge of dyke, with gabbro attached. Same locality.

843. Fine gabbro (?). S. E. ¼ S. E ¼ sec. 1, T. 64–6, north side of small bay of Gabimichigama lake.

844. Heavy, dark, biotitic band in the quartzyte. S. W. ¼ S. E. ¼ section 1, T. 64–6, east shore of Gabimichigama lake.

845. Light gray muscovado. N. ½ S. W. ¼ section 1, T. 64–6, south shore of Gabimichigama lake.

845A. Yellow muscovado. Same locality.

846. Quartzyte with magnetite and much amphibole. Near line between ranges 6 and 7, T. 64, south shore of Gabimichigama lake.

847. Muscovado from fragment in gabbro. S. W. ¼ N. W. ¼ section 6, T. 64–5, island in Gabimichigama lake.

848. Pyroxene from gabbro. S. E. ¼ S. W. ¼ section 32, T. 65–5, east shore of Gabimichigama lake.

849. Red granite from vein in gabbro. N. W. ¼ N. E. ¼ section 6, T. 64–5, island in Gabimichigama lake.

850. Muscovado from the gabbro. S. W. ¼ S. W. ¼ section 1, T. 64–6.

851. Gabbro consisting almost entirely of plagioclase. S. E. ¼ N. E. ¼ section 16, T. 64–5, east shore of Little Saganaga lake.

852. Fine granite from dyke in gabbro. E. ½ section 16, T. 64–5, east shore of Little Saganaga lake.

853. Diabase from dyke in gabbro. N. E. ¼ N. E. ¼ section 24, T. 64–6, portage leading southwest from Little Saganaga lake.

854. Quartz gabbro. S. E. ¼ S. W. ¼ section 12, T. 64–6, southwest shore of small lake.

854A. Coarse grained quartz gabbro. Same locality.

855. Muscovado. W. line of section 9, T. 64–5, a short distance from the N. W. corner of the section.

856. Muscovado. N. W. ¼ S. E. ¼ section 22, T. 64–5.

857. Typical fresh muscovado. The large faces of the specimen are parallel to the "bedding". Near line between sec. 2, T. 64-5 and sec. 35, T. 65-5, northeast shore of bay of Bashitanakueb lake.

857A. Typical fresh muscovado. A few rods north of the last.

857B. Decaying muscovado. The large faces of the specimen are parallel to the "bedding". Same locality.

858. Olivine gabbro showing a gneissic structure. N. E. ¼ N. W. ¼ sec. 11, T. 64-5, south shore of Bashitanakueb lake.

859. Olivine gabbro. N. ½ S. E. ¼ sec. 3, T. 64-5, north shore of Bashitanakueb lake.

859A. Nodules rich in olivine and magnetite, from the gabbro. Same locality.

860. Rather coarse grained fresh muscovado. S. W. ¼ S. E. ¼ S. W. ¼ sec. 36, T. 65-5, south shore of Muscovado lake.

861. Reddish granite. N. E. ¼ S. W. ¼ sec. 3, T 64-5, south shore of lake.

862. Quartzyte showing fine laminæ. N. ½ sec. 34, T. 65-5.

863. Muscovado showing banding. N. ½ sec. 2, T. 64-5.

864. Green schist. S. side of S. E. ¼ S. E. ¼ sec. 21, T. 65-4.

864A. Fine grained quartzyte band. Same locality.

864B. Magnetite band. Same locality.

865. Fine grained greenstone. N. E. ¼ S. E. ¼ section 24, T. 65-5, south shore of lake.

865A. Greenstone at contact with syenite porphyry. S. E. corner of N. E. ¼ S. W. ¼ sec. 24, T. 65-5.

866. Syenite porphyry. Same locality.

866A. Syenite porphyry at contact with greenstone. Same locality.

867. Greenstone. W. ½ S. W. ¼ sec. 30, T. 65-4, portage east from Flying Cloud lake.

868. Greenstone. N. W. ¼ S. W. ¼ sec. 30, T. 65–4, north shore of lake.

869. Coarse mottled greenstone. S. W. ¼ N. W. ¼ sec. 30, T. 65–4, north end of portage.

870. Schistose greenstone. The large flat surface is parallel to the schistose structure. S. E. ¼ N. W. ¼ sec. 30, T. 65–4, south side of lake.

871. Gabbro ten feet from contact. N. E. ¼ N. E. ¼ S. E. ¼ sec. 30, T. 65-4, south shore of stream.

871A. Gabbro within eighteen inches of contact. Same locality.

871B. Gabbro within two inches of contact. Same locality.

872. Gray biotite rock. Near north line of sec. 31, T. 65-4, west side of Gaiter lake.

873. Fine gabbro within 100 feet of contact with quartzyte. W. ½ N. W. ¼ S. W. ¼ sec. 29, T. 65-4.

874. Porphyritic diabase. S. W. ¼ N. E. ¼ sec. 29, T. 65-4, just north of Akeley lake.

874A. Diabase from contact at top of sheet. Same locality.

874B. Diabase from contact at bottom of sheet. Same locality.

874C. Quartzyte at contact with diabase. Same locality.

875. Greenstone. S. W. ¼ N. E. ¼ sec. 29, T. 65-4, just north of the workings at Akeley lake.

876. Gray rock holding graphite. S. W. ¼ N. E. ¼ sec. 28, T. 65-4, Paulson's camp.

876A. The same at gabbro contact. Same locality.

877. Fine grained gray quartzyte. E. ½ S. W. ¼ sec. 21, T. 65-4.

878. Greenstone. Same locality.

879. Fine quartzyte banded with magnetite. Same locality.

880. Magnetitic iron ore. Near center of N. ½ sec. 28, T. 65-4.

881. Coarse vitreous quartzyte. S. W. ¼ N. W. ¼ sec. 28, T. 65-4.

882. Peculiar dark micaceous part of quartzyte. N. ½ S. W. ¼ N. E. ¼ sec. 28, T. 65-4.

883. Gabbro. E. line of sec. 27, T. 65-4, north of the ¼ post.

884. Fine gabbro. S. E. ¼ N. E. ¼ sec. 29, T. 65-4.

885. Coarse olivine gabbro. S. W. ¼ N. E. ¼ sec. 28, T. 65-4, south shore of small lake.

885 A. Gabbro very rich in olivine. Same locality.

886. Fine diabase. S. E. ¼ S. E. ¼ sec. 22, T. 65-4.

887. Nickel ore. S. W. ¼ N. W. ¼ N. W. ¼ sec. 27, T. 65-4.

888. Garnetiferous band in green slates. Just N. of the S ¼ post of sec. 22, T. 65-4.

889. Diabase from dyke. Just S. of the N. E. corner of sec. 22, T. 65-4.

889 A. Fine diabase from edge of dyke. Same locality.

890. Gray quartzyte. About ¼ mi. S. of the N. E. corner of sec. 22, T. 65-4.

891. Porphyritic diabase. S. E. ¼ S. E. ¼ sec. 22, T. 65-4.

892. Gray quartzyte band from the slates. Same locality.

893. Diabase from dyke. Cross river, S. line of sec 27, T. 65-4.

IV.

PRELIMINARY REPORT OF A RECONNOISANCE IN NORTHWESTERN MINNESOTA IN 1892.

BY J. E. TODD.

ITINERARY.

Having prepared an outfit, consisting of a covered spring wagon and span of ponies, and secured an experienced assistant, Mr. Arthur W. Chase of Hastings, I left Minneapolis July 7, 1892.

We proceeded by the main road, up the west bank of the Mississippi to Little Falls, there crossed and continued on the opposite side to Brainerd, arriving July 12th.

Pursuant to correspondence with Mr. S. A. Shellabarger and Mr. Pettengill, both of Staples, I went by rail to that point. I there investigated reported finds of petroleum, found them mistaken, and with the latter gentleman visited some "curious mounds," on sections 9 and 16, T. 132, 33; they were clearly an "osar" half a mile long and 30 to 50 feet high.

Returning to Brainerd, I prepared for camping, and proceeded to Leech lake by the main trail, via. Pine River and Hackensack post offices. Of necessity I returned to the latter point, sec. 19, T. 140, 30, and thence went nearly due west to Park Rapids. Thence northwest to the county line which we followed quite closely to lake Itasca, then down its east side to its outlet, where we procured a boat and visited the southwest head of the lake and photographed its inlets and Elk lake.

From Itasca we kept a north course, fording the Mississippi at Dutch Fred's crossing, on to Mike Spain's, sec. 29, 146, 35. After making a short trip about three miles northwest, we followed the trail to lake Bemidgi, crossing the Little Mississippi on sec. 16, 146, 35, Grant creek on or near sec. 29, 147, 34, and lake Bemidgi upon the circular bar formed by the inflowing Mississippi. From Carson's trading post on the south shore of the lake, we retraced our course six or seven miles, then struck north by a trail to N. E. cor. sec. 26, 148, 34, and thence a little south of west to Bagley Dam, sec. 31, 148, 35, on Clearwater river.

After taking a foot-trip about six miles southwest from there, nearly to the Little Mississippi, we went on down the west bank of the Clearwater to Clearwater Lake dam, sec. 12, 149, 36. Thence we made a trip to Red Lake Agency, going by the "Little Rock road" and returning by the "Sugar Camp road." The two coincide as far as Sandy river. A foot trip was also taken about two miles south from the Agency. We reached the Agency July 28. After returning to Clearwater lake dam we took the old trail to Fosston via. How's, sec. 4, 147, 37, and Popple, sec. 22, 147, 38.

From Fosston we went on past McIntosh, "Bucktown," Lambert and Badger, west to sec. 1, T. 150, 45, thence south two miles, then east and north to Red Lake Falls. Thence to Thief River Falls, where finding that we could not take a short course to Jadis, we went by Excel and Bokke's, sec. 22, 156, 45, to the "Pembina trail," crossed Middle river near the S. E. corner of T. 157, 46, and the Tamarac near the middle of the north line of the same, we soon got on to the "Jadis ridge" which we followed over 40 miles nearly to that point. From Jadis we took our team to sec. 15, T. 162, 39, where we left it and taking a guide made our way on foot to the mouth of War Road river on Lake of the Woods, arriving Aug. 9th. Next day we hired an Indian with his canoe to take us past Rocky point and two or three miles northeast to a bare, rocky island which for convenience we will call Cormorant island because we found a score or more of cormorant nests upon it.

From this our farthest point we retraced our former course as far as the Tamarac river, at Nelson's, sec. 14, 158, 46, because there was no other practicable. From that point we went to Stephen by the stage route, and from there southeast to a road running east from Argyle, which we followed past Bokke's, Humboldt, Ingalls and Breese postoffices to sec. 11, T. 157, 42, where I left my team, and went on foot five or six miles east over marshy ground to the southern side of Thief lake. We then proceeded directly past Holt and Excel postoffices, Thief River Falls, St. Hilaire, Red Lake Falls and Lambert, to sec. 19, T. 150, 40; thence south about four miles, whence several short trips were taken on foot to explore an old channel, and thence southeast to Fosston.

From that point by the usual trail to White Earth Agency and on south past Richwood to Detroit, where I took the train for Minneapolis, Aug. 27th, leaving Mr. Chase to bring on the team.

SKETCH OF OBSERVATIONS AND RESULTS.

I was furnished with aneroid, compass, field glass and camera. Opportunity for extensive views were rare and over much of the way departure from the regular trail very laborious, and, therefore, seldom attempted. Opportunities for interviewing old settlers, surveyors and "cruisers," were diligently sought, and frequently led to valuable information.

1. *Exposures of Older Rocks.*—North of Little Falls no exposure of "bed-rock" anywhere was found except at the extreme limit of our journey, in Lake of the Woods. At Rocky point, showing nearly a mile along its west side and extending I was told several miles east, finely glaciated knobs rose like whalebacks 5 to 15 feet above the water level. Cormorant island, covering perhaps half an acre and rising 15 feet above the water, and a few small islands south of it were composed entirely of such rocks eroded a very little by the lake. The level of the lake was about six feet higher than a short time before because of a dam placed across its outlet at Rat Portage, as I was informed.

The rock at Cormorant island and the northern part of Rocky point is a dark magnetic gabbro as it would appear on macroscopic examination. It was found so highly magnetic that no reliance could be placed on the compass. The needle would swing all round the circle within a few feet if held three or four feet above the surface of the rock, and a mass of about a dozen cubic inches would hold the needle placed by it, in any position.

This rock is in places coarse grained and porphyritic. Upon Cormorant island it exhibited a striped appearance of flowing lines of light and dark, shading into one another.

Joining this dark rock upon the southwest is a fine grained pinkish gray granite, the intersecting plane between them being nearly perpendicular.

I met at Red lake a settler by the name of Wm. Kasson who told me that there was an exposure of dark hard rock, rising a few feet above the south fork of Battle river, on or near sec. 36, 152, 30.

Another settler who had been a quarryman said that ten miles west of where Badger creek enters the "Big muskeg," near the center of Kittson county, he dug down four feet below the surface and found limestone four feet square without seams, how much more extensive he did not discover. Not far away on a ridge he saw flaky layers of limestone, tipped.

At Red Lake Falls a well had been bored over 400 feet. From the statements of the borer, Mr. Anderson, the following section is made;

1. 47 ft. Lacustrine clay, much of it laminated.

2. 47-112 feet. Clay with small stones. Water struck in limited quantity at 47 feet.

3. 112-316 feet. Sand and gravel cemented above the water for several feet.

Struck water at 118 feet and 316. The last rose up to 47 feet.

4. 316-407. Clay without grit. Could bore 50 feet a day.

No. 4 is without doubt preglacial and possibly part of No. 3.

Mr. J. C. O'Brien of Red Lake Falls informed me that there are rock ledges along most of the course of Rainy river; that Rapid river, which is a large stream, has a branch running nearly parallel with Rainy river, and not far away from it, skirting the edge of the rocky area.

2. *Glacial Drift.*—This formation covers without doubt the whole region visited, with the exceptions already mentioned. It is in turn covered over wide areas by more recent deposits formed by lakes and rivers.

As regards the characters of the drift sheet in general, little need be said here. The upper or modified drift, which may be the enclacial drift more or less stratified by the waters of the melting ice-sheet, is generally sandy in the Mississippi basin and over the divide toward the Red Lake as far as the morainic strip running east south of the lake. A clayey strip was noticed south of Leech lake and another extending northeast—southwest crossing T. 148, 35. In this same area limestone erratics are very rare. Dr. Jas. R. Walker, sub-agent at Leech lake, after wide travel informed me that he had seen but one limestone boulder. I found none until I reached T. 146, 36, and then only one or two small shaly ones. I found a few lime-pebbles in lake Itasca. Throughout this same area black silicious slaty boulders seem more common than elsewhere.

After entering the morainic strip south of Clearwater lake, limestone boulders became more abundant and were not very scarce throughout the rest of our journey. In the rest of our course also. clay was the common subsoil, except on terraces and beaches. It was generally of a light gray, though sometimes yellowish.

Typical till was observed at the base of several high banks along the Clearwater and Red Lake rivers.

Moraines.—Not venturing to decide their relations, in most cases, I will simply enumerate them by localities.

(*a*). Rough ground was struck southeast of Gull lake, and continued more prominently west of the lake north to a little north of Twin lakes. High ground was crossed just south of Pine river in T. 137, 29. This apparently came in from the southwest, and was thought to connect with the ridges left 8 or 10 miles further south.

(*b*). A very rough country was entered in the northwest corner of T. 139, 30, and traversed for about 14 miles going north. It rose 150 to 175 feet above Leech lake and 80 to 100 above the country south. Dr. Walker informed me that it did not extend farther east than the southeast corner of Leech lake, also that there were hills southwest of the lake. I was informed by a "cruiser" that there were hills west of Pine lake which connected with those along Gull lake, therefore I am disposed to consider the morainic region south of Leech lake to be an interlobular angle of the same moraine to which (*a*) belongs.

(*c*). No distinct morainic features were noticed between Hackensack and Park Rapids, but near the southeast corner of T. 141, 36, we encountered ridges again, extending east and west, which became higher and rougher northward. These features continued till we were east of the fork in lake Itasca. Its higher points rise 150 feet or more above the lake.

(*d*). Along Grant creek in T. 147, 34, we encountered a narrow but well defined moraine running S. S. E., the knobs rising abruptly 25 and 30 feet. A trader, Mr. Carson, of lake Bemidgi, said it passed 4 or 5 miles south of that lake. We crossed an elevated strip in the south part of T. 148, 34, which is supposed to be a continuation of the same, running more directly north. From reports we judge that it joins a morainic strip running east and west, a little further north.

(*e*). A clayey elevated undulating strip was crossed in the northern part of T. 148, 35, crossing the Clearwater in an eastward direction, and rising in places 175 feet above that stream.

(*f*). The region north and west of Clearwater lake is morainic, and east of the crossing of Sandy river there are knobs rising 125 feet above that stream and 50 feet above the clayey plain north. This is believed to be the northern member of a double or interlobular moraine running east. Its northern slope is understood to extend quite directly westward through the southern part of T. 150, 40.

(*g*). The region traversed between Clearwater lake dam and Fosston was mostly morainic, higher points being crossed in 148, 36, near the east line of 147, 38, and near center of 147,39. There appears to be a moraine running southwest along northwest of the upper Clearwater, which very likely connects with the eastern morainic belt in Becker county.

(*h*). The country is morainic north and northwest of Fosston, but not so distinctly so west and south, though there are some knobs along west of the old valley leading east and south of that place.

(*i*). A very stony well defined moraine crosses the southern tier of sections in T. 150, 40, and ends abruptly near the southwest corner, where it crosses a well preserved lake beach. This is believed from reports to connect with (*f*.)

(*j*). A well developed moraine was crossed south of the Wild Rice river in T. 144, 40, where it rises over 100 feet above that stream. The same moraine was seen on the lower land, in or near T. 143, 43. I refrain from speaking of moraines already noted in reports.

(*k*). Mild morainic features were noted along west of the south courses of Thief and Red Lake rivers, in range 44, in north Polk county, particularly a few miles south of St. Hilaire. There are shallow basins separated with narrow low ridges and frequent boulders in places. It has evidently been subject to lacustrine action also. This is thought to continue southeast from 152, 44 and connect with (*i*).

(*l*). Five or six miles southwest of the mouth of War Road river we passed over a ridge lying east and west, about 45 feet in hight above the peat marshes or "muskegs" around. It was quite sandy in places, but showed boulders at various points and one circular basin was noted toward the east end. It was impossible to get a good idea of its form on account of the trees, but it appeared like an inclined sand plain sloping southward. Two other low bouldery ridges were crossed southwest of it. Mr. G. F. Schoonover, our guide, said that a similar ridge corresponding to the first mentioned was found farther east and connected with a ridge running nearly southwest from Rocky point. There is said to be a ridge a little north of the boundary, called Pine ridge, which connects north with Whitemouth ridge, just how I could not make out. High land north of the Roseau can be seen from Jadis ridge.

Rumors have come to me from several sources, some of them quite circumstantial, that there is quite a high ridge south or southwest of Rocky point. Possibly these may be morainic ridges to be correlated with (*i*) and (*k*). They are probably more or less shaped by lacustrine action.

Osars.—In or near the southeast corner of T. 146, 36, I ascended the head of an abrupt ridge rising about 100 feet above the surrounding plain. Its train of knobs of diminishing hight trended S. 30° W. mag. It was quite bouldery.

Some low winding ridges trending eastward were noted in the valley a few miles south of Fosston, which were probably of this class. They were not over 20 feet in hight.

In regions already described I noted two fine examples. One on sections 9 and 16, 132, 33, already mentioned, and one not far from Darling, Morrison Co. It is cut by the railroad and exhibits the stratified structure finely. It is 30 or 40 feet high.

Pitted Plains.—I know of no better term to express what I have observed at several points, though I am not sure that what have been so called by others are the same.

The finest example of this class is found south and southwest of Red lake. The topography is very even, rising gently to the south, but dotted with basins with abrupt sides and of quite uniform depth. These depressions are of all sizes from a few feet across to many acres. I could not resist the impression that an ice-sheet had gone to pieces, its blocks stranded and clay and sand had filled in quite level around them. Later they had melted and left their places vacant.

A similar but less perfect example is found about Leech lake and north of the east course of the Mississippi. Along the Little Mississippi this structure was marked along its channel, as though a subglacial channel had been marked by blocks of ice. This was noted particularly in the western part of 146, 35.

Old Channels.—Only a few of the more significant need be mentioned.

(*a*). There is a conspicuous gap through Moraine (*i*), beginning on or near sec. 27, 150, 40. From it a channel trends southwest and spreads out on a delta on a level with a well defined beach on or near sections 6 and 7 of the town next south. From the same gap a terrace, 40 to 60 feet higher, leads more directly southward toward McIntosh. In this terrace is a row of large basins and lakes with abrupt sides.

(*b*). There is a notable chain of lakes extending southwest from Leech lake, which is utilized by the Indians for a trail. It crosses T. 141, 32, and 140, 33.

(*c*). Several shallow winding channel-like swamps are found traversing interruptedly the plain forming the divide between the Clearwater and the Mississippi.

Striæ.—These are found abundantly on the surface of the only rocks found in the region, capable of receiving and preserving them, viz.: at the Lake of the Woods. Their direction is generally southwest, or parallel with the axis of the southwestern bay of the lake. As the magnetic needle was useless, note was taken with reference to the sun, but the results have not yet been calculated.

3. *Lacustrine and Recent Formations.*—Large portions of the region visited were formerly the bed of lake Agassiz. The several beaches of the lake were frequently traversed. We may enumerate and locate them as follows, beginning with the highest; we use local names, as their correlations are not certain:

(*a*). The Lindsay beach. This seems to intersect the moraine on sec. 31, 150, 40, and runs nearly south for three or four miles at least. It was first seen from the west and photographed with the thought that it was a terrace of Hill river.

(*b*). The Baudry beach. This passes east of north near the station Baudry. It was not closely examined. This is believed to correspond to some indistinct fragmentary beach lines noted along west of the south courses of Thief and Red Lake rivers, and possibly with the next.

(*c*). The Excel beach. This is well developed and nearly continuous, extending along the east lines of T. 155, 44, and 156,44. This, I believe, is sometimes called Oak ridge.

(*d*). The Higher Gentilly beach. Along the east side of Town Gentilly, 150, 45, are two sand ridges, one about 15 feet higher than the other. They are about 200 yards apart and a canal-like pond runs between them for some distance. Approaching the river north they turn westward and are said to pass Ives Station or ridge. They were found still together along west of the east line of T. 156, 46, and were observed between the Tamarac and Middle rivers.

(*e*). The Jadis ridge. This probably is a continuation of the last. It was followed from the northwest corner of T. 158, 46, north and then east-northeast past Pelan and Badger to sec. 22, T. 162, 40, near Jadis. It is a most imposing feature, forming a perfect thoroughfare through swamps and timber. It is grassy along its top, with oaks and elms on its slopes. It is often 18 to 20 feet high, with a breadth of 300 yards when of simple structure. It is at several points double or triple, with cross ridges. At its eastern extremity it ends in an abrupt curve to the south. It is there about 65 feet high above the plain east, with lower terraces at 12 and 38 feet above the same. It will be noticed that this is about the hight of the bouldery ridge mentioned under moraines (*l*).

(*f*). The Lower Gentilly beach. As before said there are two ridges nearly parallel along the east side of T. 150, 45. It is found in company with the Higher, where we met with it, till both have crossed the Tamarac, then the lower is said to turn northwestward to the vicinity of Hallock. The Pembina trail follows it. We were not so fortunate as to determine the exact point where the two separated.

(*g*). The Foldal beach. Another well defined ridge was found about parallel with the last. It was crossed on sec. 4, 156, 46, and on or near sec. 24, 158, 47.

(*h*). Nelson's beach. Running east through the third tier of sections in T. 162, 39, is a low sandy beach, not more than 10 feet above the surrounding flat. I judge that the inner side is north, but am not certain. It seems to mark the north side of an old delta of the Roseau river.

Bouldery Strips.—The inner sides of the ridges are bounded generally with clayey flats quite thickly strewn with boulders, so much so as to interfere seriously with their tillage when dry enough to farm, and with mowing when used as hay-meadows. This feature is easily explained by the wash of waves and the undertow, while the adjacent beach was forming. In places they are so abundant as to suggest that floating ice may have assisted in collecting them. As Mr. Upham has already observed, boulders are rarely if ever found on the beach itself. I found one boulder of limestone about 6 inches in diameter on the summit of the lower beach in Gentilly, and one or two larger on Nelson's beach. The body of the beach is usually sand and gravel, the latter rarely coarse. Boulders however are found close to the beach and not far below the summit.

Clay Flats.—Extensive areas inside and remote from a beach are commonly covered with fine clay. This is the case about Stephen and I understand between there and the Red river, and so generally north and south along the bottom of the Red River valley.

About Red Lake Falls, as was finely shown in fresh railroad cuts, there is a deep deposit of dark laminated clays of fine grain. There is a layer of dark clay ⅛ to ¼ inch thick, then a loose light-colored deposit not more than a tenth as thick, which shows plant-like structure of some Algæ compressed. These deposits, though 20 feet in depth, in places are quite inconstant in thickness and sometimes pass abruptly laterally into sand. In the Roseau valley a similar formation was observed in freshly dug wells. A case was reported as follows, near Roseau lake: Eight feet below the surface this laminated clay was struck and was 8 feet thick; then sand, red clay and pebbles for 23 feet; then the laminated clay again, which continued down as far as 160 feet from the surface.

In Ross township near by a well was dug 110 feet deep all in this laminated clay, and from that depth the water rose to the surface. This was reported by Schoonover.

River Terraces.—A few only of the more notable may be mentioned here. Along the Clearwater, about Bagley dam, a sand terrace 25 to 30 feet above the stream is quite widely developed. A section below the dam showed the full hight built of obliquely stratified sand with a bouldery stratum about the middle.

