THE GEOLOGICAL

AND

NATURAL HISTORY SURVEY

OF MINNESOTA.

The Twenty-second Annual Report, for the Year 1893.

N. H. WINCHELL,
State Geologist.

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ADDRESS.

MINNEAPOLIS, MINN., Aug. 1, 1894.

To the President of the Board of Regents:

DEAR SIR—I have the honor to offer herewith the twenty-second annual report of the Geological and Natural History Survey of Minnesota. It embraces preliminary field reports on a large amount of work, contributed by the various assistants who were engaged on the survey during the season of 1893. It also contains lists of additions to the library and to the museum.

Respectfully submitted,

N. H. WINCHELL,

State Geologist and Curator of the General Museum.

GEOLOGICAL CORPS.

N. H. WINCHELL..........................STATE GEOLOGIST
WARREN UPHAM.....................ASSISTANT GEOLOGIST
U. S. GRANT.........................ASSISTANT GEOLOGIST
L. A. OGAARD...............SURVEYOR AND DRAUGHTSMAN

SPECIAL ASSISTANTS IN 1893.

Paleontology.

E. O. ULRICH,
J. M. CLARKE,
W. H. SCOFIELD.

Field geology and topography, in charge of parties.

J. E. TODD,
J. E. SPURR,
A. D. MEEDS,
G. E. CULVER,
A. H. ELFTMAN,
H. B. AYRES,
C. P. BERKEY.

General assistants.

A. N. WINCHELL,
H. B. HOVLAND,
H. E. WHITE,
E. R. BARTON,
H. C. CAREL,
R. P. JOHNSON,
R. M. WHEELER.

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I.

SUMMARY STATEMENT.

An effort was made in 1893 to finish that amount of field-work necessary to warrant the preparation of the final report and maps of that portion of the state remaining unpublished. Although there are still many unknown elements in the geology of the northern part of the state, and some considerable tracts, remote from routes of travel, some of which have not been "subdivided" by the township survey of the United States government, which the parties of the geological survey have not been able to visit and map, yet it is thought best to close up the active work in the field and to enter upon the preparation of the last volume of the final report. It was with an earnest desire to round out the present survey with what might be called a final report, showing its completed results in systematic relations, within the reasonable term of a single administration, that the writer, four years ago, volunteered to pledge the completion of the field-work for the sum of twenty-five thousand dollars. This was stated to the appropriation committees of the Legislature of 1891. Fifteen thousand dollars were appropriated by that Legislature. The last Legislature (1893) appropriated ten thousand dollars under similar representations. Although the full sum of twenty-five thousand dollars has not yet been expended on the field-work, yet so much has been done that nearly all the remaining plates, which will represent the geology in the final report, can be drawn. There will be need yet of special examination in some difficult and some important areas, where the opportunities of the past have not been favorable to entirely and satisfactorily understand the geological structure. Practically, however, the campaign of 1893 may be said to have finished the field-work. The rest of the time to be devoted to this work by the writer will be given, as now contemplated, to the preparation of the last final volume, with the necessary accompanying maps.

During the last season parties were in the field under the following assistants:

Prof. J. E. Todd, in the northwestern portion of the state, north and east of Red lake.

Prof. G. E. Culver, in Itasca county.

Mr. Warren Upham, in Aitkin and Cass counties.

Mr. J. E. Spurr, on the Mesabi range and southward in St. Louis county.

Mr. A. D. Meeds, on the Mesabi range and southward in St. Louis county.

Mr. A. H. Elftman, on the Mesabi range and southward in Lake county.

Dr. U. S. Grant, on the Mesabi range and southward in Cook county.

Mr. C. P. Berkey, from Grand Marais northward, in Cook county, and in co-operation with Dr. Grant.

The writer also was in the field in different places, but chiefly in Cook county. Mr. H. B. Ayres began work in Carlton county, but was interrupted by sickness and afterward by other engagements, and accomplished but little. It is planned that he will finish his allotment of work in Carlton county the coming season.

In view of the proposed final mapping of the rest of the state it was deemed highly desirable to obtain such hypsometric data as would warrant the approximate drawing of contour lines in the manner shown on the final plates already published in volumes I and II. Each party was furnished with the necessary instructions and apparatus for platting these lines on the