At Red Lake Falls another section on the same stream was as follows:

20 feet. Dark lead-colored laminated clay, with very few pebbles. [Lacustrine.]

10 feet slope and undetermined, but from other sections, presumed to be occupied by the strata above and below.

8 feet. Yellow loam stratified, in places passing into fine sand. Bottom well defined.

7½ feet. Typical till, light bluish gray.

5½–3½ feet. Stratum of boulders above and laminated pebbly loam below.

19 feet. Lighter, looser buff till.

4–5 feet. Bouldery slope.

Level of Clearwater below the rapids.

The upper portion of this is doubtless lacustrine, and perhaps none is strictly stream terrace.

Topographical Notes.—In the basin of Red lake and of lake Agassiz the surface is very level and largely marshy. Elevations over five feet above the general level are rare, with the exception of the beaches and moraines already noted.

The divide between the Mississippi and the Wild Rice and Clearwater rivers is similarly even and marshy, but about 150 feet higher.

Mr. W. J. Hilligoss, of Fosston, an experienced surveyor and hunter, called my attention to the fact that the general level of the land south of the following line was about 100 feet higher than the general level of the plain north of it. The line he described as follows: Beginning on the west slope of the highland a little south of the Wild Rice, T. 144, 41, it goes in a sinuous line eastward to Schoolcraft river, and thence southeast towards Leech lake. Where I crossed it, I found his statement to hold good.

The existence of this buried escarpment, if such it be, may explain why the ice lobe from the east pushed over the divide between the Mississippi and the rivers northwest, as has been stated, so as to form its moraine on the slope northward.

Capt. Mockman, of Jadis, of wide and intelligent acquaintance with the region, informed me that Lake of the Woods is several feet higher than Roseau lake, that a "muskeg" or marsh nearly connects them, and that a low ridge, not over 200 yards wide, is all that hinders the water running.

He also stated that the region between the Roseau and Rat rivers was "mountainous," traversed with northwest-southeast ridges, that Pine ridge runs northwest, and that there are bouldery flats on the boundary west of the Roseau.

J. E. TODD,

Assistant Geologist.

Vermillion, S. D., Dec. 20, 1892.

V.

FIELD OBSERVATIONS OF N. H. WINCHELL IN 1892.

THE HALE, CINCINNATI AND BIWABIK MINES.

Field observations were begun March 5, 1892, by a hurried trip to the new mines then lately opened on the Mesabi range in secs. 1 and 2. T. 58-16. The report on the "Iron Ores of Minnesota" (Bulletin VI) had but lately been published, and had announced some of the early discoveries, but at that time none of the remarkable deposits had been found. It was not long, however, before some of the possibilities which that report had pointed out for the Mesabi range, began to take on the appearance of actualities. It was for the purpose of verifying some of these later discoveries that an early examination was made. At that time the Hale, the Cincinnati, the Shaw and the Biwabik mines were the center of interest and expectation, while further west the "Misabe Mountain" location, with numerous promising localities intervening, gave strong hope that the most glowing anticipations would be realized.

But little information was gained by this first visit to these mines, beyond the verification of ideas already published concerning the general geologic relations. At the Hale mine (S. W.¼ sec. 1, 58–16), the most easterly of the new group, the ore deposit was met with sometimes within two feet of the natural surface, and in some cases the turf itself grew in a red hematitic soil which resulted immediately from the disintegration of the ore. In other places the ore was found ten or twenty feet from the surface. This mine is just south from a low ridge of greenstone, about ten or fifteen rods distant, which, at a little further west, is replaced by granite. The ore, and the changed rock lies unconformably on these older rocks.

The Cincinnati mine property embraces eight "forties" in the central part of section 2, 58-16. At this mine the rock which intervenes between the ore and the greenstone is a rather loose quartzyte, which somtimes is charged with ore by downward infiltration. This intervening quartzyte is not visible at the Hale mine, but at the Cincinnati mine three shafts have penetrated this sand. Overlying the ore horizon is a series of slates, so called "black slates", although this rock is sometimes not at all slaty, but rather a black rock, fine-grained, in beds from four to twelve inches thick. The seven shafts which were examined on the Cincinnati property were all said to be in ore from five to fifty feet, although it was evident that this ore was not all of first class grade. These were all on the N. E. ¼ of the N. W. ¼ of section 2.

The Biwabik mine adjoins the Cincinnati toward the west, and several shafts here have entered ore of fine quality. Some of these shafts, which have been sunk by the simplest methods, and without the aid of steam power, have entered soft ore to the depth of over fifty feet, the overlying drift accumulations being from ten to twenty feet thick. Under the ore here also a sandstone has been encountered. Toward the north occurs the greenstone ridge which extends continuously from the Hale mine.

To reach these iron locations it is necessary at present to travel over an execrable road a distance of twelve miles from the Duluth and Iron Range railroad at Mesaba station. Over this road during the past winter much freight has been hauled, indeed all the lumber, supplies and all the personal accoutrements of the men here employed, as well as of those at Mountain Iron, have been hauled, at great expense, by horses, from this railroad station. This has caused the sudden influx of small traders and the establishment at the station of many transient fortune-seekers, resulting in a village of about a hundred temporary shanties.

MANGANESE OXIDE AT MONTICELLO.

Under the guidance of Mr. J. N. Stacy a visit was made (April 21) to the left bank of the Mississippi river at one mile above the village of Monticello. Here was found a bluff, about 25 feet high, (the usual bluff of the immediate river channel outside of the flood plain,) consisting of some strata of the

Cambrian, much hid by drift sand which falls from the top. The strata are of light green shale and white sandstone, the latter containing Lingula in considerable numbers, and belong in the St. Croix. This is an isolated cut by the river, inasmuch as generally the river bluff consists of drift, the lowest seen at the water level being a red till, or of fine stratified red clay. In the overlying gravel is much manganese stain. This here overlies a fine red brick clay, such as that used at Monticello.

On the west bank of the river, on sec. 32, T. 122, R. 25, is a considerable stratum of black manganese oxide. It extends visibly along the river bluff 200 or 300 feet, immediately overlying a pebley blue clay, and has an average thickness less than twelve inches. Overlying it is drift gravel and sand. The underlying blue clay extends indefinitely westward, and underlies also an extensive marsh in secs. 31 and 32. There is a suggestive topographic relation between this bog and the lower level at the river which leads to the supposition that this bog, which is itself affected with manganese and iron oxides, has its underground discharge into the river at this point. This supposition is strengthened by the existence of wad in greater or less amount over much of the surface of the marsh, mixed with greater amounts of bog iron ore. The perpendicular section at the marsh was found to average about as follows:

Peat	1—2½ feet.
Red bog iron	0—3 inches.
Black manganese and bog ore	0—2 feet.

Analysis made of the black deposit near the bottom gave but little manganese, the color being due principally, in this case, to organic matter. Analysis of the black deposit at the river bank, which first attracted attention, was given in the last report (p. 321), and is here repeated:

Sand and clay	4.98
Carb. lime	6.86
Carb. magnesia	.85
Oxide of iron	.51
Black oxide of manganese	79.83
Phosphorus	.09
Sulphur	.01
Water of hydration and organic matter	6.87
	100.00

THE MESABI RANGE ON SEC. 27, T. 60–13.

This is one mile south of the granite range. The land here is owned by the Mesabi Iron company and exploration is being made by the Mesabi Syndicate company, under the management of Capt. Wicks. Much expense has been incurred, the effort being to accomplish a thorough examination of a large tract of presumably iron-bearing lands. Capt. Wicks furnished much information, and guided the writer to several points of geological interest. He gave the following description of a drill-hole made in N. W. ¼ S. W. ¼ sec. 27, 60-13, one mile south of the granite. It is illustrated by samples of the rocks passed through, as numbered:

Diamond drill section, made on N. W. ¼ S. W. ¼ section 27, 60–13.

Drill No. 5.

1. Drift.. 6 feet.
2. Black and gray, fine, banded rock, with fine grained magnetite, the latter being distributed through the whole, and sometimes in beds six inches or ten inches in thickness. Survey number 1628.. 157 feet.
3. "Black slates," a rather massive rock to be named slate, charged with magnetite. Survey No. 1629. Closely allied to the last.. 70 feet.
4. Gray quartzyte, nearly all silica, but sometimes porous; has round secretions (or concretions), 1630A, shaped like the sponge Hindia, about ¼ to ½ inch in diameter. These are in cavities somewhat larger, but surrounded by a loose siliceous mesh which keeps them in place. This rock also has some non-homogenous places—angular and rounded masses appearing cut by the diamond drill. Survey No. 1630.. 20 feet.
5. "Ore." This is a siliceous, fine magnetite. The upper part contains some of No. 4, and the lower part is softer, and rather less in iron. This lower part gave no core, but washed away with the cuttings through the drill core, suggesting that it may have been soft ore. Capt. Wicks thinks 18–20 feet may be the average thickness of the ore (1631).. 24 feet.
6. Fine grained, pinkish-cream colored quartzyte, evidently granular, though very fine. (1632)........................ 17 feet.
7. Round, "fragmental" quartz grains cemented in a matrix of quartz. The lower portion of this stratum is of crystalline quartz, or at least of less evidently fragmental grains Some of it also appears like chalcedonic silica. The crystalline portions present faces of fracture 1-16 to 1-4 inch across, and resemble the quartz seen at Chub lake. It also contains pyrites in streaks and crystals. The transition downward to the next is gradual. (1633)...... 15 feet.

8. A hard, siliceous greenish rock, which contains many fragmental grains of quartz 1-16 to 1-8 inches across, some of them of a lavender blue color. While the mass of this is quartz it is colored apparently by fine debris from the earlier Keewatin greenstones of the vicinity, and should be considered the lower portion simply of No. 7. It also embraces rounded pieces from No. 10, and evident crystals of feldspar. (1634; compare 1637)........................	10 feet.
9. The lower portion of No. 8 becomes coarse and irregular, lighter colored, with pyrite or chalcopyrite, resembling outwardly a coarse granite. (1635)....................	1 foot.
10. Granite. (1636).......................................entered	3 feet.
Total..	321 feet.

Additional notes on the foregoing drill section.

A number of other drills also have been made in the same region, and according to the records kept by Capt. Wicks the following data were obtained:

Drill No. 1. S. E. ¼ S. E. ¼ sec. 29, 60-13. Drift, 8 ft.; black slates, 38 ft. (No. 3 of drill No. 5, above); gray quartzyte, (taconyte horizon), 12 ft. (No. 4 of drill No. 5, above); mixed ore, (50 p. c.), 10 ft. (No. 5, of drill No. 5, above); pinkish quartzyte, the lower portion of this had some of the coarser, fragmental quartz, 19 ft.; granite, 4 ft; total, 91 ft.

Drill No. 2. S. E. ¼, N. E. ¼, sec. 28, 60–13. Drift 7 ft.; black slates, 52 ft.; gray and brown quartz, 15 ft.; dark gray quartz, 9 ft. (the last two being the taconyte horizon); ore, hard, mixed, 24 ft.; mixed ore, and brown, "soft stuff," 7 ft. 6 in.; soft, green rock, mixed with quartz, conglomeratic, 7 ft.; granite, 4 ft. 3 in.; total, 125 ft. 9 in.

Drill No. 3. Surface, 4 ft. 9 in.; black slates, 81 ft.; dark, gray quartz, 12 ft.; quartz, and a little ore, 4 ft.; quartz, with seams of ore, 4 ft.; quartz and magnetite, 9 ft. 6 in. (the last four being the taconyte horizon); soft material and hard ore, 9 ft.; brown (pinkish) quartzyte, 32 ft.; white quartz, coarser, 8 ft.; granite, 4 ft.; total, 168 ft.

Drill No. 4. S. E. ¼, S. E. ¼, sec. 29, 60–13. Drift and boulders, 9 ft.; black slates, 36 ft.; mixed brown and gray quartzyte, (on the horizon of No. 4, of drill No. 5, above), no ore, 17 ft.; brown quartzyte and ore (six feet of ore in the core interbedded with the quartzyte, ore beds, 4 or 5 inches), 9 ft. 6 in.; hard ore, 14 ft. 9 in.; brown rock, soft, containing ore (30-40 p. c.), 2 ft. 9 in.; white fragmental quartzyte (bottom coarser), 10 ft.; granite, 2 ft.; total, 99 ft.

The rock of No. 6, of drill No. 5 (the pinkish, fine quartzyte), Mr. Wicks regards as complementary of the ore. Where it occurs he finds less ore, and that is impure, being mixed with this rock, and where none of this quartzyte is found, the ore, if found, is of high grade and clean. None of this rock is found in those holes where he has found the better ore. Mr. Wicks says he knows of this pinkish quartzyte in sec. 14, T.59-14, in angular pieces, evidently nearly in place; also in sec. 32, 60-13, where it is in outcrop.

The greenish, siliceous rock, No. 8 of drill No. 5, above, (Sur. No. 1634), is supposed to be in outcrop in N. E. ¼, S. W. ¼ sec. 22, 60-13, where a sample (1637) was procured from a pit 20 feet deep. This is a greenish, fragmental rock formed by debris from the adjoining granite and greenstone ridge holding conspicuous fragments of lavender-blue quartz supposed to be from the granite, and some orthoclase crystals, the latter eaten into by some agent, and showing within some of the green element which composes the matrix, and which apparently constitutes the most of the rock. Whether there be in this rock any volcanic diffusive debris, of a basic nature, is uncertain, but it appears possible, if not probable. Sometimes it contains pyrite and galenite. The general aspect is green. The rock is so soft that it cuts like semi-fibrous chlorite. In other places this member of the iron-bearing Taconic is rather a quartzyte, with green chloritic matter disseminated, the quartz grains being coarse and fragmental.

The rock 1631, the "ore" of the foregoing drill section No. 5, is seen fairly at No. 2 pit, which is on S. E. ¼ N. W. ¼, section 28, 60-13, where it embraces not only much hard, siliceous ore, but much coarser and some even conglomeratic masses and layers. The conglomerate is sometimes distinctly a conglomerate, and sometimes it appears like a cemented breccia, the matrix being "chalcedonic," or chemically deposited silica, very fine and flint-like, or hematite and silica. Sometimes the pebbles, or pieces of the breccia, are largely of flinty pieces of such silica also. In some of this are found the round sponge-like concretions (1630A), but they are rather in the more distinctly fragmental and finer layers, above the ore itself.

The rock of No. 8 of the section No. 5 (1634, also represented by No. 1637), is again repeated in No. 1638, in an extreme phase. It here shows so much coarse and rounded quartz that it should be called a sandstone, or a quartzyte. The green element supposed to have resulted, possibly, from volcanic debris of the time, being so scant as to merely speck the broken surface, or to appear more abundantly in blotches. In other specimens the sand grains are nearly wanting and the resulting rock is green, soft, homogeneous, rather fine-grained, and referable to a volcanic tuff, being another extreme condition of the rock 1634.

No. 6 of the above drill section (rock 1632) is also represented by rock 1640, which was obtained from an outcrop in N. W. ¼ N. E. ¼, sec. 32, 60-13. It is a pinkish fine quartzyte, and an interesting rock, both on account of its character and its associations. It weathers usually reddish or brownish. It appears pinkish in the drill cores, and on deep fresh fracture it is bluish and grayish. It is marked by the plainest sedimentary bands, which become evident when the rock is seen on a large scale. It is essentially a quartzyte, and it lies below the iron horizon, *i. e.*, the so-called iron horizon here, and is overlain also by a small amount of non-fragmental siliceous rock, a chalcedonic rock which grades off into the dark gray and irony layer above. This fine and chalcedonic belt is about 3 feet thick, but it is not all chalcedonic. It is sometimes made up of coarser and "fragmental" quartz grains. No. 1640, however, is in a sense intermediate between the chalcedonic and the fragmental. It may have been derived by chemical precipitation in the Taconic ocean, for it is very fine-grained; but it has none of that curly agate-like banding which characterizes the "chalcedonic" agate-like silica. This rock runs through two or three sections at least, and affords some outcrops in a series of bluffs south of the outcropping granite range. We could not see any place where it lies on anything, but it seems to come close to the granite. In the drill it was found to overlie some of the coarser fragmental quartzyte, but no great thickness of it. The most interesting point about this is its similarity of lithology and its probable identity of stratigraphy with the Wauswaugoning and Pigeon Point quartzyte, indicating the equivalence of the Peewabic quartzyte with the Wauswaugoning.

There are here three conditions of quartz, each one making rock masses:

1. Agate-like and banded, so-called chalcedonic quartz, very fine-grained, non-fragmental.

2. Very fine-grained, bedded, pinkish or brownish quartz, partly fragmental, but largely a chemical oceanic precipitate.

3. White, coarse-grained, fragmental quartzyte, mingled not only with quartz chemically precipitated but with green (tufaceous?) materials.

A dike of igneous rock.

A large green dike runs S. W. and N. E. in N. W. ¼ N. E. ¼ section 32, 60-13, and seems to have some connection with an irregularity detected by Mr. Wicks in the iron-formation, indicating a fault. But it seems to play no such roule as has been described respecting the dikes cutting the iron-formation on the Gogebic range. It appears to stand about vertical but its width and extent longitudinally could not be made out. It could be traced about 10 rods. This is the first dike the writer has seen on the Mesabi range cutting the iron-bearing rocks.

May 10. Returning past Mallman's camp (mentioned in Bulletin No. VI, pp. 135 and 202), an examination was made of the new working. Nothing new was developed. No more merchantable ore has been discovered. The work ceased, but is being renewed by other parties.

It seems from all that I can learn of the ore-bearing qualities of the eastern part of the Mesabi range, and from the results attained by the explorations that have been made by those owning the lands, or by their lessees, who certainly should be considered to be the best qualified to develop the ore deposits which the country might possess, that the outlook is not so favorable for ore in the eastern part of the range, at least in that portion eastward from Mesaba Station to Birch lake, as in the western. The ore is more likely to be magnetic, and, while magnetism itself cannot be said to be injurious, the ore is so closely mixed with siliceous impurities, or is so sparsely interleaved with the rocks of the formation; that it is not found to be profitable to work it. It is very likely that the presence of the eruptive rock in greater nearness to the ore-bearing localities has been a powerful cause in rendering the ore magnetic. The same agent has affected the associated rocks, particularly the quartzyte underlying the ore.

REPUBLIC, MICHIGAN.

In about an hour and a half a brief examination was made of the Republic mine. It is evident at once that the great hill of jasperoid hematite first encountered in going south from the depot of the Duluth, South Shore and Atlantic railroad, is in the Keewatin. It duplicates perfectly the hills and ridges at Tower. Granite and associated rocks extend almost all the way from Humbolt, where some hornblendic rocks appear. The ore is micaceous, standing vertical, and is interbeded with a coarse quartzyte. This last fact occurs immediately southwest from the old working shaft which is on the top of the hill nearest Humbolt. This coarse quartzyte is also stained greenish by some mineral (olivine ?) disseminated through it which is hard, resembling quartz, but apparently distinct from the quartz. In this quartzyte is also hematite in glittering micaceous scales and patches, and a sparser amount of light-green softer sediment, resembling the green sediment derived from erosion of the Keewatin. This quartzyte extends visibly a couple of rods and has a width of 5 or 6 feet. It acquires a gray color, as the hematitic ingredients and the jaspilyte gradually fade out, constituting a rock which is then indistinguishable from some of the siliceous graywackes of the Keewatin.

Further down along the face of the cliff, near the base, on the southwest side, this greissen is more visible, but it appears here also as an integral part of the Keewatin formation, and is seen to blend with it toward the southwest both slowly and abruptly, but near the ore toward the northeast it becomes coarse and conglomeritic with large fragments of the ore.*

On the east side of the main ridge is a large area of greenstone, but the rock is much darker and harder, and more evidently eruptive, than most of the Keewatin greenstone. In some places it approaches a hornblende schist, and in others it cuts, as if eruptive, through the sedimentary rock of the ridge.

ISHPEMING, MICHIGAN, WINTHROP MINE.

May 12, 1892. At the Winthrop mine, which is in the hill range south of town in which is also the Saginaw mine, the rock and ore dip north about 45 degrees. The ore is hematite with some limonite, and is semi-soft and porous. Some of it is siliceous, and appears like the taconyte of the Mesabi range in Minnesota. I judge the mine is in the Taconic. Greenstone knobs appear to the north and northeast, but not in the immediate vicinity of the mine. A little further west, however, appears a range of greenstone hills which would strike a few rods south of the mine.

The Saginaw mine.

In the sixteenth report of the Minnesota Survey the writer announced for the first sime a general non-conformable contact

* This is more lately referred by Van Hise and other members of the U. S. Geol. Survey to an overlying basal conglomerate of the "Upper Huronian," a parallel of the non-conformity seen at the Saginaw mine.

between two iron-bearing members of the "Huronian" in the Michigan iron region, and illustrated the non-conformity by two diagrams sketched on the spot, one at Cascade, south from Negaunee, and one at the Saginaw mine south from Ishpeming.* This examination was made because in Minnesota such a non-conformity had been discovered between two iron-bearing formations, which had been traced a distance of over a hundred miles. It was thought that a similarly profound non-conformity probably existed in Michigan and Wisconsin. Without it there could be but little progress made in any attempt at co-relation between the rocks on the opposite sides of the lake Superior basin. The discovery of evidences of this great break in the iron-bearing series at the typical localities in the well-known mining region of Marquette brought about a general concordance between the Archæan and Taconic geology of Minnesota and that of Michigan and Wisconsin, and at once confirmed the grand conclusions which had been reached from a field study of the same rocks in Minnesota.

Subsequently Prof. Van Hise, in reviewing the "Apparently conflicting views of lake Superior stratigraphy,"** attempted to show that not only had this non-conformity been seen and recognized by several other geologists, but that the explanation given by the writer was incorrect. As this is an important point as to the correctness and priority of this interpretation it will be well to review briefly the evidence adduced by Prof. Van Hise.

He refers to Foster, and Foster and Whitney***, and to T. B. Brooks†, C. Rominger‡, M. E. Wadsworth§ and R. D. Irving§§.

An examination of this literature shows the following facts: Mr. J. W. Foster made a reconnoissance under the direction of Dr. C. T. Jackson in Sept., 1848, of "the country lying between lake Superior and Green bay." His report is dated Boston,

*Sixteenth Annual Report Minnesota Geological Survey, pp 43-49, for the year 1887. Submitted for publication March 20, 1888.

** American Journal of Science. [3], XLI, 117.

***Report on the mineral lands of lake Superior. J. W. Foster. Ex. Docs., 1848-49, 2nd Series, 30th Congress. vol. ii, no. 2, p. 161. Geology of the lake Superior land district. J. W. Foster and J. D. Whitney. Senate Docs ,1851, Spec. Sess. 32nd Cong.,vol. iii, no. 4, pp 23, [22], 43, and 67.

† Iron-bearing rocks of the Upper Peninsula of Michigan. Michigan Geological Survey, 1873, vol. ii, pp. 128-129, 133.

‡ Upper Peninsula of Michigan. Mich. Geol. Survey, 1881, vol. iv, pp. 74-75.

§ Notes on the geology of the iron and copper districts of lake Superior. Bull. Mus Comp. Zool., 1880. vol. vii, pp. 30-31.

§§ Preliminary paper on an investigation of the Archean formations of the Northwestern states. Fifth Ann. Rept. U S. Geol. Survey, 1885, p. 193.

May 26, 1849. On p. 759* he states: "We explored this ridge on section 1, township 46, range 30, and found that it is composed for the most part of nearly pure specular oxide of iron (fer oligisté). It shoots up in a perpendicular cliff one hundred and thirteen feet in hight, so pure that it is difficult to determine its mineral associations.

We passed along the base of this cliff more than a quarter of a mile, seeking for some gap through which we might pass and gain the summit. At length after much toil, and by clambering from one point to another, we succeeded. Passing along the brow of the cliff, forty feet, the mass was comparatively pure; then succeeded a bed of quartz composed of rounded grains, with small specks of iron disseminated, and large rounded masses of the same material enclosed constituting a conglomerate. This bed was fifteen feet in thickness, and was succeeded again by specular iron, exposed in places to the width of one hundred feet, but soil and trees prevented our determining its width."

The place here described is about one mile northwest of Republic mountain, and undoubtedly in the same general belt. There is here no evidence that Mr. Foster realized the significance of this conglomerate. He only says, regarding it, "constituting a conglomerate," without drawing any inference. Indeed, considering the grand conclusion which Messrs. Foster and Whitney reached concerning the divisibility of the Azoic, it would hardly be a fair interpretation to suppose that he here knew he was at the horizon of the most profound and widespread non-conformity known in the region.

The first reference to Foster and Whitney's report on the lake Superior land district, (p. 23, it is actually on p. 22,) is in almost the same terms as that quoted above, and is evidently the result of the same visit. Its most important variation from the original of Mr. Foster is the insertion after the word "conglomerate," of the words *or breccia*, thus allowing the possible hypothesis which is more fully brought out on page 43.

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* This quotation is from that *omnium gatherum* of geological, mineralogical, topographical, barometrical and botanical reports usually known as *Jackson's report*, although in the same collection is found also the preliminary report of Foster and Whitney, dated Nov. 5, 1849, giving lists of lands which they recommended to be reserved for minerals, and "Reports on the linear surveys, with reference to mines and minerals in the northern peninsula of Michigan in the years 1845 and 1846," by William A. Burt, Bela Hubbard, S. W. Higgins and others, under Dr. Houghton's contract. It was the result evidently of giving to the public printer all the reports accumulated since 1844 on the region of northern Michigan, without editing, and the publication of the same without any attempt to give them any logical or chronological order.

The second reference to Foster and Whitney (p. 43), is in the following terms: "On the line between sections 29 and 32 [T. 46, ranges 26 and 27], is a remarkable knob of conglomerate, alike interesting from the fact that such a form of rock is of rare occurrence among the Azoic series of this district, and from its intimate connection with the origin of the masses of iron in its vicinity. The conglomerate forms here an isolated, rounded elevation rising at least 100 feet above the general level. It is made up of coarse blocks of various sorts which belong to the neighboring trappean and slaty beds, and are of very considerable dimensions. Among them we recognized not only fragments of the rock associated with the iron, but masses of the iron itself, and of the banded and jaspery varieties. Most of the fragments of this remarkable breccia are but slightly rounded and worn on their edges, having in this respect much more the appearance of a friction-conglomerate than of one in which the long continued action of water had played a part. The blocks are cemented together by a very hard ferruginous paste. The nature of the surrounding country, covered with soil and forest trees, prevented us from satisfactorily tracing its connection with the adjoining rocks. We are inclined, however, to regard it as connected with the eruption of the adjacent granite, and rather as the effect of the crushing and elevating forces which such an elevation must have called into play. If this is the case it may be considered as analogous, in its mode of formation, to the conglomerates of Keweenaw point. A fact worthy of notice in this connection is, that, in spite of the heterogeneous structure of the mass, it exhibits a distinct tendency to separate or flake off in thick concentric layers like some eruptive granites.

The nature of the fragments composing this breccia, and of the cement by which they are united, proves conclusively that the process of formation of the ores of iron, and the impregnation of the slaty rocks with metallic matter, must have been one of long continuance and not a merely momentary operation. The various kinds of ore must have been in existence before the formation of this mass, but they were subsequently broken off and mingled together in confusion. Emanations of metallic matter must still have been issuing from beneath, since we find the whole deposit thoroughly impregnated with it, and converted into one firmly coherent mass."

The significance of this extract needs no elucidation. It is only necessary to call attention to its bearing on the interpretation which Prof. Van Hise seems inclined to give it. It is plain that such an interpretation would have been repudiated at once by the gentlemen responsible for the words quoted. It was presumed by them that they saw a breccia due to upheaval and crushing instead of a conglomerate marking a wide-spread non-conformity in the "Azoic."

The third reference to Foster and Whitney (p. 67), shows the following:

"The Azoic period having been one of long-continued and violent mechanical action there is no reason to doubt that many of the strata of which it is composed may have been derived from the ruins of previously formed rocks of the same age, both sedimentary and igneous. This is clearly shown to be the case in the remarkable knob of conglomerate described on page 43 [quoted above], which contains rounded fragments of the various kinds of ore found in the adjacent region."

This description refers to the same occurrence as that last noted, and simply repeats the supposed effect of local disturbances and destruction of some of the earlier formed rocks of the same age. It would be very far from the truth to suppose that Messrs. Foster and Whitney here suggested a possible plane of separation between two parts of the Azoic, for it was one of their final conclusions that the Azoic could not be subdivided on any chronological or petrographical basis into recognizable and widespread members.

The first reference to T. B. Brooks (in vol. i, instead of vol. ii) shows the following:

"The upper quartzyte at Republic mountain is a gray massive rock, sometimes banded, and, near the contact with the iron, sometimes conglomeritic, containing large and small flattened fragments of flaggy ore."

The second statement of Brooks referred to is:

"Overlying the ore formation here [Saginaw and New England mines], is the upper quartzyte, XIV, dipping at a low angle to the north, as may be seen just north of the Parsons mine. This quartzyte again comes to the surface about half a mile north, in a flat synclinal where it again dips north and does not rise until we reach the new Excelsior mine, owned by the Iron Cliff Co., which is shown on the section.

"Returning to the New England mine we find between the ore XII, and the quartzyte XIV, a mass of specular conglomerate, somewhat similar to that described as existing at the Republic mountain, where it was regarded as belonging to the ore formation. The fact that it overlies the pure ore at this locality, and has lithological affinities with some of the conglomeritic varieties of the upper quartzyte, leads me to doubt in which formation it should be included. I incline to the view that belongs to XIV."

There is no indication in this that Mr. Brooks thought he here was at a separation plane of great importance. Indeed his doubt as to whether the conglomerate belonged with the ore or with the quartzyte shows that it was not a question, in his mind, of moment. The word "formation" here was simply the general word used to designate one of the twenty parts into which the Huronian was divided by him.

The reference to Dr. Rominger's report shows that he likewise encountered this "brecciated" condition of the basal portion of the quartzyte, and also that he comes nearest of any writer, up to that date, in comprehending its import.

"A very rich seam of ore is almost invariably found on top of this jasper-banded rock-series, immediately beneath the quartzytes which form the terminal strata in all these exposures. This upper ore belt is almost regularly brecciated in its upper part, and the same is true of the lower quartzyte beds, which often are a mixture of ore-fragments with quartzyte pieces held together by an arenaceous cement. *As this is the case in nearly all the mines of the district, we must suggest that disturbances of not only* [i. e. not merely] *a local extent must have occurred at the end of this era of iron sediments.*"

It is evident, however, not alone from the above statement, but from many references to the probable cause of these irregularities which are scattered through Dr. Rominger's report, that he entertained a view similar to that of Messrs. Foster and Whitney. Eruptive action of igneous rocks, in his opinion, was solely responsible for these breccias and plications. So far was he from making a profound stratigraphic separation of the rocks of the Marquette district at the base of this conglomerate, as one might suppose from the fact that he is quoted by Prof. Van Hise, he entirely ignored it, and extended his iron group upward so as to include it, thus separating it wholly from the quartzyte with which it belongs and of which it presents simply the initial phase. It was after the writer had discovered such phenomena as proved the duplicate nature of the iron-ore formation in Minnesota that he studied carefully the report of Dr. Rominger, and he referred to his (Rominger's) report to call attention to facts in the Marquette district which, when properly interpreted, bore out his general interpretation of the rocks of the lake Superior basin, and showed that *there also* there were two non-conformable iron-bearing formations, and that there *were two iron horizons instead of one*, and that they could be stratigraphically distinguished if time should be given, by a competent geologist, to work it out*.

Prof. Van Hise's quotation from Dr. Wadsworth is as follows:

"These [*i. e.* quartzytes and coarse fragmentals] of course mark old beaches water-worn after the jasper and ore were *in situ* in nearly their present condition, and, if the logic of the geologists of the Michigan and Wisconsin surveys were carried out, these unconformable detrital formations would mark a new geological age."

When it is remembered that the chief result of Dr. Wadsworth's effort was to prove the jaspilyte had an eruptive origin, and thus to controvert the "logic" of the Michigan and Wisconsin geologists, and that he attributes such appearances to the intrusion of the ore and jasper (jaspilyte) through the surrounding rocks, and the later protrusion of the granite (*i. e.* the greisen or modified quartzyte as at Republic Mountain) through the jaspilyte and earlier rocks, no one should have the hardihood to quote him as authority for the structural break that is here considered. That he saw, as others did, the rocks exhibiting these structures, is of no import so long as he did not assign the structures to their proper cause. Again, the writer has never, as yet, encountered a statement of the "logic" to which Dr. Wadsworth refers, applied to this horizon in the iron regions of Michigan and Wisconsin, prior to the date of Wadsworth's paper. Logic of that kind applied to this important horizon would have constituted one of the brightest spots in the able reports of the geologists of Wisconsin and Michigan, and would ere this have attracted much attention.

As to Prof. Irving, Prof. Van Hise makes the following remarkable statement:

"The real significance of the break was recognized by Prof. Irving, who not only found it in the Marquette district but knew of its equivalent in the Vermilion lake district of Minnesota."

For authority for this statement he quotes the following from Prof. Irving's paper on a "Preliminary investigation of

*Geol. and Nat. Hist. Survey of Minn 17th annual report, for the year 1888, pp. 43-44 the Archean formations of the Northwestern States," in the Fifth Annual Report of the United States Geological Survey, published in 1885, p. 193.

"I refer to the occurrence in the quartzytes overlying the ores, at several of the Marquette mines, of abundant rounded, fragments derived from the ore below. A very much more striking occurrence of this kind is met with in the Vermilion lake district of Minnesota where the fragments included in the conglomerate overlying the iron belt are often several feet in length and angular. That these fragments prove the existence of the jaspery and chalcedonic material in its present condition before the formation of the quartzyte is sufficiently evident."

Far be it from the writer to attempt to detract from the brilliant halo that surrounds justly the name of Irving. Far be it also from the writer to put words and sentiments upon his pen which do not belong there. Justice is keen-eyed, and will allow no more favors to a deceased geologist than she would to him when living. That is all that Prof. Irving would ask of his successors, and that is no less than his successors are bound to yield to his work. It is found sometimes that it is an injustice to attribute opinions to a geologist which he does not entertain, and which he may never have expressed. It appears to the writer that Prof. Van Hise is liable to a charge of such injustice toward Irving, not to mention others.

There is a speciousness in the manner of presenting Prof. Irving's statement which can only be made apparent by a slight consideration of the subject. It will be found, on consulting the fifth report of the U. S. Geological Survey, page 193, and some of his later papers, that three very important facts are suppressed by Prof. Van Hise, which bear directly on the understanding that should be entertained of Prof. Irving's statement, viz.:

1. Irving does not give the facts on his own authority, but on the authority of Dr. Wadsworth. He says:

"Wadsworth has drawn attention to a very interesting occurrence at numbers of points in the Marquette region, and has made use of it to sustain his theory of the eruptive origin of the jaspery ores. I refer to the occurrence in the quartzyte" etc., as quoted above.

2. Irving is not discussing the stratigraphy in this connection, nor any question connected with the stratigraphy of the rocks of the region, but the origin of the cherts and the ores. His desire is to bring out the fact, which is a very important

one, that *the ore was completed in its construction and composition during the time of the formation* in which it is found, and that, inferentially, there has been no progressive accumulation or concentration of the ores, at least on a grand scale, in subsequent time.

3. Prof. Irving did not look upon this as a break, or non-conformity in the stratification, either at this time or subsequently. This is evident from the fact that he puts into his upper, or "iron bearing member" all the strata here concerned, viz., the quartzyte, the conglomerate, the iron ore and the green schist. His plane of separation was largely a theoretical one, derived from a consideration of the difference in crystalline condition manifested by the two ends of the series. The upper one he found to be evidently clastic, and but little crystalline, the lower he found wholly crystalline. The separation was by him put between these distinctions, and he placed it theoretically above the crystalline schists and the Laurentian. In no place does he refer to this plane of non-conformity with the proper understanding of it. He refers to the contact of the "quartztye" upon the Laurentian, but he then, in all cases supposes he is considering a quartzyte underlying all the ore, and (if he mentions it) also the green schists. His plane of non-conformity would apparently be that which Dr. Wadsworth has more lately reported to occur between his Cascade and Republic formations, where he describes a conglomerate like that which exists at the plane under consideration.* This lower break also has been noted by Van Hise in the same paper here criticised p. 117). It is a curious fact, however, that while Irving theoretically referred to this lower break, all his cited examples belong to the upper, and that he failed to give significance to it at the horizon to which his examples pertain. Of this error Dr. Wadsworth has said:

"While Irving was correct [though at a later date than the writing of this paper quoted by Prof. Van Hise—N. H. W.] in the observation of the conglomerates, he was wrong in his views of their position in the geological column, and thus actually overturned the series. This mistake of Irving's exercised a powerful influence upon his work and upon his views concerning the origin of the iron ores and the jaspilyte.

"It is very unfortunate and confusing in the history of geological opinion concerning these basement conglomerates, that

*Report of the Michigan State Board of Geological Survey for the years 1891 and 1892, (1893), pp. 114, 116.

Van Hise has overlooked this mistake of Irving's, and speaks as if Irving had the same views as himself, i. e. that the conglomerates overlie the lower series of iron-bearing rocks, when Irving clearly and distinctly held that these conglomerates were at the base of all the iron-bearing rocks." Op. cit., p. 114.

It is plain, therefore, that Prof. Irving did not "recognize the significance of this break," as claimed by Prof. Van Hise. It is also plain that no one understood it prior to the interpretation put on it by the writer in the 16th annual report of the Minnesota survey, pp. 43-47, 1887. Instead of admitting this priority, Prof. Van Hise diverts the reader by inconsequential criticisms of some of the details of the illustration accompanying the description.

It is not necessary here to enter into the question of the existence, or not, of such a break in the Vermilion lake district. It is only necessary to repeat that in Prof. Irving's reference to that region, in this connection, he does not intimate that there is any such break. He only refers to evidence which he had seen there that shows the iron ore was fully formed prior to a fracturing which it suffered. The large pieces "several feet in diameter" evidently were parts of a remarkable breccia which has since been examined in the region north of Soudan. No data were given by Irving to show where his observation was made, but as the members of the Minnesota survey have not been able to find any conglomerate holding such pieces, but only coarse breccias (reibungs breccias) which could not at all answer to the brief description given by Irving, it is sufficient to say that probably the feature seen by him at Tower, should not be considered as pertaining to the horizon of the conglomerate now known at Marquette.

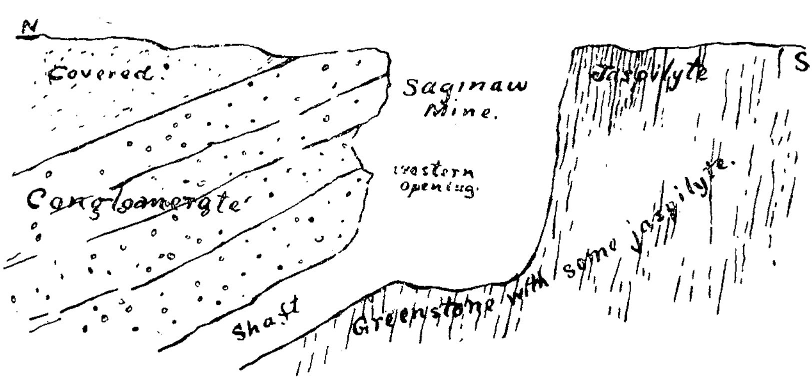

FIG. 1.—Section N. and S., at the western opening of the Saginaw mine.

The re-examination of the Saginaw mine resulted (in May, 1892) in no material correction of the views presented in the 16th Minnesota report already referred to. At the western opening, which is nearest the Goodrich mine, the stratigraphic relations were sketched carefully, as shown in the figure opposite (Fig. 1).

At this pit the later iron-bearing strata lie non-conformably upon the older. The jaspilyte is seen to fade out into the green schist. The overlying conglomerate is coarse with water-worn quartz and jaspilyte pebbles, and with much iron. It is simply the basal conglomerate of the Taconic affected by proximity to the jaspilyte beds of the Keewatin. The sloping shafts are run mainly in the greenstone, below the conglomerate, but the ore worked is associated with the Taconic conglomerate. The exact contact of the conglomerate on the greenstone is indistinct, as it is often on granite, but the dip, structure and lithology change within the space of six or twelve inches. The fragmental iron here worked was in the Taconic, very different from that at Republic, though the ore from the two is essentially the same. The eastern

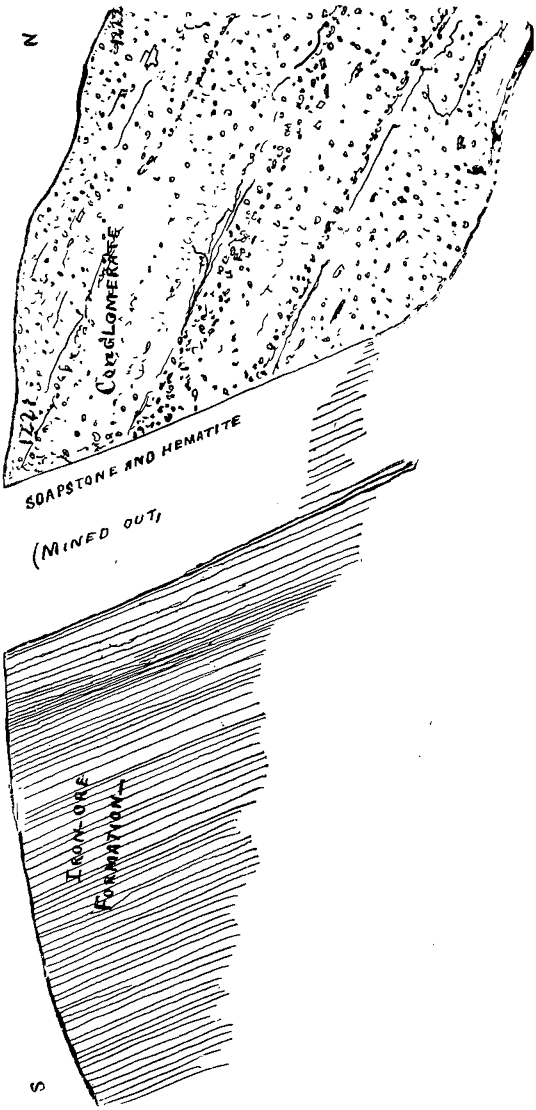

Fig. 2.—Section N. and S., at the eastern opening of the Saginaw mine.

opening of the Saginaw mine is that examined and figured by the writer in the Sixteenth Minnesota report. Here the conglomerate lies also non-conformable on the Keewatin, and the latter consists partly of greenstone and partly of a poor hematite—an ore that is siliceous and grayish, rarely banded like the jaspilyte of the formation—yet distinctly Keewatin, although hardly an ore of any merchantable quality. At this particular point there is an inclination northward in the Keewatin jaspilyte, and that is the ore formation represented in the figure in the sixteenth report as unconformably under the conglomerate. The two approximate the same dip, though they do not have the same. The figure is here repeated. It needs no correction (Fig. 2).

It is apparent that the criticism of Prof. Van Hise is wholly gratuitous and misapplied. These figures are produced from sketches at the Saginaw mine, while he assigns them (at least the latter) to the Goodrich mine, of which he gives a diagram*.

At the Goodrich mine the following diagram was drawn, which is quite different from that shown by Prof. Van Hise, from the same mine. This was made at a point some distance east of the large open pit, and on higher ground. It is evident that the direction of structure in the jaspilyte bands is continually changing, and that it is a character of no importance, whether they are nearly parallel or nearly perpendicular to the bedding of the conglomerate. The jaspilyte here is nearly perpendicular, twisted, but in the main running about east and

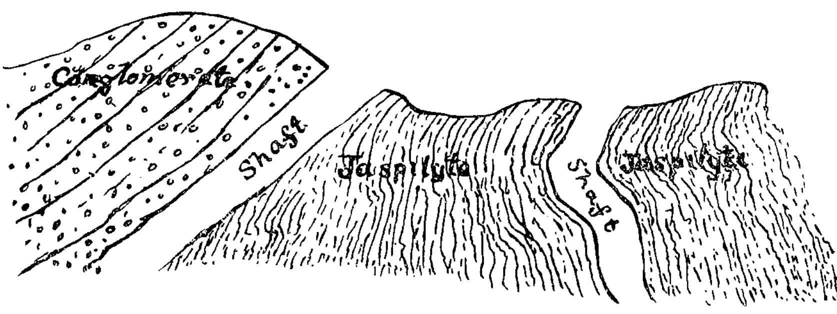

FIG. 3.—Section at the Goodrich mine.

west. On the very summit of this ridge is a bared spot which fortunately shows the exact contact of the conglomerate, mostly made up of fragments from the jaspilyte, upon the jaspilyte itself. This line of contact is traceable, on the top of

*American Jour. Sci. (3), XLI, 120.

the knob, for a distance of 25 feet. This is along the south side of the main pit, but north of another pit and deep working which has really been done in the Keewatin. Here, then, we have both formations iron-bearing and both considerably wrought. The shaft and working in the base of the Taconic slopes north about coincident with the dip of the conglomerate, and is quite regular, compared with the crooked shaft and underground working in the Keewatin which resembles the early Breitung mine at Tower. The ore from the conglomerate is hard and specular, and, as ore, is good, but it embraces pebbles of quartz and jasper, and is too poor for that reason. Still there is no doubt that much good ore was taken out here both from the Keewatin and from the Taconic.

This conglomerate becomes a well characterized white or reddish fragmental quartzyte at points remote from the outcrops of the Keewatin hematite. These observations are very important, and show, as I have before contended, that there are two non-conformable iron formations even in the original Marquette region. The Taconic ore here is wholly of fragmental secondary origin, *i. e.*, it is derived bodily, in form of detritus, from the underlying Keewatin, and there is no possibility of applying to it any substitution hypothesis to account for its origin here. The soft ore horizon of the Gogebic and Mesabi ranges is entirely above this conglomerate.

THE POTSDAM SANDSTONE AT POTSDAM, N. Y.

An excursion was made, in company with Dr. U. S. Grant and Mr. Charles Schuchert, into the region of the northern slopes of the Adirondacks. It is a singular fact that this region, in which centers the discussion of one of the perplexing problems of Paleozoic geology in the United States, has been substantially unexamined since the early work of Emmons and Mather, and that the uncertainty as to the age of the true Potsdam sandstone has rather increased as time has passed. This has resulted from the error which was made by all the early geologists who dealt with the "Potsdam sandstone," in applying that term to sandstones which, stratigraphically, are widely separated from each other, and to the difficulty of determining to which of these horizons the true Potsdam belongs. It was hoped that an examination at a few points would tend to solve the uncertainty*. The following notes were made.

Approaching the region from the northwest it was noticed that the country between Pembroke and Carlton Junction (Canada), as well as much of that south to Brockville, has been long submerged. The surface consists of a fine laminated, gray clay, sometimes seen 15 feet thick, without boulders or stones, and makes fine farms.

Sandstone. At Brockville is a hard, nearly white quartzyte. The same rock appears in islands in the St. Lawrence river, and along the shore at Morristown, where it is used, at the docks, for crib-filling. At the last place it is partially red, or reddish, bedded, weathering, at the river bank, into layers from two to four inches thick. From four to six feet in a perpendicular section are exposed at the dock. Between Morristown and Philadelphia this rock is seen much of the way. It is considerably quarried at several places, rising into hills and ridges from 20 to 50 feet high. Erosion gorges are cut in it to some extent, and these hills and ridges are the remnants left by such erosion. It appears to underlie some of the flat areas, but a few inches or feet below the surface, in a nearly horizontal position, and in other places it is tilted in one direction or the other, forming undulations. When broken, as in frequent anticlines, the strike is boldly presented. In the railroad grade cuts this rock is angular, sharp, rigid, much jointed. Along with these quartzyte exposures are also ridges of granite, especially toward Morristown. Indeed the road seems to cut through a granite area for many miles soon after leaving that town. The granite is reddish, both coarse and fine, and from the train could not, in some cases, be distinguished from

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* Since this visit, which was made in May, 1891, two geologists of New York have made examinations in some of the northern portions of tho Adirondacks, and their preliminary reports are published in the Transactions of the New York Academy of Sciences, Vol. XII, 1893, "A Geological Reconnoissance in the vicinity of Gouverneur, N. Y." C. H. SMITH, JR.; "A review of work hitherto done on the Geology of the Adirondacks." J. F. KEMP. The latter gives a summary of the scant literature pertaining to this region prior to 1892, thus concluding: "In summing up the geology of the Adirondacks it may be stated that the following views relative to the stratigraphy of the crystalline rocks have been held:

I. It has been usually believed that the gneisses are the oldest and are metamorphosed sediments; that the norytes are later, some regarding them as igneous and others as metamorphosed sediments; that the limestones are latest of all.

If this be admitted and the norytes be regarded as igneous intrusions, how is it that no dykes or apophyses have been mentioned as radiating or offsetting from this enormous mass?

II. That there is a core of central and oldest noryte, having later gneiss as a metamorphosed sediment on its flanks, and still later limestones on both noryte and gneiss."

the red quartzyte. A conspicuous hill range, rising two hundred feet, more or less, extends for many miles parallel with the railroad, southwardly, beginning a few miles from Morristown. Its form and persistence, and its rather uniform hight, seem to indicate that it marks the strike of some of the quartzyte, although by the railroad the only rock seen was granite.

At Philadelphia the underlying rock is granite. It is exposed at numerous places in the village, and especially along the course of Indian river. The rock weathers reddish but within it is a dark gray, assuming a purplish tint.

The Potsdam quarries are on the Racket river about three miles east-southeast from Potsdam. Some of them have been worked for sixty years. At Clarkson's quarry the rock is light red or pink. It dips west mainly, at an angle of 30 deg., but on account of false bedding some of it dips more and some less, one large layer lying about horizontal. At Merritt and Tappan's quarry, which is on the river half a mile southwest from Clarkson's, we come to a deep and old quarry, formerly known as Cox's quarry, one that was running probably when Emmons visited the region. The rock here is similar to that at Clarkson's, but is marked by conspicuous color bands of light pink and brownish red, coincident with the stratification. These give the large slabs, on their broken edges, a bizarre appearance. In general the rock between here and Clarkson's quarry should underlie this. It is darker colored. But at this quarry there is a synclinal structure, and the quarrying has gone down in the trough of the syncline, to the depth of 30 or 40 feet below the surface of the river. The dip on one side is about 25 deg. S., and on the other it is about 15 deg. N. We saw at Potsdam a great variety of the sandstone quarried at Hammond, which is in the extreme western part of St. Lawrence county, southwest from Morristown. While it is all rather softer than any quarried at Potsdam, and nearly all of it white, or nearly white, like the St. Croix sandstone in Minnesota, and especially like the white (or nearly white) sandstone seen at Morristown, &c., yet there are some slabs nearly as uniformly red as the Potsdam rock, and some that are spotted in the manner of the sandstone at the falls of the St. Mary's river, at the east end of lake Superior.

At about a mile and a half below Potsdam, at the river's bank, just above the saw-mill, is a gray to white sandrock which presents an irregular surface exposure. It has been quarried to a small extent. It is mainly horizontal, and its upper layers or its upper surface, at least, is roughened by remnants of fucoidal marks, and rusted by, apparently, rotted patches of calcareous rock, or pyrites. The total surface exposure is only about two feet, and the rusty disintegration is about three inches thick. This rock looks more like the Brockville and Morristown rock.

Three and a half miles east of Malone is Paddock's quarry, in a coarse, light-colored sandstone, which makes good, but rather fragile, flagging, worked but feebly. The rock-grain and color are quite different from the Potsdam sandstone, yet there is a light reddish tint apparent in most of it, as well as in spots. This color is deepened in shade in a manner similar to the Sault Ste. Marie sandstone, but in general is lighter than that. It is affected by false bedding in a rather remarkable manner. In this respect it is like the Potsdam sandstone at Merritt & Tappan's. The following sketch is designed to show the false bedding. The flags are rigid though only 1½ or 2

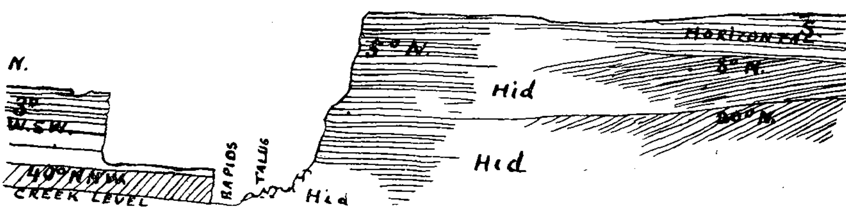


FIG. 4.—False bedding at Paddock's quarry.

inches in thickness, *i. e.* more rigid than such coarse sand-rock can usually be. The grains of quartz are not entirely compacted by cement, but there are vacant interstices. It would appear, from the false bedding, that this sediment was laid down in a very turbulent ocean, and one that was constantly cutting up and re-distributing the sediment previously arranged, but that quieter water followed the turbulence. The same rock has a slight exposure near the depot at Malone. While these strata are probably later than the strata at Potsdam, it is impossible to affirm that they do not belong to the same general age.

At Keeseville, N. Y., can be seen a conspicuous white sandstone, or quartzyte. The chasm of the Au Sable cut in this rock is narrow and in some places quite crooked. The river follows apparently a fissure or a series of fissures in the quartzyte which is also otherwise fissured and faulted, causing local dipping in different directions, and breccias at the fault lines.

Below the foot of the stairway one can walk for a considerable distance down the chasm, following a natural platform on the right side of the river. The rock shows various local changes in dip, making sometimes an apparent non-conformity between two formations. One such, which is the most remarkable, is at "the elbow," where the river first turns at a right angle. There is an appearance here of an upper sandstone formation unconformable on a lower. This idea is not weakened any by the obvious contrast in the lithology, the lower one (which forms the platform along which one walks on the right side) being very hard, finer-grained and redder than the upper, and polished by the friction of the water when the river runs over it. This polishing was noted by Emmons. At first I took this for a plane of non-conformity, but similar irregularities occur further down, some of them being in the supposed upper portion. Through a part of the distance down to the narrow place where no one can pass, the beds dip from the chasm in opposite, or partly opposite, directions, the left-hand cliff having fallen away from the rocks on the right hand, the river lying in the fissure. The strata on the left hand side, at and below the first elbow, dip conspicuously *into the left bank.* At another narrow spot, where another elbow occurs, in the opposite direction, the cause of the location of the river is seen. Just where the river turns the breccia-plane, which it occupies between the two elbows, is seen in the angle of the right bank, continuing on across the formation in the same direction, but it is blocked up and filled with the remaining rock, the cliff on the left-hand side there overhanglng the breccia plane, falling on it and tightening it so as to keep the passage closed. Under such an obstruction the river, in some earlier portion of its history, had to leave the course of the fault and turn to the left, though here it also occupies another fault plane which crosses the former nearly at a right angle. Below this last turn the chasm continues, with still water, while above it the river runs with a rushing and noisy current.

At Hanawa falls, near Potsdam, a perpendicular section exposing about 30 feet appears below the falls. The right bank here seems to have two brecciated or fault planes, the strata lying about as shown by the diagram on page 104.

The gneiss and marble. At the rapids in the Racket river at Potsdam, is a peculiar gneiss, consisting almost entirely of quartz. The grain is fine and uniform in size and has a subrounded outline surface, and bands of varying composition cross the rock surface. This banding is emphasized by greater accumulation of lichens on some than on others. The most lichenous bands are red within, when freshly fractured, and the intermediate layers are lighter, but seem to have some specks of chloritic substance. In some places this gneiss becomes mica schist, which is visible in the city. It is cut by ancient dikes of a basic rock, probably originally a diabase, which have also been subjected to some metamorphism. The dip cannot be made out.

We made an excursion westward from Potsdam to a locality known as Crary's mill, situated about seven miles from Potsdam. At five and a half miles the road crossed a creek, where at the north side of the road, appears a gneissic rock containing lenses of coarsely crystalline white marble. The marble also embraces pebbles and angular pieces of rock which is now micaceous and quartzose. Some of these siliceous pieces are banded with sedimentary structure.

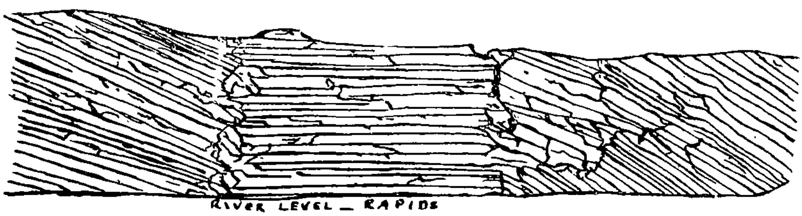


FIG. 5.—The east bluff at Hanawa falls.

At Crary's mill similar gneiss appears at the dam dipping, like the last mentioned, W. N. W. about 20 degrees. There is also here a large amount of marble which is used extensively for economic purposes, principally for quicklime. The gneiss toward the east, by the dip, must pass below the marble, which forms an extensive belt, and is traceable for several miles across the country southward. The marble is conglomeritic (but the most of it is free from pebbles), massive, colored by bands of sedimentation all dipping uniformly W. N. W. It is said to maintain this dip for six or eight miles toward the south. It appears again at the iron location of Capt. Wood, about five miles south from Crary's mill. Here the marble is associated with some verde antique and serpentine. Occasionally are seen fine alternations of red jasper and hematite in paper-thin films, but these are about the exterior portions of the iron masses, and of later origin, having no bearing on the method of origin of the ore itself. The iron is bright, pure, specular hematite, in lenticular masses in the marble. If there be no irregularities in structure, or faults, this marble must lie below a vast thickness of gneiss, for in reaching this locality we passed, for nearly three miles—indeed all the way from Crary's mill—almost perpendicular to the strike, the dip being from 15 to 30 degrees all the way W. N. W. or N. However there may be a succession of faults, causing a reduplication of the same section. The working is small, and is abandoned, apparently from lack of a sufficient supply of ore. The dip of the marble cannot be made out, as the whole exposure is confused and rotted; but immediately north of the most northern pits is a range of gneiss dipping N. E.

At an iron exploration situated a quarter of a mile from the river, about four miles E. S. E. from Potsdam, the rock shafted is a conglomerate which, from the geographical position, is probably the bottom portion of the Potsdam sandstone. In association with this conglomerate is some red hematite, rather soft, but yet firm, as an ore, and apparently of fragmental origin. Below this conglomerate the exploration was continued by diamond drill about 50 feet, and the cores brought out, some of which still lie about the drilled hole, disclosed a serpentinous marble comparable with that seen at Capt. Wood's. The drill happened to strike no hematite in this distance, but, from the existence of the fragmental hematite in the conglomerate, and the existence of hematite in the marble, as at Capt. Wood's, it may be presumed that in the near vicinity is a deposit of hematite in the older formation from which these fragments were derived. In the immediate vicinity of such original deposits of ore, the conglomerate would naturally contain much fragmental ore, and when the conglomerate lacks such element it may be inferred there are no near sources from which it could be supplied.

Dr. U. S. Grant made a special trip to Gouverneur, and the following is the substance of his notes: At four miles from Potsdam, on the southeast side of the railroad track, is an outcrop which has an evenly rounded, apparently glaciated, form; it has the appearance of being granite, or gneiss similar to that southward from Crary's mills. No other rock outcrop was seen along the track between Potsdam and Canton. But immediately southwest from Canton, much rock exposure occurs at the crossing of the stream, and thence all the way to DeKalb. Almost all these exposures are rounded glaciated domes. In some instances a parallel arrangement of lighter and darker bands could be distinguished in this rock from the train. The dip is about 35° northward, with a strike about N. 75° E. At several shallow cuts made in this rock it could be distinguished as gneiss of the same character as that seen south from Crary's mill. From De Kalb to Richmond are many outcrops. From Richland to Gouverneur are others that seemed to be of marble.

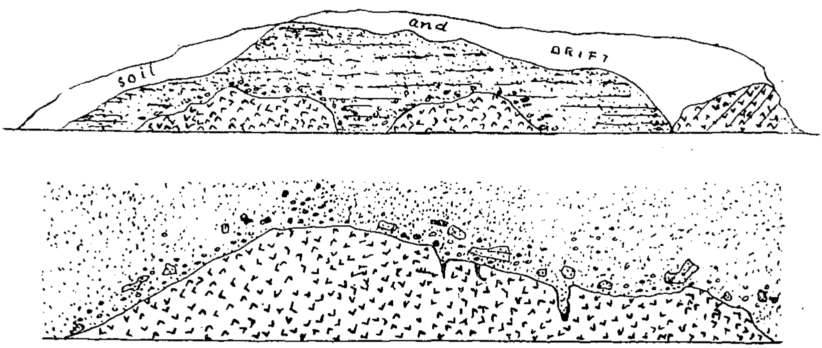
At Gouverneur, three-fourths of a mile southwest of the town, just on the south side of the railroad, are three large quarries in marble. This rock is of a general gray color and coarse grain, and rather indistinctly striped with white and gray irregular bands. Some of these bands are wide, so as to include much of the rock in some instances. This irregular banding is presumed to be parallel with the original sedimentation. It is the only structure shown in the rock,—not even are there any distinct jointage planes. The rock is very massive. It does not split any easier in the direction of these bands than across them. The dip is 30° N. The foreman at one of these quarries furnished the following information: "In this vicinity, especially farther southwest, and near the railroad, are several other quarries, all in the same kind of marble. The general dip is 35° to 45° toward the north, but at one quarry the rock stands vertical, with an E. and W. strike. The gneiss is found several miles N. and N. E. of Gouverneur, and also near Wood's quarry which is in marble, near the railroad, and three miles southwest of town. Here the gneiss and marble come quite near to one another, the gneiss being found a short distance south and southeast of the marble and dipping N. as does also the marble. There are three or four iron mines in the vicinity of Keene's, about 7 miles S. W. from Gouverneur, some of which are now shipping ore. They can all be reached in a few minutes walk from Keene's. The ore is generally a soft red hematite, but with some blocks of hard hematite. The ore is not in the marble, nor in the gneiss, but in a hard sandrock which is distinct from both." From the description of the ore it was understood by Dr. Grant that it is similar to that seen by him between Richland and De Kalb, as described below.

About half a mile from Richland station, northeastward, the railroad passes near several outcrops. One of these is of a hard siliceous rock holding some softer mineral. It is narrowly and conspicuously banded, some of the bands not being over ¼ inch across. The most of the bands are of quartz, and appear like bands of vitreous quartzyte. Between these are smaller bands of quartz mixed with more or less of a rather soft greenish to whitish mineral, looking like talc, but too hard for talc. This banding appears very sharply on weathered surfaces. Aside from this banding there are no remains of clastic structure in the rock, which is holocrystalline. The rock has been bent and twisted considerably, but the average or resultant direction of the banding is about N. 20° E., and the dip is from vertical to 70° towards N. 70° W.

A short distance further, on the east side of the track, is a ridge of gray, coarse grained marble, in which are streaks of quartz rock like the last. The strike is also N. and the dip is about 60° W. At some distance still further the quartz rock above described appears again. Here the strike and dip could not be determined.

About two miles from Richland is a low cut in coarse gray marble, having bands of the quartz rock in it. Strike about N. and S.; dip about 80° E. A few rods further, on the W. side of the track is an exposure apparently the same as the last. The dip is plainly seen about 45° W. N. W.; and a little further a gneiss, similar to that seen south from Crary's mill, is seen dipping N. W. about 45°.

At three miles and a half from Richland is a cut in the marble and quartz rock. Dip not clearly seen except in one place, where it is N. N. W., about 30°. Less than 100 yards further N. E., is another cut, some 200 feet long, through a sandstone. This sandstone is of rather fine grain, more or less friable, and usually red in color, due to large amounts of hematite disseminated through it. In a few places this rock is not charged with hematite. It is then more firm, and of a yellow color, but this is in comparatively small amount. The two qualities grade into each other. The lower part of the sandstone contains rounded pebbles and angular fragments of marble and quartz of all sizes up to one foot in diameter. Just below this conglomerate is a gray, coarse-grained marble with an irregular upper surface (see figs. 6 and 7). In only one place could the dip of the marble be observed. This was at the north end of the cut, and was S. about 45°. The sandstone is broken into parallel layers which lie nearly horizontal, but in some places are tipped 10° to 15° in various directions. In two places a lamination was noted in this sandrock, running parallel with the layers, about horizontal. The lower part of the sandstone is often very compact, and apparently cemented by calcite. It has veins and pebbles of red jasper. The sandstone grades into a soft red hematite, which appears like a good ore. The upper surface of the marble is fissured in places, and the hematitic material of the sandstone extends down into these fissures (fig. 7). Further toward De Kalb are several other low outcrops of similar gray marble.



FIGS. 6 AND 7.—Sections 3½ miles N. E. from Richland.

About one-fourth mile south of the station at De Kalb is a rounded dome of compact siliceous gneiss, mottled with red. The gneissic structure is not always present. The only dip shown is that of this gneissic structure, but in general the outcrop appears very massive.

From these observations Dr. Grant remarked that the impression left on his mind was to the effect that all the gneiss, quartz rock and marble belong to one and the same formation, though of uncertain age. It is the oldest formation seen in the vicinity of Potsdam. The marble is included in the gneiss and has gneiss both above and below it. The general strike of this formation is about E. and W. with a northerly dip of 35 deg. to 60 deg.; but there are some sudden changes both in strike and dip.

The sandstone seen between Richland and De Kalb is a much newer terrane, has been but slightly disturbed, lies on the edges of the gneiss and marble, and received debris from both in a crystalline condition, indicating that the metamorphism and tilting of the lower formations were complete before the deposit of the sandstone. The sandstone and the associated ore are undoubtedly the same as those seen about 4 miles E. S. E. from Potsdam on the east side of the Racket river, and the inference is that the conglomerate and the ore lie at the base of the Potsdam.

Other limestone. Two miles north of Norwood, on the left bank of the Racket river, are several quarries in a dark-gray, fine-grained but crystalline limestone which is spotted, in the upper layers of the quarries, with conspicuous lumps of white calcite. The rock is practically non-fossiliferous, but by considerable search, by Mr. Schuchert and the writer, we succeeded in finding some imperfect fossils, viz., fragments of some *Asaphus* and of some *Pleurotomaria*, which cannot be specifically determined, and several specimens of *Lingula irene* Bill. This rock is extensively spread in this region, and is quarried at several other places not visited, viz., at a point on the O. and L. C. railroad four miles northwest from this place, and north, at Massena springs. This evidently belongs stratigraphically above all the foregoing.

Summary and conclusions as to the stratigraphical succession at Potsdam. If an attempt be made to correlate these observations so as to express a generalized section for the northern Adirondacks, the writer would put the formations together in some such manner as follows:

1. The gneiss, containing, interstratified with it, the marble and the quartzyte, seem not to belong in the true Laurentian. Anyone familiar with the gneiss and schists which appear at the bottom of the geological scale in the Northwest would at once notice a great lithological difference. The Adirondack gneiss is more regularly and conspicuously a banded, sedimentary rock, and varies more frequently in composition; and its variations at the same time are of greater variety and greater extent. The rock is perhaps as wholly crystalline as the lowest Laurentian gneisses and schists, but there is a fresher facies, *i. e.*, an incompleted, still non-differentiated, association of minerals, and a remaining suggestion of fragmental structure permeating the rock which is not seen in the old Laurentain gneisses. Its color also varies. In the schists are rocks that are black and fine-grained, finely micaceous, but apparently carbonaceous or graphitic. They also embrace this marble, which itself is sometimes conglomeritic, and reaches a thickness of several hundred feet. In the marble is a crystalline pure hematite, in lenses that sometimes have attracted attention as valuable iron ores. The marble is sometimes siliceous, and sometimes is interstratified with quartz rock, and finally gives place entirely to a banded quartzyte. This change takes place in a direction toward the gneiss, *i. e.*, the quartzyte outcrops are between known outcrops of marble and of gneiss,

but the manner of transition is unknown. Whether the gneiss here supposed to underlie the quartzyte is a conformable member of the same formation and similar to that with which the quartzyte and the marble are associated, is unknown. It may lie non-conformably below the quartzyte, and represent a portion of an older formation, but our observations did not happen to bear upon this point. This marble, quartzyte and associated schist seem to be the northern Adirondack representatives of the marble, quartzyte and associated schists seen in the eastern side of the Adirondacks, extending with the Taconic mountains, through southern Vermont, western Massachusetts and southeastern New York and further south. Their lithology, stratigraphic order and topographic relations to the Adirondacks are similar. It is now well known that they appertain to the original Taconic of Dr. Emmons and that they have been found to contain a primordial fauna. There can hardly be a question as to their geological identity in the two regions here considered. These regions are immediately adjoining each other and must be considered as belonging to the same basin or area of deposition; with this similarity of relations to the Adirondacks coincides the fact of similarity of stratigraphic order and lithologic composition.

2. *The overlying sandstone.* The great sandstone which swings around the northern slope of the Adirondacks lies non-conformably on the foregoing gneiss, quartzyte, marble and iron ore, dipping generally gently away from the Adirondacks. The writer here is disposed to consider this entirely as one and the same formation, for taken altogether the evidence rather tends in that direction, though there is one anomalous fact which cannot be explained easily on that supposition. There has been need of constructing for the Potsdam region, if the stratigraphy there is analagous to that in the Champlain-Hudson basin, a succession of principal parts in the geological scale that will agree substantially with that made out in that basin. In the Potsdam region hitherto but one great quartzyte has been known, and no fossils have been found in it, *i. e.*, none from the rock at Potsdam, although an "Upper Cambrian" fauna is known to exist in the light-colored sandstones outcropping in the country surrounding Potsdam. The writer has been disposed to consider that the true Potsdam sandstone, or quartzyte, is more likely to belong at the horizon of the lower of these quartzytes, notwithstanding the existence of an "Upper Cambrian" fauna in the surrounding sandstones. The rather

exceptional dip and the metamorphic condition of the rock at Potsdam seemed to require its separation from the "upper Cambrian" of the region. The discovery of a persistent quartzyte associated with the limestone and schist of the region, as above stated, supplies the demand for a harmonious comparative stratigraphy, and allows of the reference of the Potsdam sandstone at Potsdam to the upper horizon. This will accord with the *general appearance* of the geological environment, as it has been generally interpreted, and will supply a representative, in the Potsdam region, of that other quartzyte which on the eastern side of the Adirondacks and further south has so often been considered Potsdam, but which really exists at the bottom of the Taconic or near the bottom of the Lower Cambrian, as the latter term is employed by the U. S. Geological Survey. This upper quartzyte varies to a nearly white rock, though even then sometimes as hard as any quartzyte, and to a red, highly ferruginous sandstone. The latter phase passes into an iron ore which is economically valuable and has been worked for ore. In this condition it is conglomeratic with remains of the underlying formations, some of the fragmental pieces being from the hematite lenses that exist in the underlying marble. It remains yet to discover the non-conformable contact of the lower quartzyte with a lower gneiss or granite, a true Laurentian formation comparable with that which lies below the "granular quartz" in the Green mountains. Should this be found by future examination in the region, nothing would be lacking to complete the stratigraphical evidence of this succession. The fauna which exists in the "granular quartz" and associated strata in the eastern part of New York, if found in this lower quartzyte and marble, would furnish the most conclusive evidence.

There remains, however, one alternative as a possible error in the foregoing conclusion. The outcrops of the quartzyte as quarried at Potsdam may not belong to the general sandstone of the region, and of this there is this evidence: (a) The rock is firmer and apparently more crystalline; its color and general grain is not remarkably different from some so-called gneiss, which outcrops below the dam in the Racket river at Potsdam, about three miles distant. In some known instances a rock resembling the Potsdam at Potsdam has been known to be converted into a siliceous gneissic rock like that below the dam. (b) The dip of the rock at Potsdam seems also to be anomalous, if that rock be in parallelism with the light-colored sandstones. This possible alliance with the gneiss formation would make the Potsdam at Potsdam of the same age as that of the quartzyte seen by Dr. Grant northeast from Richland.

MORRISON COUNTY, MINN.

A re-examination was made here for the purpose, chiefly of getting evidence, one way or the other, of the Archean age of the slaty schist which is seen in the Mississippi river at Little Falls.

At the rapids below the dam, at Little Falls, the direction of the sedimentary bedding is various. It is difficult to say whether it is prevailingly in any direction. Yet in one instance it was carefully measured and found to be 75° W., 3° S. by compass, the slaty cleavage being about vertical and striking S. 25° W. On the west side of the island there is a plain crumpling of the sedimentary structure and in the main a small synclinal trough, though the prevailing direction here is westerly. The lenticular, so-called crystalline masses of quartz-dioryte described by Mr. Kloos (Eleventh annual report, p. 74) are always vertical, and coincide, in their longer diameter, with the slaty cleavage. They cross the sedimentation. They are not dependent on the direction and apparently not on the character of the sedimentation, but on some later force. The same is true of some white quartz veins, as they also run with the cleavage. It is true, however, that these dioryte septaria frequent certain layers of the sedimentation, occurring in a belt parallel with the sedimentary structure, at least in one place, though individually even then they are elongated with the cleavage. This seems to show the production of quartz-dioryte in a sedimentary rock, the process being completed in certain of the sedimentary bands over small areas, forming crystalline masses, these masses being still surrounded by such materials as went to form the ordinary schist of the place. The petrographic alliance of this segregated rock with the laminated dioryte on "the point," as noted by me in the sixth annual report (p. 51), taken in connection with their elongation, and the further fact that the lamination on "the point" is parallel with the cleavage of the slates, points to the probable origination of the lamination on "the point" from the complete metamorphism of a sedimentary rock, and also to the necessary separation of the lamination structure from any dependence on the original sedimentary structure, at least in the direction which it maintains. These nodules, when sufficiently elongated, would constitute bands resembling these seen on "the point." The production of these dioryte septaria, or dioryte bands (when elongated) seems to be favored by the occurrence of certain elements in the composition of the original sedimentary rock, since, as stated above, they frequent certain sedimentary strata, and are wanting in others.

In Gravelville in the eastern part of Morrison county, with the guidance of Mr. Robert Brown, a large granite area was visited. This rock outcrops generally on section 18, T. 41–13, and its color is red to grey, sometimes gneissic, but mainly is massive, as if formerly molten. The red is sometimes very coarse and *Scotch*-like, but also often is fine-grained and siliceous, resembling some seen on the Kawishiwi river some years ago, and also that seen at "La Framboise" place a short distance above New Ulm in 1873. In the latter case it may be sedimentary rock metamorphosed in place. This granite area runs alongside of a valley in a direction S. S. E., the valley being on the east.

In the town of Randall, on the west side of the Mississippi river, section 7, T. 130–30, greenstone is cut by the railroad. A low ridge extends S. S. W. about a quarter of a mile. The rock is fibrous-massive, and typical Keewatin. It has much calcite in spots and in veinings, also quartz, with some small pyrite cubes. This is evidently a fragmental rock, and the grains and pebbles of differing hardness stand out on the weathered surface. It is a conglomerate, of the Kawishiwin kind. The main structure stands nearly vertical but dips S. E. Numerous boulders of gabbro are strewn about here.

The rock which I visited about a mile west of Little Falls 15 years ago,* is now quarried for foundations. It appears like a modified gabbro where it lies in the streets, and when cut by the workmen, and also at the quarry, but on close inspection it is found to be a dioryte. I do not see any amygdaliodal structure, such as that mentioned in 1877.

Accompanied by Messrs. Williams and Rothwell, of Little Falls, another visit was made to Pike rapids. The rock's principal structure strikes about E. and W. and dips N. at 70° from the horizon, running diagonally across the river up stream to the left bank. At a point a short distance below the mouth of Swan river, and where the principal rock-reef causing the

*Sixth annual report, 1877, p. 53.

principal water-fall enters the right bank, is a limestone layer, standing several feet above the water, rather poorly exposed in the bank. It appears a little too far down-stream to be certainly the cause of this riffle, but the dip would certainly bring it near that position under the water. It is disconnected and cannot be traced to the riffle. It is a pinkish, fine-grained marble, marked by close sedimentary (?) structure which coincides in direction and dip with the principal structure of the staurolite schists of the place.

Near the centre of S. E. ¼ N. E. ¼ sec. 30, Town. 128–29, Morrison county, is a rather singular mica schist. This is some miles below the limestone above noted, and on the upland a mile and a quarter from the river, on the west side. The low, small ridge is situated in a swampy tract, runs about N. and S., rises about 10 feet, and apparently extends under several acres. It shows no general structure and is very fine-grained. Yet it contains occasional nodules like those in the slates at Little Falls, characterized principally by long, conspicuous black hornblende crystals which are sparingly disposed about the periphyry of the mass in a lighter colored band. In some other cases there appears to be no completion of the concretionary process, and there can be seen only a few scattered long crystals of the same mineral running at random and gathered about a point in the schist, the whole area affected being about three inches in diameter.

Lincoln, Morrison county. This is in the northwestern corner of the county, on the "cut off" branch of the Northern Pacific railroad. Here are remarkable morainic ridges, very abrupt and high, running almost like a kame, extending past the station southwest from lake Alexandria. They are remarkably abrupt and high. The region is one of red till, which extends from Little Falls to Philbrook, though beyond Lincoln the surface becomes sandy like that at Little Falls and Brainerd. These hills were only seen from the cars.

Philbrook, Todd Co. Still further northwest, at the point of junction of the Fish Trap with the Long Prairie river, an examination was made, under the guidance of Mr. Hartshorn, of Staples, and Mr. Robert Brown, of Little Falls, of the rock outcrops in that neighborhood. These outcrops, so far as could be discovered, are all of gabbro, but the rock manifests some variations which have not before been seen in the great gabbro of the region further east. It varies in patches or in vein-deposits, to a nearly white rock consisting almost wholly of a feldspar which is striated, with a little quartz. This may be a segregation product, and not an original constituent of the mass. It also varies to a very dark and heavy trap-looking rock, which, however, still contains long cleavages of a striated feldspar. Throughout all these, except in the white feldspar, are many crystalline grains of magnetite which is probably titanic. There is also a narrow belt, not well exposed, seen below the dam of the Fish Trap in unfavorable situation for examination, where this gabbro is converted by shearing into a schistose rock, the schistose structure standing about perpendicular. In this schist, which might inadvertently be taken for an outcrop of an older formation, are still seen many of the magnetite grains, and all the feldspars as well as the hornblendes are broken and flattened. This gabbro forms a low hill range, and can be traced, according to Mr. Hartshorn, S. S. W. or nearly S. about 3 or 3½ miles, and has a width of half a mile, so far as known. It extends 2½ miles from Philbrook southerly and some distance north.

The principal object of this re-examination in Morrison county was to determine, if possible, whether the Little Falls slate be Taconic or Archean. There seem to be several strong points indicating it is of the Archean, viz:

1. The garnets and the general micaceous composition of the Little Falls slate point to its identity in age with the staurolitic and garnetiferous mica schist at Pike rapids.

2. The existence of the nodules of quartz dioryte in the Little Falls slates, and the petrographic relation they bear to the laminated dioryte at "the point," indicating a close connection in age and metamorphic transformation between the slate and the dioryte, show that both rocks have suffered a greater change through some general or regional crystallizing force than has been found in Minnesota for any strata of the Taconic.

3. Toward the eastward from Little Falls the rocks are granitic, so far as they appear above the drift, not allowing any great extension of any schists or slates in that direction, and toward the west, so far as known, all the outcrops show a more crystalline rock than is known at any place in the Taconic. It would appear as if, generally, toward the west the rocks are of the Keewatin or the Vermilion age, and that toward the east they may be of Laurentian.

4. The fine mica schist seen some miles below Pike rapids (S. E. ¼ N. W. ¼ sec. 30, 128-29) contains nodules of quartz dioryte that are indistinguishable from those that occur conspicuously in the slates at Little Falls.

5. There is therefore a general alliance between all the outcrops from Little Falls southward that requires them to go altogether into the same formation, whether Archean or Taconic. It is therefore most likely that they all belong in the mica schist belt (Coutchiching or Vermilion) of the Archean.

[*Note on the water power at Little Falls.*—Mr. M. M. Williams states that there is more water power at Little Falls than at Minneapolis,—*i. e.*, that there is more water passing over the dam at the former place. Last winter, while the water power company at Minneapolis had to shut off all leases beyond eleven mill-powers, owing to the low stage of the water, at Little Falls they were running 13-15, including wastage at the dam. The fall at the dam at Little Falls, is 20 feet; from the canals it must be a little more. At Minneapolis the perpendicular natural fall, at the falls, is about 16 feet, and by the dam and the canals, in the turbine wheels it is made to be about 52 feet. If it is demonstrated, as it appears to be, in the opinion of Mr. Williams, that more water passes Little Falls than St. Anthony falls, it is a remarkable and interesting fact, and can only be explained by supposing the water, after passing Little Falls, enters the St. Croix and St. Peter sandstones, both of which cross the river in their strike, between the two points, and both of which afford abundant artesian water at more southern points.]

THE MESABI RANGE.

At the Hale mine men have lately found (July, 1892), a soft ore at 38 feet below the surface. The rock struck at first is taconyte*, a grayish, cherty rock which is abundant on the Mesabi range, in connection with the ore. In larger quantities this rock frequently overlies important beds of hematite. It is also frequently brecciated; as a rock it varies from cherty jasper to hard ore, and in some positions it appears to have been the rock which has been changed to ore, sometimes more evidently to a hard hematite than to a soft ore. The figure below (Fig. 8) shows the geological situation at the Hale mine.

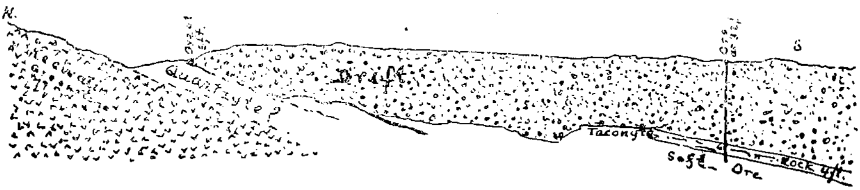


FIG. 8.—North and south section at the Hale mine.

* This name was suggested by Mr. H. V. Winchell, for the cherty, or siliceous, gray rock which in many places appears to have been the basis from which, by a progressive change to hematite, the ore deposits of the range have been formed. The rock has not yet received an accurate description, but is recognizable by any geologist who visits the region.

At the Cincinnati mine thirteen shafts or pits, have been sunk (March 5th, 1892), which disclose soft hematite ore. Their distribution, as indicated by the captain in charge, is shown on the small map below, figure 9, which represents section 2, 58–16. These pits vary in depth from 50 to 75 feet, and are reported to contain ore of merchantable quality ranging in thickness from five feet to fifty feet. Nos. 1, 2 and 3 struck a sand-rock, while two others, near the center of the section, encountered slates, i. e., the well-known black slate. A portion of the Biwabik mine is in the extreme N. W. corner of the section.

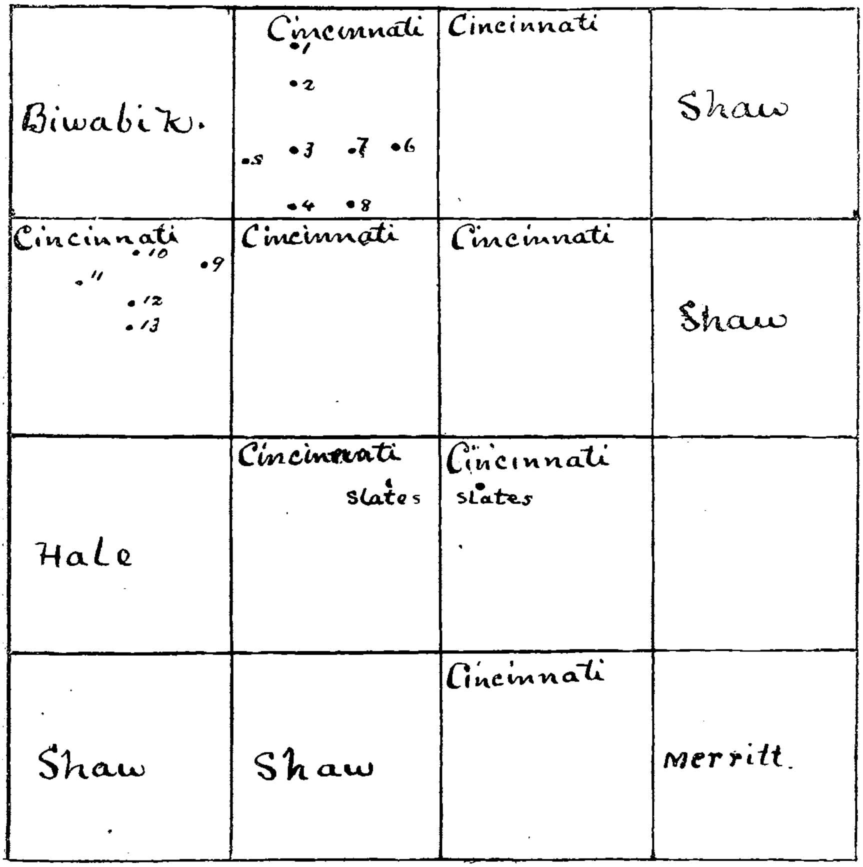


FIG. 9.—The Cincinnati mine, section 2, 58-16.

In July, when a second visit was made to the Cincinnati mine, the situation was somewhat changed. Pits Nos. 2 and 3 were extended through the ore, and the underlying rock was found to be a sandy quartzyte, rather soft, for two feet in No. 2, and in chunks in No. 3, for two feet. Pit No. 8 was 70 feet deep, the bottom below 60 feet being in a quartzyte containing a little jasper, making a banded quartzyte. This rock is flat, with ore between the layers. It is "altogether different from the lower quartzyte." Shaft No. 3 has 45 feet of ore, and No. 2 has 35 to 40 feet. Shaft No. 4 had a bed of rock, or a bunch of taconyte eight feet in thickness lying in the ore. Shaft No. 9 went down 75 feet, with 45 feet of "paint rock" and ore alternating. Water then stopped the work. Shaft No. 10 is 100 feet deep, having mixed ore and paint rock, something like No. 9. Shaft No. 11, 300 feet west, is 65 feet deep, and has 25 feet of ore like the other, 10 feet of paint rock, 10 feet of ore, 5 feet of paint rock, lying on the quartzyte which dips 25° westward. Shaft No. 12 is 96 feet deep. Struck no rock but has 45 feet of good brown ore, and ten feet of paint rock, with ore again below. Shaft 13 is down 40 feet, and struck black slate, not worked further.

The "banded quartzyte" in No. 8 shaft on examination proves to be a form of the taconyte generally overlying the horizon of the ore and of the true granular quartzyte. The "black slate" of shaft 13 is probably the lowest part of the black slate horizon, but it is not slate, nor slaty. It is dark, nearly black, varying to greenish to grayish, a fragmental rock entirely, so coarse as to be conglomerate (1689). While very siliceous, the silica is in the form of flint pebbles, and more or less angular pieces, and a little chalcedonic silica (i. e., minutely granular like the silica of the jaspilyte). It also has rounded pebbles of a dark, softer rock, more like some of the thicker slate beds into which the slates graduate upward. Most of the rock in places is made up of these, and in finer condition they also act as cement for the coarser portions. But pervading the whole and filling the smaller interstices is black magnetite in such amount as to disturb the needle markedly.

Combining these observations with those made at Wicks' camp (May 8), the downward succession seems to be, for the rocks of the Animikie in the Mesabi range, as follows:

General section of the Mesabi range rocks.

1. Black slates, often magnetitic. Thickness unknown, but very great.
2. Conglomeratic portion of the black slates, often magnetitic (1689 and some part of No. 4 of Wicks' drill.) This is not easy separable from the next, and in some places is confused with the next, or graduates into it. Thickness may be 20 feet.

3. Taconyte horizon, mixed with ore or graduating into ore, often styled "cap-rock." Thickness 5 to 50 feet.
4. The ore horizon, sometimes encroached on by No. 3. Thickness 10 to 50 feet.
5. Fine "chalcedonic" quartzytes. In some places this is not found, but when it is present it seems to occupy, in part at least, the horizon of No. 4 (No. 6 at Wicks'). Thickness at Wicks' 17 feet.
6. Rounded, granular quartzyte. Thickness 20 to 100 feet.
7. Basal conglomerate. Thickness 5 to 10 feet.

The non-conformable underlying formation may be any part of the Archean, even the iron-bearing portion of the Keewatin; and the basal conglomerate in consequence assumes various lithology and composition.

In the bottom of shaft No. 2 at the Cincinnati is a disintegrated quartzyte (1690). The grains are angular and subrounded. There is here no jaspilyte, as at Prairie rapids, and at Gunflint lake, but the sand is stained with iron and manganese oxides. N. W. from pit No. 2, 400 feet, another pit struck "chalcedonic" quartzyte, irregular and twisted, associated with a sandstone and a conglomeratic mass, sometimes kaolinic.

Further north, 250 feet, is a pit in greenstone, and at 150 feet north of pit No. 1 is a pit in sandstone.

In general, so far as can be seen at the Cincinnati, there is a jaspilitic silica only near the bottom of the Pewabic quartzyte. A pit was seen at the Hale mine which struck the greenstone. It was all reddened by oxide of iron, but it had the schistose structure and the texture of the Keewatin; however, at the Cincinnati mine the greenstone, where struck, is still green, and unaffected by transference of iron from the upper horizon. Another pit, at the Cincinnati mine, struck a phase of the Pewabic quartzyte not often seen. The rock was greenish and hard, and fine-grained, but evidently laminated by sedimentary stratification. It had been mistaken by the superintendent for greenstone. This phase here is near the basal conglomerate, and in grain it resembles that seen at Wicks' (No. 1632), though its color is usually not pinkish. In the form of boulders it is quite common on the surface, weathering nearly white, so as to resemble marble.

The rock taconyte prevails along the eastern part of the the Cincinnati, and probably in the eastern part of the section, the ore becoming more and more abundant in the western pits. There are so many pits scattered through this region that it gives the impression, the rock and dip being uniform, (with one exception), that the ore originated from a grand change in the taconyte rock toward the west. Further observation, however, is needed, to demonstrate this.

The Biwabik mine. The adjoining figure shows the three "forties" on which this mine is located, and the positions of the various shafts here mentioned, as they appeared July 19, 1892.

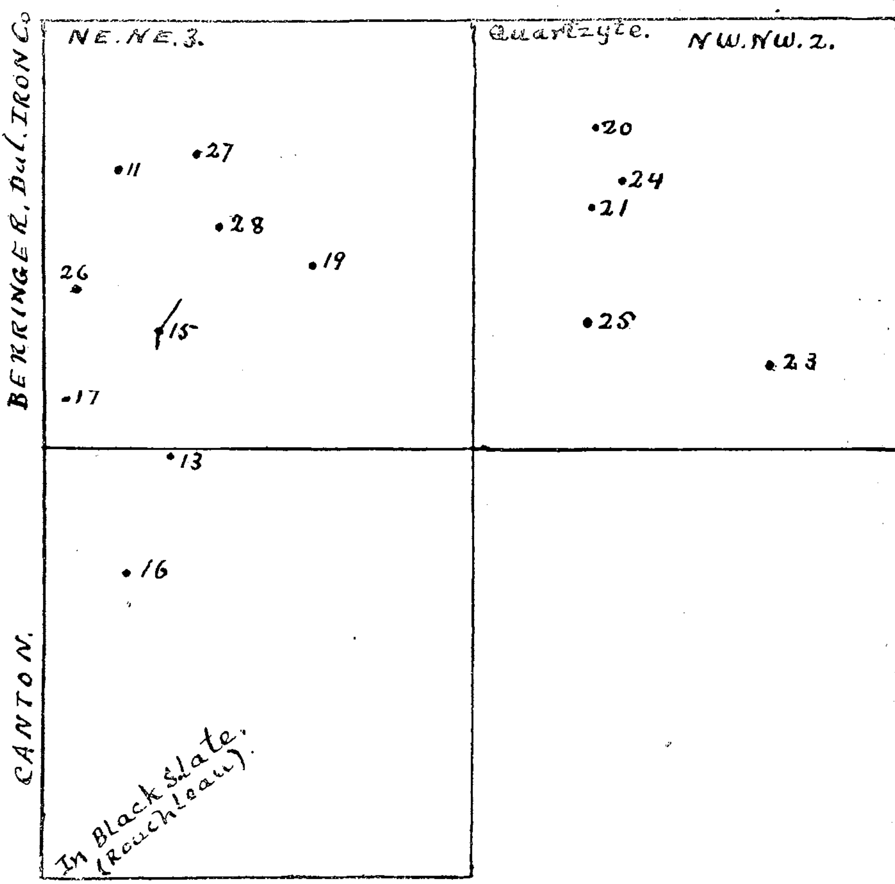


FIG. 10.—Map of the Biwabik mine, July 19, 1892.

Shaft 13 has the following section: surface, 36 ft.; paint rock 18 ft.; mixed ore and paint rock, 34 ft.; purple paint rock (56 Fe.), 8 ft.; yellow ochre, 4 ft.; total, 100 ft.

An average analysis of ores from shaft 13 was made by E. E. Brewster, with the following results. This included the upper "paint rock," and "mixed ore and paint rock." Iron, 50.05; Phosphorus, .049. The upper paint rock alone gave: Iron, 46.10; Phosphorus, .041; Silica, 14.44, being still a bessemer ore.

Shaft 15 has the following section: surface, 30 ft.; paint rock, 13 ft. (44 p. c. Fe.); yellow ochre, 7 ft. (62 p. c. Fe.); blue and red ore, 7 ft.; soft blue ore, 27 ft. (67 p. c. Fe.); brown ore, 22 ft., limonite (63.20 p. c. Fe.) Stopped here on account of water. At the depth of 85 ft. a drift was in "soft blue ore" in a N. E. direction, and another was run south. The former was extended 150 ft. from the shaft, and the latter 45 ft. They only found the same ore as at the shaft. Five hundred tons of the blue ore were taken out, and now lie in the stock pile. An average analysis of the ore in shaft 15 gave Messrs. Rattle and Nye 66.5 of iron, and E. E. Brewster, 65.40 Fe., .034 Ph. The complete analysis from shaft 15 gave the following result, by W. E. Rice, of Newcastle, Pa.:

Metallic iron,...........	69.054	Alumina,..........	.300
Silica,....................	1.340	Manganese,...........	.130
Phosphorus,............	0.168	Magnesia,.............	.072

Shaft No. 17 has the following section; surface 28 ft.; paint rock, 16 ft.; yellow ochre (some brown ore), 17 ft.; blue and brown ore mixed, 46 ft. An average analysis from this shaft was made by E. P. Jennings, Hurley, with the following result; iron, 63.25; phosphorus, .032.

Shaft 19 has the following section; surface, 52 ft.; mixed surface and ore, 2 ft.; brown ore, 12 ft.; "sand," 2 ft.; soft ore, (blue and brown), 6 ft.; soft blue ore, 12 ft.; brown and blue ore (hard), 6 ft.; soft blue ore, 13 ft.; brown ore, 2 ft.; total, 107 ft. This entire shaft is dry.

An average analysis by Brewster from the first 20 feet in shaft 19, gave the following result: Iron, 64.35; phosphorus, .045. The next ten feet gave, iron, 65.95; phosphorus, .047.

Shaft No. 20 has the following section; surface, 5 ft.; brown ore, 19 ft.; hard blue ore, 11 ft.; brown and blue ore, 6 ft.; hard brown ore, 10 ft.; soft brown ore, mixed with some blue, 17 ft.; brown ore, 1 ft.; stopped, no water. Analyses (average) from this shaft gave Brewster: first 15 feet; iron, 62.40; phosphorus, .065. The next 10 feet gave iron, 62.40; phosphorus, .068. The next 10 feet gave iron, 63.30; phosphorus, .068. The next 10 feet gave iron 58.65; phosphorus, .104, and the next 10 feet gave iron, 60.20; phosphorus, .081.

Shaft 21 has the following section; surface, 6 ft.; brown ore and yellow ochre, 20 ft.; hard blue and brown ore, 5 ft.; soft blue ore, clean, 8 ft.; brown and blue ore, 4 ft.; soft blue ore, 10 ft.; brown ore, 10 ft.; blue and brown ore, 7 ft. Stopped, no water.

Average analyses by Brewster gave the following results from this shaft:

First fifteen feet, Iron, 50.85; Phosphorus, .097.
Next ten feet, Iron, 62.50; Phosphorus, .063.
Next ten feet, Iron, 63 45; Phosphorus, .029.
Next ten feet, Iron, 62.25; Phosphorus, .051.
Next ten feet, Iron, 63.45; Phosphorus, .038.

Shaft 21 has 56 feet of ore, varying from blue to brown, excepting five feet of taconyte, the brown being about three or four feet at the bottom. This shaft apparently also has a bed of soft manganese at the depth of 94 feet.

Shaft 24 has a "surface" of 29 feet, and about 50 feet of blue ore, brownish at the bottom, still sinking.

Shaft 25 is a repetition of shaft 13, with the exception that a blue ore appears below the yellow ochre, at the bottom, and the ochre was found to be 13 feet thick. This gives reason to expect that the blue ore of shaft 15 will yet be found below the bottom of shaft 13.

Shaft 26 has the following section: surface, 23 ft.; yellow ochre, 10 ft.; brown and blue ore, 4 ft.; soft blue ore, 31 ft.; brown ore, 2 ft. (just touched); total, 70 ft.

Analyses were made from this shaft with the following results:

First ten feet in ore, Iron, 60.65; Phosphorus, .043.
Second ten feet in ore, Iron, 64.70; Phosphorus, .042.
Third ten feet in ore, Iron, 66.55: Phosphorus, .025.

It is noted by Mr. Jones that there is a body of soft blue ore of highest grade, between two beds of hydrated ore, as shown in all the sections.

Near the town line, in the extension of the line between sections 2 and 3, a shallow pit struck green siliceous rock, evidently a part of the quartzyte. It is similar to the greenish schists and slates lying south of the quartzyte foot wall at the Aurora mine on the Gogebic range.* It is a slaty, gray quartzyte, in part, brittle and sharp, and in part it is soft, greenish and largely made up of debris from the underlying greenstone, with sericite and argillyte. Much of it cannot be called quartzyte. However, it is apparently nearly on the horizon of the fine-grained phase of the quartzyte seen at Wicks'. Here it is below a coarser sand rock, but at Wicks' it was reported by Wicks to be above the principal mass of coarse sand rock.

*Compare 16th Report of the Minnesota Survey, p. 58.

The following complete analyses was made of the Biwabik ore by Frank D. Crolaugh (Stewart Iron Co.):

Iron	66.864
Phosphorus	.009
Alumina	.840
Silica	.880
Lime	.041
Manganese	.100
Sulphur	.030
Magnesia	.021
Loss at red heat	2.000
Titanium	None.
Arsenic	None.
Copper	None.
Chromium	None.

The Biwabik apparently has ore on three-fourths of two forties, an average of 50 feet thick. Allowing ten cubic feet for one ton of ore, the amount of ore "in sight" is found to be 9,905,000 tons. This is a conservative calculation. The ore is often 60 feet thick, and even, in one case, 68 feet in thickness, and there is great probability that the ore underlies more than one and a half forties. Mr. Jones, under whose guidance the foregoing facts were ascertained, estimated the total ore "in sight" at *eleven* millions of tons, and others have made it as high as twenty-three millions.

The Chicago mine is on sec. 4, 58-16. The land of this company is outlined on the following sketch map, fig. 11.

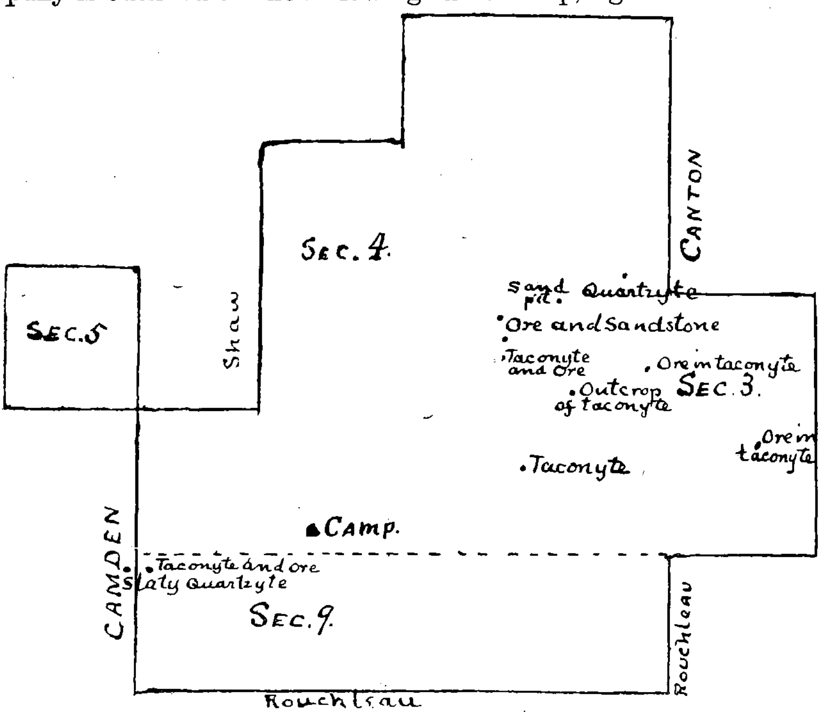


FIG. 11.—Outline map of the Chicago Co.'s land, July, 1892.

The Chicago company's land was visited July 20 and 21, 1892, and the examination was made under the guidance of captain Johnson. It was a pretty thorough examination, all the trial pits and shafts having been visited. On the accompanying figure a few of these pits are shown, viz., such as were important as to some geological features disclosed. The only ore body found is near the eastern side of the property, where nine feet of good, soft, blue ore was found in a pit. It lay within the taconyte rock, having:—

Surface	15 ft.
Taconyte	17 ft.
Taconyte, with ore in lumps	10 ft.
Soft, blue ore	9 ft.
Taconyte	12 ft.

But this shaft was abandoned at 63 feet because there was no return of ore on going deeper, and because the shaft had not been well prepared for working deeper with safety. At a later date Mr. Johnson reported that he had begun a drift in this shaft at the level of the ore, about 50 feet below the surface, and he found the rocks dipping at an angle of about 30 degrees toward the west, and that the ore apparently was increasing in amount.

In the course of the examination of this tract it was observed that the taconyte comes close upon the quartzyte, in separate pits, with little or no ore, at least in some places. This occurs at the eastern and western extremes of the property, and there is nothing shown by the intervening pits to indicate any probability of a change. This examination also tends to establish some principles respecting the ore bodies.

1. The soft ore occurs in the midst of the taconyte rock, though I had believed that it occurred, when in considerable amount, first at the bottom of the taconyte.

2. The taconyte is separated from the quartzyte by a thin stratum of hard brown ore.

3. There is a stratum of hard, fine-grained quartzyte, similar to the pinkish quartzyte at Wicks', embraced in the basal quartzyte (1696). This seems to be the same as that detected at the Cincinnati and Biwabik mines.

4. The first phase of the quartzyte below the ore is coarse and rather loose, as at the Colby and Aurora mines on the Gogebic range.

5. It is fine-grained, becomes slaty and sometimes apparently sericitic, but hard and brittle, at a lower level. In this

condition it is gray or green, and might be styled novaculyte, similar to that lying below the mass of quartzyte at the east end of Teal lake at Negaunee.

6. The rock all about the Chicago property is nearly flat, and is unfavorable for the progress of the change which has been supposed to have produced the ore, and so far this rather confirms that hypothesis.

The McKinley mine, July 21, 1892.

On the accompanying sketch map the various shafts and pits, as referred to here, are located. Many others which revealed nothing important are not noted.

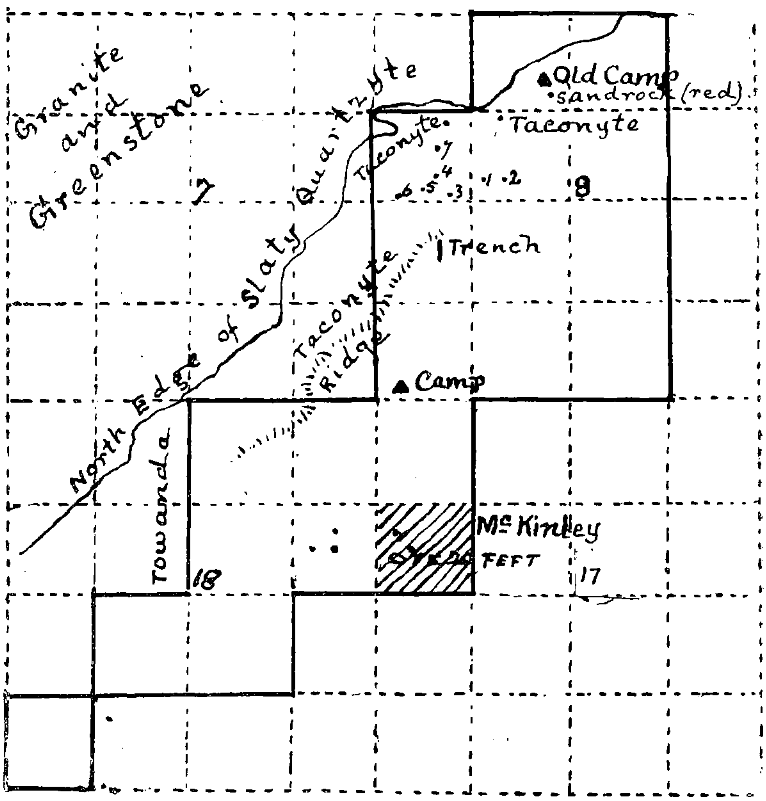


FIG. 12.—McKinley mines.

Pit No. 1, the first one sunk, has 18 feet of ore, with no taconyte overlying. It is 40 feet deep and stopped in the ore body.

Pit No. 2 passed through the hard pan down to the ore. No capping; 42 feet deep.

Pit No. 3. Surface, 7 ft.; capping, 5 ft.; ore, 57 ft.; stopped in ore; much water at the bottom.

Pit No. 4. Surface, 11 ft.; mixed ore and taconyte, 29 ft.; ore, 25 ft.; still in ore; much water.

Pit No. 5. Surface, 20 feet; capping, none; ore, 30 feet; taconyte, 12 feet; ore, 1 ft; expect to resume.

Pit No. 6. Surface, 60 ft.; ore, 8 ft.; incomplete from bad weather; will resume.

Pit No. 7. Surface, 12 ft.; broken taconyte, 28 ft.; no ore yet.

At the "old camp" a well struck a "red grindstone rock," but no samples were preserved. It may be a rusted condition of the Pewabic quartzyte, or it may be some Cretaceous sandstone.

The map shows the line of strike of a taconyte body, the outcropping bluff facing north and running northeastwardly, and below it all the ore thus far found in section 8 has been found. At the present camp (see fig. 12) a well was dug in black slates 8 to 10 feet. The well is 32 feet deep.

On some of the McKinley land the black slates appear, and at the well at the new camp, they give a water carrying sulphuric acid, evidently derived from the oxidation of pyrite, which is in the slates in crystalline form. In a pit further north the rock, which is apparently of the black slates, is somewhat different, resembling some of the so-called ash-beds of the Cupriferous.

The ore pits south of the camp, near the townsite of McKinley, are probably all above the main ore body. It would require some unexpected break or irregularity in the strike of the taconyte, to cause the appearance of considerable ore deposits in that locality, as the surface is probably not only above the ore body but also above the main taconyte mass. It is the opinion, however, of Capt. Hill, that there may be important ore deposits on the present townsite. It was reported that a bed of 20 feet of ore had already been discovered in this vicinity and that it was likely that the townsite would be changed to some other place. On examining this ore it was seen to be quite different from that known to occur at the lower horizon. It is lean, hard and soft (ochery), mixed with some green clay, some slaty portions, some magnetitic, and altogether as yet nonmerchantable. It may be possible to get a bed of ore in there, but as it would be on a new and higher horizon, it would be a new thing and indicate a great increase in the possibilities of the range.

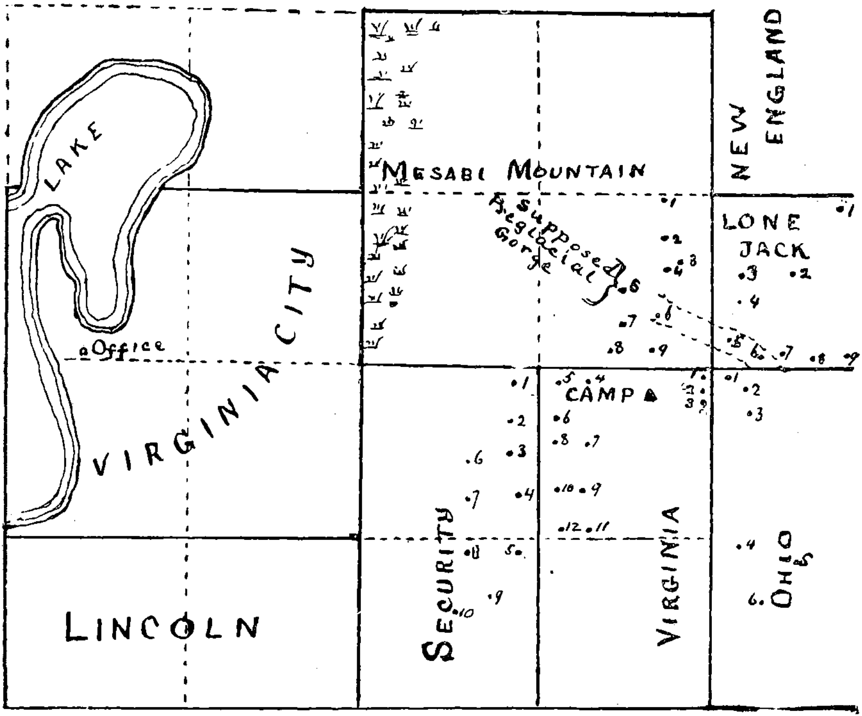


FIG. 13—Mesabi Mountain, Security, Virginia; sec. 8, T. 58-17.

Mesabi Mountain, Security, Virginia, etc.

The accompanying sketch shows the relative positions of these properties, and some of the pits that had been sunk to July, 1892. Here the dip is reversed from that usually met with on the Mesabi range. The rock bearing the ore lies on the N.W. slope of a greenstone ridge, which is a spur of the general greenstone area further north, and has a N.W. dip, varying from N.W. to 12 degrees south of west, amounting to 5 to 15 degrees. In the axes of these ridges granite frequently is found to take the place of greenstone. In sections 15 and 14 the bluffs of Pike river are precipitous and high with cliffs of greenstone, the precipitous cliffs usually facing E. and S.E. The same kind of surface is in sec. 29, in the same town. From some of these hills of greenstone it is reported that the eye controls a vast country toward the south.

In this region some interesting observations were noted. Mr. W. J. Merritt, who is in charge of the Mesabi Mountain property, is of the opinion that the main ore deposit lies above the taconyte rock, thus agreeing with some evidence tending to the same conclusion already noticed at the McKinley mine This opinion is based on some general observations made by him on the geographic relations of those trial pits in which ore has been found compared with those which do not contain ore, but have encountered the rock taconyte.

The following notes describe the pits represented on fig. 13.

First, Mesabi Mountain.—As given by Mr. Merritt or his superintendent, pit No. 1 encountered taconyte after passing through three feet of good ore; pit No. 2 struck what is known as taconyte and to which was given the local designation "stove-plate rock" by the workmen; it was very ferruginous and resembled ore, but in thin and brittle sheets; pits Nos. 3 and 4 encountered a fine blue ore; pit No. 5 struck red ore; pit No. 6 encountered a peculiar irony gravel, supposed by the superintendent and others to be from an old pre-glacial gorge cutting the iron ore beds; pit No. 7 encountered a black ore, good quality, and No. 8 had blue ore.

Some of these pits are from 50 to 75 feet deep and have, sometimes, 50 or more feet of nice clean ore.

The supposed glacial gorge represented on the sketch map (fig. 13) passes from the Lone Jack property onto the Mesabi Mountain, and is considered to be a very uncertain hypothetical explanation of the existence of certain gravel. It may be that there is a gorge in the rocks running about as supposed, but the gravel may be of Cretaceous age rather than post glacial. The gravel itself exhibits every feature of a promiscuous fragmentary accumulation. Some of it is completely made up of ore like that of the region, but of rather low grade, and some of it is apparently derived from a rock but little affected by ferric oxide. It seems to vary exactly as the rock of the country does, that is, it is "lean" or not, and its different constituents can be referred entirely to the country rock adjacent. The further phenomena of this gorge will only be revealed by the mining operations that are sure to follow. At the present time this gravel is simply overlain by the common till and graduates rather abruptly upward into an irony till and then into a gray till. The pebbles are cemented together by a coating of ferric oxide deposited on them since they were placed in their present position, indicating the later supply of some water, in large amount, capable of parting with iron oxide. Some of the pebbles have an irony crust harder than the interior, and from the crust toward the center there is an increase of coarseness of texture, even becoming somewhat spongy, indicating some progressive change from the circumference toward the center, the whole pebble, however, becoming good Bessemer hematite; but such pebbles are not common. The great mass of the gravel, some of it being coarse as walnuts, consists simply of very irony rock of some sort, of very uniform grade throughout. It does not appear that the gravel has become ferruginated to any great degree since its deposition as gravel. The ferruginous surface film is nothing more than such as might be found on any exposed surface over which the waters of this region might pass.

In the Lone Jack property in one pit the gravel was found to be 35 feet, and below that a fine blue ore, continuous to a total depth of 102 feet. The other pit has gravel ore 66 feet and goes no deeper.

Second, Security.—Two lines of trial pits had been run by the superintendent, J. M. Huggins, north and south across the north forty of this property, which revealed some interesting facts as to the relations of the ore to the rock taconyte. The second series also extends over onto the south forty. The eastern series includes the following pits from 1 to 5 inclusive. In these pits a large body of purple ore has been developed at a short depth below the surface. The other series, which lies further west, including 6, 7, 8, 9 and 10, encountered generally nothing but rock, though in some cases overlain by ore, reaching a thickness of 6 to 9 feet; yet in No. 9, which really lies further east than the rest, Mr. Huggins reported that he found an alternation of good ore and taconyte, about one-half being ore, the beds of which were one to two feet thick. At the pit No. 10 of this series careful measurement was made of the dip of the taconyte, the result being 10° to 15° west, 10° north, by compass.

The facts seem to show, so far as the Security property is concerned, that the strike of the ore and rock is about north and south, or a little northeasterly, and that the main ore deposits are stratigraphically below the taconyte. It seems, however, that the ore is not entirely below the taconyte, as shown by pit No. 9, but it is interbedded with it. It also appears by the depth of the pits in the western series that the main body of ore ought to have been struck there if it maintains a stratigraphic relation below the taconyte. Upon the whole it is unsettled whether the ore body runs below the taconyte or results from a change in the taconyte.

Third, the Virginia.—While there was a series of pits along the western side of the north forty (see fig. 13), evidently striking the same body of fine ore as revealed on the Security next west, the whole dipping west northwest, yet there was another belt of rock disclosed by a still further eastward line of pits, which apparently belongs near the bottom of the ore body and manifests about the same uncertain stratigraphic relations as the taconyte on the Security. It was the occurrence of this body of rock, which was taken by Mr. Merritt as the stratigraphic equivalent of the taconyte and the existence of ore above the taconyte on the Security, that induced him to regard the ore-body as generally stratigraphically above the taconyte rock. But it is probable that this is not the stratigraphic equivalent of the taconyte, but lies below it. This rock is a marked and persistent stratum; it cannot be called taconyte; it is a hard ore, or impure jasper conglomerate ore and furnishes many boulders that lie all over the surface in this country; it as certainly lies below the main ore deposit at this place as the taconyte further west lies above it. This stratum was struck in pits 7 and 9. The dip on the Virginia was reported to be 12° to 15° west, 10° south.

From pit No. 12 on the Virginia was thrown out a large amount of kaolin, the whole thickness being 16 feet. This kaolin is in the midst of ore, which lies both above and below it. This ore and kaolin are intimately associated; they make blotches in each other. The kaolin has apparently a sedimentary structure agreeing with that of the rocks of the region, and the hematitic interlaminations in the kaolin are very marked. When the kaolin is massive and coarse and nearly white, it contains balls and lenticular masses of silica. These balls are in both the kaolin and in the red and hematitic portions, which seem to be kaolin stained with ferric oxide. They have a uniformity of position, being elongated in the same direction. There is usually an abrupt transition between the white and red colors, but aside from the presence or absence of ferric oxide there is no apparent difference in this kaolin.

To further establish the relations of the ore to the taconyte, a special exploration was entered upon by Mr. J. W. Merritt, of the Mesabi Mountain Iron Co., and Mr. P. W. Scott, of the New England and Virginia mines. The former has begun to sink a shaft in the taconyte with the view of going through it or deep into it (pit No. 2 of Mesabi Mountain); and the latter has sunk three trial pits near the mutual limit between the ore and the rock, as detailed below. This last trial has demonstrated that the rock is actually converted, on the same stratigraphic plane, into ore. The facts are as follows, and they can be illustrated by figures 14, 15 and 16:

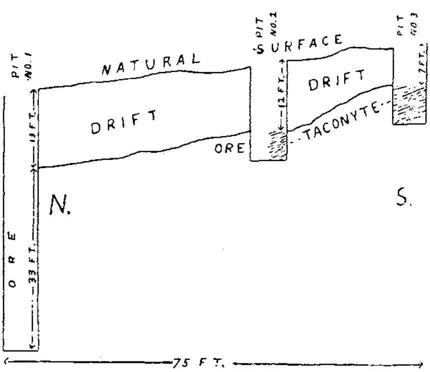


FIG. 14. A perpendicular section through three pits adjacent to each other, north and south, on the Virginia.

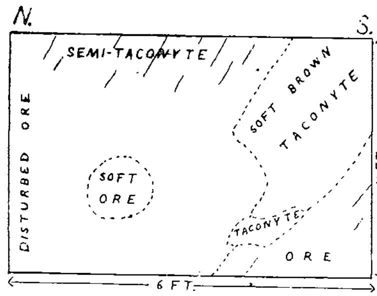


FIG. 15. Plan of the bottom of pit 2.

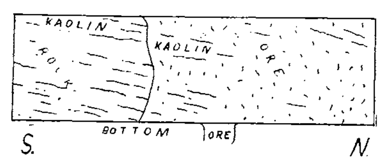


FIG. 16. Portion of the west side of pit 2 at the bottom.

On the sketch map (fig. 13) may be seen the location of these three trial pits, numbered 1, 2 and 3, on the Virginia property. Pit No. 1 of this series encountered black ore in large quantity at the depth of 13 feet below the surface, the ore being found to be at least 33 feet thick. Numerous other pits in the immediate vicinity had gone deep in good blue ore, one being the deepest in the ore yet sunk on the range—102 feet; others were so near an area of taconyte rock that it appeared easy, by one or two intervening pits, to develop what relation exists between the ore and the rock. There is a distance of 75 feet between pits 1 and 3 (see fig. 14), the former being further north and 46 feet deep, with 33 feet of good, clean, black ore, and ore still deeper; the latter but 7 feet deep and on the ledge. Then pit No. 2 was sunk at 50 feet from No. 1; this one struck the rock at 12 feet, dipping, as in No. 3, about 10° or 12° N. N. W., or toward pit No. 1. In this pit (No. 2) rock exists on the south side and ore on the north side (see fig. 15). There is an indistinct trace of the sedimentary structure in the form of a thin white kaolinic sheet running from the rock well out into the ore; but in general the ore part is disturbed and sunken down from the rock. There are irregular pockets in the rock, consisting of ore, connected with the main ore body, but the bottom of the pit is almost wholly in ore. The kaolinic sheets of the rock remain white and distinct as such—even in the otherwise changed rock—and show that the kaolin antedates the ore as a native element in the formation. Messrs. Scott and Short both went down with me into this pit, and with pick and hammer we made close examination. The outlines of the rock on the bottom of the pit and its appearance on the west side of the pit are represented in figures 15 and 16. Some specimens were taken from the line of junction of the rock and ore, showing distinctly the rather abrupt change between them, the sedimentary beds being continued from one part to the other (1707). This was of a rather soft ore and a rather soft rock.

Mr. L. W. Ayer, who was much interested in this trial, subsequently wrote the following report as to further developments.

MESABI MOUNTAIN CAMP, Aug. 7, 1892.

PROF. N. H. WINCHELL, MINNEAPOLIS, MINN.

DEAR SIR:—Agreeably with my promise to keep you posted as to the results of the work in the pit No. 2, on the Virginia property, in the N.E. corner of the N. E. ¼ of S. E. ¼ sec. 8, T. 58, 17 W., I beg to report as follows:

On the 28th ult., the day you left here, the pit was twenty feet deep with fourteen feet surface clay and boulders, then taconyte apparently in transformation—the half of the pit toward the northwest or toward the ore bed being mostly good ore, though generally of low grade, and running into the taconyte in almost imperceptible gradations.

In the next four feet the relations continued about the same, the ore a little better perhaps.

In the next two feet appeared a comparatively high grade soft ore mixed with a light colored quartz sand.

Next eighteen or twenty inches—thin layers of hard ore, low grade, one and a half to two inches thick, alternating with sand. When blasted this ore broke into small fragments from one to three inches, with rectangular faces.

From this depth (about thirty feet) to the bottom of the pit, a depth of thirty-five feet in all, was quartzyte, very slightly "banded" by streaks of iron.

The property having in the meantime been leased, the original intention to put the pit down to determine the thickness of the rock and the question of an ore body under the rock was abandoned, and the pit left as above stated at a depth of thirty-five feet, with the connected problems still unsolved.

The appearance of the pit when you were here very strongly supported the replacement theory, and I was nearly a convert, but the later developments make the matter look uncertain again.

* * * * * * *

Yours very truly, LYMAN W. AYER.

It would appear from Mr. Ayer's letter that the location of pit No. 2 was such that when the rock was first struck it revealed the line of transition from rock to ore, yet on being sunk deeper disclosed only unchanged rock or nearly so. It is evident, therefore, that the line is a zigzag one and that the further developments do not throw any doubt upon the conclusions indicated at first. Had the workmen followed the rock lying to the north, instead of going perpendicular, they doubtless could have kept the line of transition within sight.

The following figure (No. 17) is intended to express, so far as revealed at this visit, the areas of three taconyte bodies separated by ore bodies, both lying nearly horizontal. It is not possible that such a relation could exist without a local change of the rock of the country to iron ore. It remains yet to discover what was the original rock and what were the causes of its transformation.

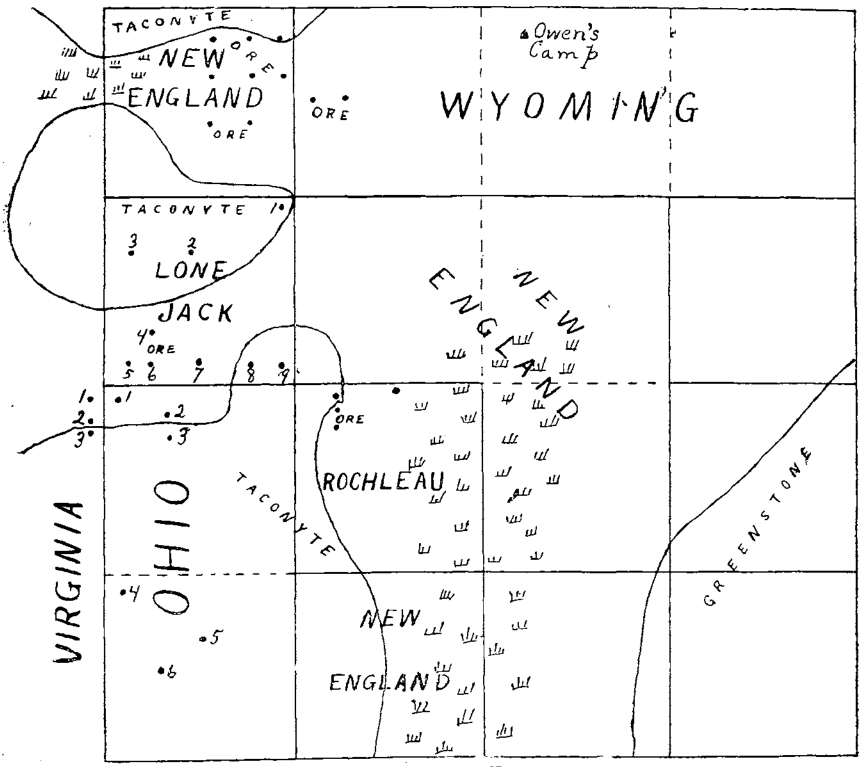


FIG. 17.—Three atocnyte areas in sec. 9, T. 58, 17 W.

In the midst of these interesting developments the writer made a summary of the facts developed on the Mesabi range touching the problem of the ores of the range, and read the paper before the American Association for the Advancement of Science.* Subsequently this paper was printed in full in the American Geologist, †as follows:

SOME PROBLEMS OF THE MESABI IRON ORE.‡

N. H. WINCHELL, Minneapolis.

CONTENTS.

Perhaps there is no more important or more interesting question, at present debated, relating to the iron ores of the Northwest, than that of their origin and their stratigraphic relations. From an economic standpoint, no less than from a scientific, there could be no more important question, for it is not until the geological relations and origin of these ores are understood that proper methods of mining them can be entered upon, and with the least expense. It is because of recent studies in the field, adding some new facts to the solution of this problem, or complicating it by the injection of some new conditions, that the writer desires to review the elements of the problem and to show the difficulties that yet lie in the way. It will be well to enumerate briefly the hypotheses that have been propounded recently, as an introduction to this discussion. There are five.

*Rochester meeting, 1892, p. 176.

†Vol. X, pp. 169-179, Sept., 1892.

‡Read August 22, 1892, before Section E, of the American Association for the Advancement of Science, Rochester, N. Y.

1. *Substitution for limestone.* Microscopic examination revealed the existence of remnants of calcite, or dolomite, in some of the "cherts" accompanying these ores in some places, and after long research the late professor Irving arrived at the conclusion that the whole body of the ore horizon was originally in the form of a limestone essentially a "cherty carbonate," simulating, in origin and essential characters, the black-band ores of the Carboniferous. This inferentially led to the idea of a great primordial carboniferous age.

2. *Substitution for carbonate of iron.* Owing to the frequency of such a change observed in nature, it was but a short step to suggest a carbonate of iron instead of a carbonate of lime. This would more readily supply the iron, which must be explained, than carbonate of lime, and at the same time would only require a slight change, if any, in the nature of the original rock, and in the conditions of its deposition.

3. *Concentration of iron oxide from the decay of ferriferous schists, or other rock.* When rocks decay, it makes but little difference what they are, they part with their contained iron. It may go off in solution, if the proper acids be present, and be gathered as oxide under ordinary natural drainage and weathering, in considerable quantities, on the evaporation of the solvent at some lower level. This process has been suggested as the possible cause of the accumulation of these ores at the stratigraphic horizon where they occur.

4. *Accumulation in troughs formed by dykes cutting tilted strata at a somewhat uniform inclination,* the iron itself being supposed to have been carried down and deposited by ferriferous waters, replacing a supposed "cherty carbonate." This hypothesis involves the same conditions and processes as No. 1 above, but also gives explanation of the location of the supposed ore lenses. At the same time it involves the decay and concentration in a definite rock horizon which is demanded by No. 3.

5. *Deposition from oceanic solution at the time of the formation of the rocks associated.* That the iron ores of the Keewatin age were deposited from solution, has been inferred from their association with rocks whose composition requires the cotemporaneous action of eruptive forces—but which are stratified by oceanic agency—such eruptive action causing chemical reactions that would result in the precipitation of iron and silica. This hypothesis has been applied by the writer also to a portion of the Mesabi ores, viz., such as are embraced as some-

what irregular (wandering) strata in the lower portion of the formation. Such may be either hematite or magnetite. It may perhaps be extended farther than has been proposed.

Some facts of the manner of occurrence.

The Mesabi iron range extends, within the limits of Minnesota, a known distance of more than 150 miles, and it is iron-bearing through its whole extent. It commences at the west end of Gunflint lake, on the national boundary, and has been partially explored southwestwardly as far as the Mississippi river near the falls of Pokegama. The iron horizons do not fluctuate in their stratigraphic positions. The iron varies as the character of the accompanying rock varies. It is a duplex range and embraces ores of two distinct origins and kinds.

The more southerly portion of the range, which is made up of gabbro hills, contains large deposits of titanic magnetite, and this may be dismissed with the statement that this ore is at present not used, and of little economic concern. This discussion appertains wholly to the more northern belt where the recent remarkable developments have been made. This northern belt embraces non-titanic magnetite and hematite as well as limonite and gœthite, or "yellow ochre," as it is sometimes denominated by the miners. The magnetite thus far discovered is not of economic importance, compared with the hematite and gœthite, but there are explorations now being made in some of the magnetites which promise to become perhaps equally valuable with the hematites.

The non-titanic magnetite is found in the eastern portion of the range and at a lower horizon in the strata than the hematites, and when it is represented in considerable amount there is little or no hematite in commercial quantities. It is sometimes in close asssociation with the gabbro containing titanic magnetite, and it is a reasonable hypothesis to refer the magnetic quality to the effect of the heated gabbro on the original ore, concentrating the iron by the expulsion of some of the oxygen. Still there is a trace of magnetic ore further west. It is there found in lean iron-bearing rock, and occupies belts of a few inches which pass through the rock in a rather peculiar zigzag or wandering fashion. But still further west the Pewabic quartzyte, which is the horizon which holds the magnetite in the eastern end of the range, is again regularly interstratified with magnetite in considerable amount, and as such it has been explored for commercial uses.

Hard hematite is found in the Mesabi range, but it is rather as an accidental appendage of the soft hematite, and usually it grades into low-grade ore and is discarded.

Hard limonite is found in larger quantities than hard hematite. It is apt to be impure, and it occurs in somewhat the same manner as the magnetite—*i. e.*, it branches and permeates a rock bed irregularly, though frequently seen in distinct nodules and in vugs when it is found to be a valuable ore.

The hydrated oxide, however, in the form of gœthite is quite abundant. Some shipping mines will depend largely on this ore. The ore is in the form of ochre-yellow powder, or small masses easily reduced to powder. It is found only in the region of the recent new developments, in the western portion of the range.

Soft hematite, however, is the ore for which the "Range" will be celebrated. This has recently been discovered in indefinite and almost incalculable amounts. It is generally amorphous, but in lumps, frequently as if a breccia of some sedimentary rock, easily crushed, and it also exists as a granular powder, finer than mustard seed, and can be mined by the simplest methods. The plans now being entered upon for excavating it only require a steam shovel and a railroad train.

Stratigraphic relations.

The horizon in which this ore occurs is that which has been identified as Taconic, or primordial. The strata have a gentle dip toward lake Superior, and a uniform strike from one end of the range to the other. The strata are as follows in descending order, omitting minor variations.

1. Black slate with interbedded sheets of eruptive materials which are widespread and non-amygdaloidal.

2. Gabbro out-break. Titanic ore horizon. The line of this outbreak is found not to follow the present northern strike of the hematite ore horizon, but to encroach upon it, giving hard ores in the eastern end of the range, while toward the west its line of outbreak turns more southerly, passing the head of lake Superior at Duluth, but apparently forming a bed of conglomerate and breccia along the ore belt, noted at various places between Gunflint lake and Pokegama falls.

3. A peculiar siliceous rock, partly jasperoidal, partly of hard hematite, or hard limonite, sometimes conglomeritic and brecciated, cherty, flinty, usually gray, sometimes partly black or purple, and, toward the west, kaolinic, toward the east hold-

ing some magnetite. Altogether this is a non-descript rock, which sometimes is fifty feet in thickness, but so far as developed near the mines is less than twenty. It is a pretty constant rock and when the ore is absent it lies on or varies to the Pewabic quartzyte. This is the horizon of the hard hematite, hard limonite and of some of the non-titanic magnetite. In some way not yet fully determined it is associated with the next. It is not yet certain that all the soft ore is derived from a change of this rock to ore, but it is very certain that in some cases this rock is converted to ore. It overlies, apparently, the chief ore body of the range, or its lower portion is changed to ore.

4. The chief horizon of soft hematite. The greatest thickness this bed has yet been found to exhibit is 105 feet. In the midst of this ore are found sometimes irregular masses of rock like No. 3, as if remnants of that stratum not yet converted to ore, while some strata of soft ore are found also in the midst of No. 3. Not enough working has been done yet to reveal all the relations of the ore to No. 3.

5. Pewabic quartzyte. In the near vicinity of the gabbro foci this is remarkably modified. Originally probably a chemical oceanic precipitate in its upper portion it is consolidated to a vitreous quartzyte, but at more distant points it is composed of distinct rounded grains. The upper portion is in the form of chalcedonic silica(so-called), a phase which extends westward with modifications, so far as observed, at least to town 60-13. On the other hand this quartzyte becomes less siliceous, having a feldspathic element, and even an olivinitic constituent, and sometimes large hornblende crystals embrace the quartz grains in a common matrix. When olivinitic it is also magnetitic and constitutes an important iron ore. In some places farther west, near the Mississippi river, is a quartzyte which is evidently the same, regularly interbedded with magnetite in thin alternations.

6. Conglomerate. This is simply the base of the quartzyte, and takes on the character of the older underlying rock. When it lies on the greenstones its cementing matrix is green, when on the granite it is more siliceous and lighter.

Northward from the strike of these strata extends the Archæan complex, embracing the rocks and ores of the Vermilion range and the foregoing beds lie unconformably on the upturned edges of the older rocks where the two formations come into contact. But, wherever the highland spurs of the older rocks extend further southward, the primordial strata sweep about their bases, dipping in opposite directions on opposite sides of the spurs. They occupy no constant level, which might be considered an oceanic shore line, but they seem to exist where erosive agents have not been able to remove them. Hence they may have extended formerly much further north. It happens, however, that a range of granitic hills, the Giant's range, occurs but a short distance to the north, and sometimes the strike of the Taconic is coincident for some miles with the southern base of this range. In other places a belt of "greenstone," which, however, is itself rather rough and rises nearly as high as the granite hills, intervenes between the Taconic and the granite.

It is evident that the present surface contour is but a poor guide to the stratigraphist in attempting to determine the relative ages of these terranes, for the surface must have suffered a profound degradation. The gabbro rock, which is by all conceded to be an irruptive rock, shows no sign of ever having outflowed at the surface of the earth. It is not bedded by amygdaloidal partings, nor has it, so far as known, any variable texture due to contacting with other older rocks. Yet it comes into contact with various older terranes, having crowded backward upon them while yet confined within the crust of the earth, without reaching the surface. It has been seen overlying the Pewabic quartzyte, the Keewatin greenstone and the granitic rocks of the Giant's range, but maintaining everywhere a coarse and crystalline texture. It seems as if the irruptive movement must have been very slow, and that it progressed not forcibly, but as rapidly as the heating of the adjacent rocks rendered them more flexible. Subsequent to the molten invasion the surface degradation took place revealing the deep-seated contacts which we see. It has been the writer's opinion that this event of the eruption of the gabbro took place immediately after the deposition of the Pewabic quartzyte, based on the interbedding of that quartzyte with a rock resembling the gabbro, and on the observed immediate overlie of the gabbro on an extensive area of the quartzyte. This observed overlie, however, loses its importance when it is learned that the gabbro also overlies the Keewatin and the crystalline granite of the Giant's range, and the date of the disturbance will have to remain, as heretofore, not definitely established.

In further considering, however, the Mesabi iron ore, certain problematic difficulties appear in the way of accepting any of the proposed theories for the origin of the ore. These may be enumerated:

1. There is no limestone known in the region which could be considered the parent rock giving rise to this ore by a process of substitution, nor has there been any struck by any of the diamond drills that have recently been driven through the ore horizon.

2. There is no known horizon of spathic iron which can be considered to have been converted to oxide.

3. There is no dissemination of carbonate of lime in the form of calcite, such as to indicate that the ore may have resulted from a substitution of iron for lime. The sparse mingling of minute fragments of calcite crystals, in microscopic sizes, with the silica of the chert, in some of the less ferruginous parts of the formation, is hardly sufficient to account for such a vast deposit of iron ore. It seems like trifling with the problem to appeal to such a cause for the ore.

4. As to concentration by decay of ferruginous schists —the process seems to have been the reverse, viz., from the ore has been diffused iron oxide through non-ferruginous schists, so that for several feet from the ore the surrounding rock is stained a vermilion or brownish red. This has not only affected some of the green schists, but also some of the underlying quartzyte. And again, on the theory of ferruginous concentration from schists, or from any rock, it is necessary to explain the singular fact—singular under that hypothesis—of the occurrence of the ore always at the same stratigraphic horizon in the same formation. Why should not this ore accumulate, at least sporadically, at some lower or slightly higher stratigraphic horizon? Here we find it, for 150 miles, maintaining its position in the series as constantly as any of the beds that are associated with it.

5. The absence of dykes of irruptive rock. These have been supposed to have played an important role in the concentration of the hematites of the Penokee range, on the south side of lake Superior. Yet, on the north side but one such dyke has been discovered, and that is in the eastern extension of the iron range where, notwithstanding a year's costly exploration in the vicinity, no hematite has yet been found in commercial quantities. At the western end of the range, where the recent discoveries have been made, not a single dyke has been discovered. Further, the strata that enclose the ore are not impervious, and could not form troughs

by any combination of dyke and dip, but the underlying rock is a loose white sandstone. It has sometimes become deeply stained by the downward percolation of surface waters carrying the ore mechanically amongst its rounded grains.

6. There is an apparent extensive change in the rock of the country. The details of this change cannot be given here. As one stands at the brink of one of the excavations and sees distinctly a sweep of plainly originally sedimentary layers, across the face of the cut, manifesting all the usual characters of sedimentation, and reflects that the strata which he now beholds consist of bessemer hematite, slightly brecciated, soft, easily mashed, he is driven to one of two conclusions—either, first, that the ore was deposited as a constituent part of a sedimentary series, or second, that it is the result of some grand substitution process by which hematite has been made to take the place of the original sediments. There are besides numerous minor evidences of some transition in the rock from its original composition to hematite, viz.:

(a) Sometimes a gradual encroachment of a hematite coloration from the outer portions of a block, or layer, upon a gray or blue central area.

(b) Sudden cessation of a band of hematitic coloration at a fissure which evidently the waters producing the coloration could not pass, and the passage of the same waters, as shown by the narrow streak of hematite in the fissure, down the fissure away from the band before affected, leaving that portion on the other side of the fissure unstained—while at the same time the sedimentary banding of the whole rock sweeps unimpaired across the whole face, from one side of the fissure to the other.

(c) There are larger areas where, as revealed by some of the shallow shafts on the western end of the Mesabi range, there is an abrupt change, horizontally, from rock to ore, the separating line being distinct for a perpendicular distance of at least two feet. In other places in the same shaft the ore and rock encroach irregularly upon each other. In these cases the ore is soft red hematite. If the process of substitution were now going on it would be reasonable to expect the oxide would be hydrated, especially as such transition is within a few feet of the surface and easily accessible by atmospheric waters.

(d) Not only is the rock changed *in situ*, but as breccias and gravels large deposits are found in which the pebbles, rounded as in a river current, or on an ocean beach, are converted to hematite. Such pebbles were rounded, while still rock, and were subsequently converted to hematite. This is evinced by the varying texture, and concentric structure which change somewhat regularly from the surface to the center, the outer crust being dense and the central portions being vesicular. Whether such pebbles appertain to the rocky strata, or are of the age of the drift, has not as yet been determined.

Some necessary postulates.

Notwithstanding it seems inadmissible to adopt any theory proposed hitherto for the origin of this ore, and that we are not qualified to propose a new one, there are some important facts which must be taken into account when the true explanation is discovered. These facts, which are based on observations made partly during the present season, may be set down severally as postulates on which some satisfactory theory may possibly be, in part, built at some future time.

1. The ore has a definite position in the stratification.

2. It is underlain by a porous quartzyte.

3. It is overlain by, or results from a change in a peculiar rock to which we have given the name taconyte. [To be described fully at a later date.]

4. The whole ore bed is sometimes a breccia of some sedimentary rock, lying loose, and sometimes compact brecciated or even conglomeritic phases are common. Rarely a pebbly ore is found.

5. It is associated with much kaolinic, but water-stratified rock, and often the white kaolin, though embraced in the ore, is unstained by it.

6. It occurs at the same horizon the whole length of the Mesabi range.

7. When the gabbro of the Mesabi range is adjacent this ore is found to be hard—either hematite or magnetite, but it is never affected by titanic acid—though it is by sulphur under such circumstances.

8. Apparently it runs southward with the dip of the formation, and by boring it is found under a large thickness of black slate about a mile south of the line of strike.

9. The horizon of the ore is the same that has been assigned by the writer to the date of the disturbance of the gabbro flood. But as that assignment is not sufficiently established it cannot be said that the ore has any relation of cause and effect to the gabbro.

Conclusion.

There are but two items in the conclusion to which we are driven:

First. The Mesabi ore is not satisfactorily explained by any theory that has yet been proposed for it, or for its equivalent (Gogebic) ore on the south side of the great lake. There are some facts that favor all of the theories that have been proposed, but they meet with opposing facts of greater import.

Second. There is but one known cause acting with sufficient force and on a geographic area sufficiently wide, to which we can appeal for the geographic and stratigraphic distribution of this ore—and that is *oceanic sedimentation.* That there has been a profound change in the sediments since their origination is quite evident; but whether this change took place, in whole or in part, prior to consolidation or after it, is as yet unknown; and if after consolidation it is equally unknown whether it was accomplished in Taconic or in Recent time. There seems to have been something peculiar either in the nature of the sediments of this horizon or in the influences to which they have been subjected, and this peculiarity is expressed on both sides of the Lake Superior basin.

(Other field notes made in the season of 1892, pertaining to the region of Snowbank lake and thence northeastward to Knife lake, will be reserved for the final report, likewise those of a re-examination of points on Gabimichigama, Flying Cloud and Kekequabic lakes, and of a visit to the Twin peaks.)

REMARKS ON THE SO-CALLED MUSCOVADYTE OR MUSCOVADO ROCK.

In several of the annual reports of the Survey an undefined term has been used to designate a rock of certain macroscopic characters that prevails along the northern limit of the gabbro. The term has been used because of its convenience in the field and because of its expressing at the same time the general outward character of the rocks to which it was applied. There is no doubt, however, that in many cases these rocks have been collected without receiving this designation. It is thought best to make some examination of some of these rocks to determine their petrographic characters and, if possible, their structural relations. In all cases the field relations have to take precedence in discussing their origin and systematic relations. By means of microscopic and chemical examination, however, some intimate mineral associations are determined, which throw light upon their probable origin. Several of these that have been designated muscovado have been sliced and mounted by Mr. Ogaard and examined microscopically by Dr. Grant, and some chemical analyses have been made by Mr. Meeds.

The term muscovado seems to have been used first in the fifteenth annual report, page 351, and applied to rocks collected in secs. 15 and 16, 63-9W., on the northeastern waters of the Kawishiwi. It is here part of a biotitic, more or less gneissic rock with more or less quartz, which by later study has been separated from the gabbro, although at the time the rocks were collected they were supposed to be a phase of the gabbro.

Dr. Grant has made the following microscopical notes on No. 983.

Description of No. 983. Kawishiwi River.

Macroscopical:—A grayish rock of rather fine grain. The hand specimen is homogeneous throughout and shows no gneissic or other parallel structures. It is compact and not crumbling. Numerous glistening scales of biotite are easily seen, and under the lens the rock appears granular, but the constituent minerals cannot be made out, although one would judge that quartz formed a large part of the rock. Rock appears fresh. Does not effervesce with cold hydrochloric acid.

Microscopical:—The section shows a closely compact, fine grained, granular mixture of quartz, feldspar, biotite, iron ore, and a mineral referred to pyroxene. The grain is so fine that under crossed nicols the different grains are not all distinctly separated, nor do some of them extinguish completely; this, however, is due to the overlapping of the grains; there is no "amorphous" or "chalcedonic" silica present (compare section of jaspilyte in Bul. 6, pl. 8, fig. 1). The rock is thus completely crystalline, and is quite fresh.

The *biotite* is the most noticeable mineral; it occurs in large flakes which often hold many pieces of quartz, some magnetite, and occasionally pyroxene.

The *pyroxene* is in small rounded grains and elongated ones which, however, never show any crystal faces. It has quite a high index of refraction. It contains enclosures of magnetite and numerous transparent areas which seem to be liquid cavaties. A slight cleavage is often developed parallel to the long axes of the grains. The extinction is almost always parallel to this cleavage and the mineral often is slightly pleochroic; from these two facts it is referred to the group of orthorhombic pyroxenes—probably it is enstatite or bronzite. On account of the smallness of the grain and the difficulty of obtaining a good interference figure with the instrument in use, the optical properties were not further studied. This mineral is greenish in color. In the pleochroic individuals the ray vibrating parallel to the cleavage is colorless or greenish and the other of a very light pinkish or reddish shade. This corresponds to the pleochroism of orthorhombic pyroxenes. The *iron ore* is undoubtedly magnetite; it is in small grains with more or less distinct faces, but with the angles rounded.

The pyroxene and iron ore are probably older than the mass of the rock which is composed of quartz and feldspar, and the biotite encloses all.

The *feldspar* is abundant; it frequently shows polysynthetic twinning, and is thus plagioclase; but the kind of plagioclase is uncertain. There is also considerable feldspar which is not twinned and which may be orthoclase, or untwinned plagioclase.

The *quartz* is in fine grains, even finer than most of the feldspar. There are many grains, which show no cleavage, or twinning, whose nature it is not easy to determine. Many of such grains, supposed to be quartz, give a biaxial interference figure; and others give no distinct figure. I examined about 20 sections which I thought might be basal sections of quartz; only one out of these 20 gave a distinct uniaxial interference figure; this was tested and found to be +. Four or five gave biaxial figures; and the others gave no definite figures. The feldspar is unaltered, and so is hard to distinguish from quartz, when twinning, cleavage or interference figures are not to be seen. It is my opinion that there is much less quartz in the rock than I had supposed. Thus, so far, I am sure of but one grain; there are, however, undoubtedly more, but I should guess that quartz makes up less than 1-10 of the rock, and I feel certain that it does not make up 1·5 of the rock.

The magnetite of Nos. 982 and 983 was tested for titanium, but none was found.

The rock now shows nothing that can be taken as proof of an original clastic nature. It is lithologically a fine grained quartz biotite noryte. It may be a recrystallized sediment or an original eruptive.

These rocks have been identified under this name at several places, viz., on Disappointment lake by H. V. Winchell*, who considered this muscovado to be a changed mica schist, and his general description makes it evident that at that place the muscovado has no connection with the gabbro. It was also observed on Illusion lake by A. Winchell† and by N. H. Winchell‡.

No. 1039. Island in Illusion lake.

A light gray rock of fine grain holding numerous and distinct flakes of biotite. The section is made of fine grained granular quartz with some orthoclase. In this are scattered numerous biotite scales.

At this place the rock was likewise considered to be a part of the gabbro, but it is evident that it is a part of the older (Archean) rocks that have been affected by the gabbro contact, at least the rocks of the islands of the lake; the south shore may contain a true gabbro or eruptive muscovado. It is again known on the river flowing northward into Kekequabic lake, S.W.¼ N.E.¼ sec. 11, 64-7 W., where it is reported to contain grains of reddish feldspar and some quartz, and is probably a part of the older rocks. It is reported abundant about the eastern and northeastern shores of Gabimichigama lake. Dr. A. Winchell described and illustrated an observation on an island in this lake, where he found coarse crystalline gabbro lying upon and embracing angular fragments of muscovado, the interstices being filled with gabbro. His figure (56) is here reproduced. Further examination of

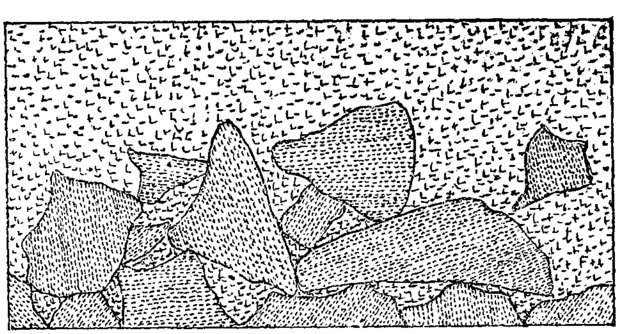


Fig. 56. Gabbro on "muscovado" fragments, Hall 841., Gabimichigama Lake.

*17th Ann. Rept., pp. 116, 117, 130 and 131.
†15th Ann. Rept., p. 183.
‡Ibid., p. 359.

this lake has revealed the fact that the rock here called muscovado is a part of the Archean affected by contact with the gabbro. Numerous specimens have been collected at points further northeast, where this underlying rock is exposed in many islands and low shores, and where its fragmental and stratified characters are more evident. Rock 1088 was collected on the little island at the entrance to the bay which forms the northeasterly end of Gabimichigama lake. It is found in other islands farther north and along the shores. On the east side of the bay it was found to be overlain by characteristic coarse gabbro. Of this rock Dr. Grant has made an examination as follows:

Description of No. 1088 (15th Ann. Rept., p. 379).

Macroscopical:—This rock apparemtly would be included under "muscovado." It is a fine grained, seemingly granular, rock of a grayish or brownish-gray color. It contains a few small white spots which look like feldspar; shows no parallel structures in hand specimen. Appears pretty fresh. Does not effervesce in cold HCl. It is too fine grained for study with the lens.

Microscopical:—A fine grained aggregate of quartz and biotite. The latter seems to make up about ⅓ of the rock; biotite is in small scales arranged in no order. The quartz is in small sub-angular, angular and irregularly outlined grains imbedded in a very fine grained matrix which is also apparently quartz. I recognized no other minerals. The rock is undoubtedly part of the clastics of the region.

Description of No. 1089 (15th Ann. Rept., p. 379).

Said to be "the same as No. 1088, but shows an intenser action of the gabbro;" from the north side of Muscovado point.

Macroscopical:—A fine grained gray rock, much like No. 1088 but not showing the brownish color.

Microscopical:—Rocks composed of biotite, quartz and amphibole(?). Quartz and biotite about as in No. 1088; some of the biotite has faded and become almost colorless. A few small grains of magnetite are present. All through the rock is an indistinct light greenish to light yellowish mineral, sometimes massed together in aggregates of fine grains and fibers and sometimes in minute particles all through the rock. In a few veins are also accumulations of this mineral. While not very clearly defined, still this mineral seems to be an amphibole, perhaps actinolite.

This rock also is undoubtedly part of the clastics.

Rocks from the south side of Muscovado point were also examined, viz., 1090, 1091 and 1092, and 1350 from the north side.

Nos. 1090 and 1091 (15th Ann. Rept., pp. 379-380).

1091 and one slide of 1090 are essentially similar to No. 1088, with only slight differences.

Another slide of 1090 is somewhat coarser grained and has a confused altered appearance. It is composed of feldspar, both polysynthetically twinned and not, quartz, biotite, magnetite, hornblende and what I take to be an almost colorless pyroxene. The last appears in places to be altering to hornblende. Some of the feldspar has become cloudy. No evidence of a clastic structure remains in the rock.

No. 1092 (15th Ann. Rept., p. 380).

This is essentially the same as the last described slide of No. 1090, except that considerably more hornblende is present and the pyroxene is in larger and better defined pieces.

No. 1350 (16th Ann. Rept., p. 89).

Is finer grained than the last, but is very similar to it in composition.

These muscovado samples about Gabimichigama lake are from the general formation, which can be traced continuously in one direction into the great Ogishke conglomerate, *i. e.*, toward the northwest, and eastwardly into the so-called greenstone at Flying Cloud lake and Akeley lake, and therefore have no connection with the gabbro proper.

On an excursion, which was made from Gabimichigama lake eastward to Flying Cloud lake, this relationship to the greenstone was plainly brought out. Samples also were collected, viz., 1780 and 1781, the former from the N.E. ¼ N.E. ¼ sec. 34, 65-5 W., and the latter from a point a little farther east, both on the north side of the creek, which here, for some distance, marks the boundary line between the greenstone and the Pewabic quartzyte. The quartzyte is seen to dip, at an angle of about 45°, southwardly, rising in a continuous strike about 40 or 50 feet above the creek on its south side; while on the north side the greenstone occurs in scattered low knobs, but rising within a short distance to a hight of perhaps 200 feet above the creek, having its characteristic topography. These features extend eastward to Chub (Akeley) lake and further, where they have been also described.*

No. 1780. This is a part of the underlying greenstone form ation.

The section shows a confused, more or less granular aggregate of plagioclase, hornblende, biotite, pyroxene (diallage?) and magnetite. The pyroxene seems to be altering to hornblende, in fact all of the hornblende, which is in large amount, may perhaps come from this source.

No. 1781. Along stream east of last; also underlving the quartzyte, in fact immediately below the quartzyte. The section shows a rock quite similar to No. 1780, but containing more biotite and some hornblende which is probably secondary. A granulitic gabbro lithologically.

It will be noticed that the characters of the rocks 1780 and 1781 show a much more basic nature (also indicated in the field) than those that are above described from Gabimichigama lake It will also be noticed that the strike of this older formation at Gabimichigama lake, as well as at Illusion lake and on the northeastern waters of the Kawishiwi, is about north and south; this being an irregularity in the usual northeastward trend of the Archean in northeastern Minnesota. Thus it appears that, in passing eastward from Gabimichigama lake, we first pass across the strike and soon enter upon a greenstone which resembles that of the Twin peaks. It is not necessary at this place to consider the question whether this greenstone and the so-called diabasic and gneissic rock, seen below the gabbro, are of the same formation; it is sufficient to say that all the evidence that the Survey has at hand tends toward that conclusion.

All of the foregoing examples of so called muscovado are from the underlying Archean rocks, and, therefore, do not illustrate the original idea of muscovado, that it was a form of the gabbro; while at the same time when the specimens were collected, they were supposed in some cases to be from the gabbro itself modified by contact with the sedimentaries. We have now to mention other forms of so-called muscovado, which lie in a belt of country further south, even south of large areas of characteristic coarse gabbro.

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*16th Ann. Rept., pp. 82-86.

There is a lake in sec. 36, 65-5 W., named Muscovado lake from the prevalence of this rock, and about its western shores and extending southwestwardly into sec. 3, 64-5 W. is an extensive hill range composed of muscovado rock. This hill range lies to the south of an area of fresh crystalline gabbro, which again also lies to the south of the strike of the Pewabic quartzyte, above mentioned. The quartzyte and gabbro distinctly dip to the south, and, if there be no fault in the region, this muscovado must lie above a large amount of gabbro. It has been sampled and sliced, and the following examination was made by Dr. Grant:

No. 1784. Muscovado, north end of Muscovado lake.

A fine grained *noryte.* This specimen (macroscopically) appears to me to be "*typical muscovado.*"

The section is especially beautiful. A granular aggregate of plagioclase, hypersthene, which is beautifully pleochroic, and titanic magnetite. This rock, except in the large amount of hypersthene, is the same as those from Bashitanaqueb lake, which see.

Mr. Meeds "found a very strong test for titanium" in this. He powdered the rock and by the magnet got considerable of the magnetite, which he tested with the above result.

Other samples have been collected from the shores of Bashitanaqueb lake, the north side of which lies largely in this rock. These have also been examined and found to have the following microscopic characters:

Specimens from Bashitanaqueb lake.

On the north shore of this lake are fine exposures of this rock. A number of specimens have been collected here. Here are probably the best exposures of this rock south of the north limit of the gabbro.

The specimens taken here and sectioned are 1785, 857G, 857 AG and 857BG.

These rocks are rather fine grained granular aggregates of plagioclase, pyroxene (mostly diallage), magnetite, and sometimes a little olivine and biotite. They are *gabbros* petrographically. Some pleochroic pyroxene (hypersthene) is sometimes present, and pinkish diallage is frequent.

No quartz was detected. Secondary hornblende is sometimes seen.

Analysis of No. 857G. Mr. Meeds reported the following chemical composition of one of the above samples, 857G.

$Si O_2$	49.07
Al_2O_3	17.21
Fe_2O_3	.46
$Fe O$	12.18
$Ca O$	9.66
$Mg O$	3.60
H_2O	1.55
Na_2O	2.96
K_2O	trace
CO_2	2.70
$Mn O$	trace
Total	99.89

The CO_2 above is probably due to decomposition products, as the rock is not entirely fresh.

In addition to the differences here indicated by chemcial analysis and by the microscope between this southern muscovado and that before described, belonging to the Archean, there are also structural differences which are very noticeable in the field, viz.; this southern muscovado never shows the knotted and seamed condition and the quartzose veinings and the gneissic structure and vertical attitudes seen in the northern muscovado. Taken altogether it is a much more homogeneous and massive rock, its only variation consisting in a bedding or sheeted lamination, dipping toward the south, conformable with the general gabbro structure, such sheets sometimes being not more than an inch thick. The most remarkable exhibition of this sheeting, which has been seen, is at the east end of Muscovado lake on the north shore.

Similar muscovado has been collected by Mr. H. V. Winchell near the west quarter post of sec. 14, 63-9 W.;* and of this rock Dr. Grant has given the following microscopical description.

No. 505H. *Macroscopical:*—A rather fine grained rock of a gray to brownish gray color. Not gneissic. Composed of grains of a glassy mineral and smaller ones which are yellowish to black in color.

Microscopical:—A granular aggregate of feldspar, pyroxene, olivine, magnetite and a little biotite. The feldspar is largely, perhaps entirely, plagioclase. Some grains do not show twinning striæ, and in some the cleavage is not well marked. Such grains might be quartz; however, a dozen such grains which, if quartz, would be approximately basal sections, were examined for interference figures and every one showed a distinct biaxial

*17th Ann. Rept., p. 120.

figure. I think there is no quartz in the section. The pyroxene is distinctly pleochroic, and is probably hypersthene. The minerals of this rock, except the olivine, are unaltered and fresh.

The rock is lithologically an *olivine noryte* of rather fine grain. There seems no reason for considering this rock a metamorphosed sediment; it shows all the characters of an eruptive of the gabbro family.

The south east shore of Illusion lake also contains this form of muscovadyte, shown by

No. 1037. Illusion lake.

This is a fine grained brownish gray rock. In section it is seen to be composed of a fine granular aggregate of feldspar (largely, if not entirely, plagioclase), pyroxene and magnetite. The pyroxene is in large amount and is both diallage and hypersthene. This rock seems to belong to the gabbro phase of the muscovado.

Conclusion.

It would appear from the foregoing that the term muscovado rock (or muscovadyte) has been applied in the field to rocks of different stratigraphic position and origin. This has already been asserted by Mr. H. V. Winchell in the seventeenth annual report, pages 130-131. It is also apparent that one of these is produced by the action of the gabbro upon the sedimentaries. It appears also probable that the southern belt of muscovado is a phase of the gabbro proper and that, if to either the name should be continued, it should be applied to this southern belt.

There remains, however, this possibility, if not probability, that this southern muscovado represents the profound action of the true gabbro upon a basic Archean greenstone, which has been brought to the surface in the midst of the gabbro area by a later fault. We have learned from numerous observations that all the rocks in this region have in some places been extensively faulted. It will be well, therefore, still, before adopting this duplicate theory of the origin of the so-called muscovado, to examine further critical specimens collected at points where it can be shown that the true gabbro was superposed upon a basic greenstone of Archean age.

VI.

ADDITIONAL ROCK SAMPLES COLLECTED IN 1892.

TO ILLUSTRATE THE REPORT OF N. H. WINCHELL.

1627. Hard hematite, the ore of the Mesabi Iron Co.'s land, sec. 27, T. 60-13, one mile south of the granite.

1628. No. 2 of the drill at Wicks', black and gray fine banded rock, with magnetite.

1629. No. 3 of the drill at Wicks', "black slates."

1630. No. 4 of the drill at Wicks', gray quartzyte, sometimes porous, also sometimes non-homogeneous with angular and rounded masses.

1630 A. Siliceous balls or concretions from 1630.

1631. No. 5 of the drill, ore.

1632. No. 6 of the drill, fine-grained pinkish quartzyte.

1633. No. 7 of the drill, crystalline quartzyte; it contains fragmental quartz cemented in a matrix of quartz.

1634. No. 8 of the drill, "greenstone" materials embracing many pebbles and grains of quartz.

1635. The lower portion of the last.

1636. No. 10 of the drill, granite.

1637. Sample of rock like 1634, but taken from the NE. ¼ SW. ¼ sec. 22, T. 60-13; mainly fragmental material in which are conspicuous fragments of lavender quartz, supposed to be from the granite.

1638. An extreme phase of 1637, mostly quartz; SE. ¼ NW. ¼ sec. 28, T. 60-13.

1639. Greenish rock, supposed to be the fragmental substance more scantily disseminated through 1638. Same locality as 1638.

1640. Pinkish fine quartzyte. NW. ¼ NE. ¼ sec. 32, T. 60-13.

1641. Magnetite from NW. ¼ NE. ¼ sec. 32, T. 60-13; natural loadstone, only found in small quantity; blends off into the rock of the iron belt (1631 of the drill record).

1642. Represents the average characters of the rock at the silver pit opened by Chester; it is Keewatin but quite (finely) siliceous; quartz veins are numerous; compare 442, also Bulletin No. 6, page 203 and footnote.

1643 Republic Mountain, Mich. Quartzyte or greissen, supposed by Wadsworth to be of eruptive origin.

1644. Greenstone from the north side of the Republic hill, approaching hornblende schist.

1645. Hematite from the non-conformable conglomerate or upper iron horizon at the Goodrich mine, Mich.

1646. Potsdam quartzyte, Clarkson's quarry, Potsdam, N. Y.

1647. Light pink gneiss from the dam in the Racket river at Potsdam.

1648. Darker gneiss from the same place.

1649. Still darker gneiss, same place. These have the appearance of possible derivation from the Potsdam quartzyte.

1650. White marble, Crary's mill, 7 miles westward from Potsdam.

1651. Gray conglomerate marble, Crary's mill.

1652. Specular hematite from Capt. Wood's mine, 5 miles south from Crary's mill.

1653. Hematite ore from a shaft 4 miles E. S. E. of Potsdam.

1654. Conglomerate in which this ore occurs.

1655. Dark limestone samples, Norwood, N. Y.

1656. Sandstone from Paddock's quarry, 3½ miles east of Malone, N. Y.

1657. Gabbro from the Adirondacks, as worked for monuments at Keeseville, N. Y.; location unknown.

1658. Fine granular gabbro, same place.

1659. White quartzyte, Keeseville, N. Y.; near the water; dip 8° to 10° N. N. E.

1660. Emery, so-called; seen on the beaches of lake Champlain and at Keeseville on the shores of the Au Sable river; quite abundant. It is gathered and shipped in barrels as emery for emery paper.

1661. The hard quartzyte forming the platform, right bank of the river, Au Sable canyon, below the stairway.

1662. Marble, grayish to white, Gouverneur, N. Y.

1663. Banded quartz rock, near Richland, N. Y.

1664. Ferruginous sandstone, 3½ miles N. of Richland, N. Y.

1665. Yellow sandstone, same place.

1666. Marble, same place.

1667. Breccia, same place.

1667 A. Impure quartzyte, same place.

1668. Hematite, same place.

1669. Gneiss, DeKalb, N. Y.

1670. One of the smaller segregations of quartz dioryte from the slates at Little Falls, Morrison Co., Minn.

1671. Fragment of the hornblendic layer which encloses the segregation, showing a portion also of the fine softer interior; this interior portion weathers out entirely when they are broken.

1672. Another segregation, hard to the center; also showing garnets in the slate attached; Little Falls.

1673. Garnetiferous slate, Little Falls.

1674. Red, fine-grained granite, sec. 18, T. 41-30, Morrison Co.

1675. Darker, highly micaceous, from the same place.

1676. The same, showing contact with coarser granite.

1677. Keewatin greenstone, from Randall, Morrison Co.

1678. Dioryte, quarried at Little Falls on the west side of the river.

1679. The same, with coarser hornblende crystals.

1680. Still coarser, more gabbroloid in general appearance.

1681. Fine limestone, has a pinkish color, dense in grain; in outcrop on west bank of the Mississippi just below the mouth of Swan river.

1682. Massive mica schist, west side of the Mississippi river near the center of SE. ¼ NW. ¼, sec. 30, 128-29, Morrison Co.

1683. Hardened segregation from 1682, similar to those seen at Little Falls.

1684. Gabbro, Philbrook, near the mouth of the Fish Trap creek, northwestern corner of Morrison Co.

1685. A darker, more magnetited condition of 1684.

1685 A. Subsequently obtained at the same place and sent by Mr. Robert Brown.

1686. White forms of this gabbro (labradoritic?), somewhat quarried.

1687. A sheared schistose condition of this gabbro having a vertical structure; Philbrook.

1688. Three samples of taconyte showing various conditions of change toward hematite, Hale mine, near Merritt.

1689. Conglomerate from the Cincinnati property, but not showing any of the flint pebbles.

1690. Disintegrated quartzyte from the bottom of shaft No. 2 at the Cincinnati mine.

1691. Form showing the penetration of iron into this quartzyte, hardened and reddened, Cincinnati mine.

1692. Taconyte from a shaft on the Cincinnati mine.

1693. Ditto, from the Duluth Ore Co. (Berringer).

1694. Manganese from shaft 23, Biwabik mine, 94 feet down.

1695. Hard blue ore with some soft ore, shaft 25, Biwabik mine.

1696. Pinkish fine quartzyte from the pit in SE. ¼ NE ¼ sec. 4, 58-16, Chicago property; resembles the fine pinkish quartzyte from Wicks'.

1697. Black slates from the well sunk for water at the McKinley camp.

1698. A clayey ball changed to hematitic rock, from the southern pits at McKinley's; probably from the black slate horizon.

1699. Iron gravel, Lone Jack mine, near Virginia.

1700. Mixed kaolin and spongy ochre and hematite, Mesabi Mountain mine, near Virginia.

1701. Banded kaolin, same place.

1702. Flinty, fine grained rock associated with the kaolin, varying from white to pinkish; apparently a part of the kaolin stratum; same place.

1703. Lump of taconyte showing various changes of some of its ingredients to hematite and gœthite; Security mine, near Virginia.

1704. Kaolin, Mesabi Mountain.

1704 A. Silica balls from 1704.

1705. Hard, conglomeratic, jaspery ore, Virginia mine. Over this bed is a stratum, thickness unknown, which has received the local designation "stove-plate rock," because it is in thin, heavy, firm sheets, regular and sonorous, sometimes becoming a lean ore. This conglomerate and the "stove-plate rock" apparently belong below the main ore horizon.

1706. Hard hematite, with kaolin in specks disseminated throughout; also with other rounded pebbly parts.

1707. Crucial specimen from the crucial pit on the Virginia; taken from the point of transition between the rock and ore, one specimen showing both. See fig. 16.

1708. A dark, massive portion of the black slates, near the Partridge river, a little west of Allen Junction; very silicious, though not properly a quartzyte.

1709. Magnetite ore, non-titanic, and associated with vitreous quartz; SW. ¼ NW. ¼ sec. 4, T. 62-11. Probably from the Vermilion; same as that at the rapids at north end of White Iron lake.

1710. Rock associated with magnetic ore at Spellman's, north side of Birch lake, about 200 feet from the granite; sec. 23, T. 61-12.

1711. Magnetic ore taken from this pit.

1712. Hornblende rock from the same pit; thought to be the footwall.

1713. Sample of the hanging wall of the pit, granitic in aspect, though allied to the gabbro; siliceous; from Mr. Honnald, superintendent.

1714. So-called black slate, presented by Mr. Honnald; in his opinion this overlies all the ore and the rock concerned.

1715. Quartzose gneissic rock, or quartzyte. It is from the small island in the Kawishiwi river, NW. ¼ SE. ¼ sec. 19, T. 63 9. (See No. 981, 16th report.)

1716. Similar to 1715; from the island next south of the last island. This does not manifest any sedimentary characters but is variable in its fineness of grain as well as in its manner of decay. This island is within 60 feet of the south shore.

1717. Fine grained olivine gabbro, or coarse grained muscovadyte, from the south shore. These beds stand vertical in the same manner as on the islands.

1718. Red granite, near the center of sec. 2, T. 63-9, Snowbank lake.

1719. Darker granite at the point near the center of sec. 36, T. 64-9, Snowbank lake.

1720. Greenstone, sec. 34, T. 64 9, west shore of Snowbank lake.

1721. A little further west, and hence near the granite, the greenstone is granitic.

1722. Boot island; this island is composed essentially of red granite. This sample, however, represents the rock at our camp, and also shows a common coarse crystallization of orthoclase occurring in old joints or veins. The rock now disintegrates by opening first along these seams, leaving a layer of coarse orthoclase crystals on each part. This island is in the central part of Snowbank lake.

1723. The rock 1721 develops further east into bold exposures, forming hills 125 feet above the lake, becoming a characteristic coarse conglomerate, hard, semi-granitized, generally green, but weathering with a red tint. This No. (1723) is from a dyke of very siliceous rock, appearing very much like the mass of the formation, cutting over the hill in the NE. ¼ sec. 34, T. 63-9; it is not wholly crystalline, but has some needles, apparently of feldspar; it is 6 in. to 36 in. in width, and weathers light red; it contains no boulder forms, winds about like a dyke and is porphyritic with a feldspar.

1724. A gray, fine grained, crystalline rock; shore of Snowbank lake, NW. ¼ sec. 35, T. 64-9. It appears some like the Ogishke conglomerate, but will have to be classed with the granite. There are areas here that show really granitic structure with abundant orthoclase crystals.

1725. The country rock, SW. ¼ sec 26, T. 64-9, a short distance east of the last.

1726. Eruptive granite or syenite, in irregular patches, somewhat dyke-like, appearing in 1725, though these two rocks apparently grade into each other. Along this shore is one of the most striking instances of the conversion of a conglomerate into a crystalline rock.

1727. A granitic dyke cuts a micaceous condition of this conglomerate; contact runs about east and west; SW. ¼ sec. 26, T. 64-9.

1728. A micaeous condition of this conglomerate, same place as the last. The dip here appears distinct on the tops of the knobs; about 75°

E. SE., and the strike is 15° E. of N. The dip is such as to throw it under the granite.

1729. Porphyry, on the north side of the same point, in a narrow, westward running bay; this must underlie 1728. This bay is not shown on the township plat.

1730. Porphyry like the last, but irregularly associated with and blending into

1731. A part of the conglomerate. These are both intimately associated with characters pertaining to the Keewatin greenstone rock, of which they seem simply to be advanced conditions toward crystallization.

1732. Mica schist. The conglomerate graduates into this; it is cut by many dykes of red granite. SW. ¼ sec. 24, T. 64-9.

1733. Represents this conglomeratic mica schist in sec. 24, T. 64-9.

1734. Seems to be a portion of 1733, but is a dark gray, fine grained rock, sparingly interspersed with some crystalline red grains; secs. 29 and 30, T. 64-8.

1735. Dark syenitic rock, which takes the place of the granite in forming dykes in 1734; this continues further east, forming the coast.

1736. Dark greenstone, crystalline, SW. ¼ sec. 20, T. 64-8, cut by

1737. Red granite.

1738. Graywacke-greenstone, outlet to Snowbank lake.

1739. Coarse hornblende granite, east side of sec. 31, T. 64-8, Snowbank lake, presenting the so-called "bedded" structure of much of that about Bassimenan lake.

1740. Dike cutting granite in sec. 1, T. 63-9.

1741. Red granite, appearing suddenly in graywacke, on the west shore of Boot lake; NW. ¼ Sec. 21, T. 64-8. It is transitory; graywacke prevails all about.

At the great Knife Lake headland, near the portage to Doughnut lake, the following specimens were collected:

1742. Southwest corner of the headland at the water level.

1743. The same, having a flint film.

1744. The same, having different grain.

1745. A layer 1 foot thick running straight in the rock of the hill for at least 25 feet, when it becomes hidden under the water at one end, and under the soil at the other.

1746. A conglomeritic portion of the rock of the hill, with many pyrite cubes. The rounded boulder forms that are dislodged and roll out are from 3 to 8 inches in diameter, all charged with pyrite, same as the rock itself. The pyritiferous character gradually fades out upward and is entirely wanting at 45 feet above the lake. This is on the north side of the promontory.

The following specimens were collected in making a trip over the headland from north to south:

1747. Twenty-five feet above the lake.

1748. Fifty feet above the lake.

1749. From the northern crest of the hill.

1750. Top of the headland near the center.

1751. From the southern crest of the hill.

Anyone examining these would at once pronounce them all the same rock, excepting 1745 and 1746. They appear very much like gabbro, and the general physical aspect of the hill and the jointage of the rock increase the resemblances, but they are probably a condition of the Ogishke conglomerate. The headland may rise 250 feet above the lake.

1752. Sample of a dike cutting grit and argillaceous schist; SW. ¼ NE. ¼ sec. 32, T. 65-6. Dike runs approximately north and south.

1753. Grit, rings like cast iron, cut by the above dike; rather coarse, but some is coarser and some is finer. Pieces of slate are embraced in it.

1754. A fragmental, gritty rock, very hard and gray, outwardly resembling gabbro; the matrix is flinty, but not flint. From a little island in a lake in SW. ¼ sec. 33, T. 65-6. The sample is from a thin bed (6 inches) embraced in the rock of the island. This wedges out as if squeezed into a space of that shape while the whole was semi-plastic. Resembles the rock of the Knife Lake headland.

1755. On the same island the rock 1754 becomes finer, still gray, felsitic, with quartz grains disseminated, exactly like the rock of the pebbles of the Stuntz conglomerate. It is however a portion of the Ogishke conglomerate. Sample shows contact between two aspects.

In ascending the westerly of the Twin peaks with Messrs. Grant and Ogaard, the mountain was found to be made up almost entirely of the so-called ambiguous greenstone, nearly all the way showing conglomeritic structure, but in many cases becoming much like a true irruptive greenstone. That it is wholly fragmental, however, at least on its northern slopes, is the plainest of facts.

1756. On leaving the little lake in sec. 33, we first came upon a low ridge of fine grained greenstone, apparently of igneous origin.

1757. Going on we pass innumerable places where the rock contains boulders and fragments of all sizes and is quartziferous. This specimen shows a prevalent phase.

1758. Shows the coarseness and evident igneous characters.

1759. The same.

1760. Fine grained condition of the country rock on the top.

1761. Coarser grained condition of the country rock on the top. These both look much like true diabases, and no boulder forms appear in the rock.

A dike of diabase, 10 feet wide, runs distinctly through this peak, 45° W. of N., and has characteristic contacts on each side, the contact being fine grained and the center coarser.

1762. Central part of this dike.

1763. Near the edge.

1764. Showing contact with the country rock, the black is the diabase and appears like black slate.

1765. Is a piece of the finer hornblende porphyrel, north side of Kekequabic lake.

1766. SW. ¼ NW. ¼ sec. 31. T. 65-6; sample which seems to be a partial porphyry, partial conglomerate and partial granite. Grant's 787. In this conglomerate here are many pebbles, many of red jasper.

1767. Pebbles from a porphyry knob, SW. corner sec. 29, T. 65-6, on Kekequabic lake.

1768. From the same knob at the NE. extension, where the rock is not porphyritic; fine grained, almost felsitic, not evidently fragmental, graduates into the porphyritic portion.

1769. From the N. side of the narrows of Zeta lake; porphyritic conglomerate or porphyrel.

1770. From the south side of the narrows, near the point. Samples from this place suggested to Dr. A. Winchell the term *porphyrel* for this porphyritic conglomerate.

1771. SW. ¼ NE. ¼ sec. 36, T. 65-6, N. shore of Agamok lake. Hardened, semi-crystalline graywacke, from the summit of a hill about 250 ft. above the lake. The dip is NW. 40°.

1772. NW. ¼ SW. ¼ sec. 31, T. 65-5. Graywacke. This holds pebbles and one of what appears like jasper under water. No dip nor strike visible; doubtfully belonging to the graywacke series. There is a dim appearance of strike northeast.

1773. One hundred yards north of the last is another low sloping surface of similar rock, with still no certainty of dip nor age of the rock.

1774. At the extreme head of the bay; similar rock to the last, rising from the water and forming low ridges. On one of these ridges the dip is plain, varying foom vertical to 70° eastward; strike is north and south. While this rock bas some argillitic features, such as those of the black slates seen on Knife lake, yet in most cases it resembles a very fine grained muscovadyte.

1775. From the older formation near the gabbro, on the east side of the northeastward bay.

1776. NE. ¼ SE. ¼ sec. 30, T. 65-5; from hill rising about 150 feet; sample of this doubtful muscovadyte.

1777. Several samples collected from Muscovado point, Gabimichigama lake.

1778. Rather fine grained gabbro or muscovadyte, from the top of the cliff facing north at NE. ¼ NE. ¼, sec. 34, T. 65-5, near the junction of the two branches of the creek.

1779. Sample of the quartzyte from the same place, on the north slope of the hill; some of this appears micaceous.

1780. Just across the creek, north from the foregoing, is the extension of the muscovadyte range, seen yesterday on Gabimichigama lake, but here it has a greenish tinge, approaching the greenstone of Bingoshick lake, as well as that of Twin peaks.

1781. Muscovado greenstone, immediately below the quartzyte; NE. ¼ sec. 35, T. 65-5.

1782. Quartzyte from the top of the ridge, same place.

1782 A. Quartzyte near the contact with 1781. The bedding must amount to nearly 100 feet.

1783. Magnetite from the east end of Flying Cloud lake; from a large, nearly vertical cliff at the southeast corner of the lake.

1784. North side of Muscovado lake. This is a remarkable rock, as it resembles muscovado, which we suppose to be the result of a change in sedimentary rocks; it is a remarkable circumstance also that so far south, within the gabbro area, so much of this rock is found. It is heavily jointed, nearly horizontal and slides in sheets into the lake towards the southeast, the sheets being from ½ inch to 6 inches thick. Small nodules weather out on the surfaces and some larger, harder patches also appear, resembling some seen in the changed graywackes on Gabimichigama lake. This rock prevails about the shores of Muscovado lake, on the shores of the north half of Bashitanaqueb lake, and just north of the latter it forms some high hills.

1785. Muscovadyte from the north side of Bashitanaqueb lake. The south shore of this lake is made up of fresh, gray, coarse gabbro.

In October, 1892, some samples were collected at the original working at the Mountain Iron showing the forms of the quartz in this formation, designed for microscopic examination, viz.:

a. Taconyte, siliceous cement (chalcedonic?), embracing iron ore both massive and in rounded pellets. Magnetite?

b. Chalcedonic silica from the same place, showing inclusions of kaolinic (?) stuff, rounded.

c. Greenish, fine Pewabic quartzyte, clearly striped.

d. Same as c, but coarser.

e. "Quartzyte," a sandstone, apparently feldspathic, rusted in blotches.

VII.

Additions to the Library Since the Report for 1891.

The present list consists of the additions made from Dec. 1, 1892, to Dec. 1, 1893.

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ERRATUM.

Page 69, 12th line from bottom: For "Nelson's" read "Nelson Park."

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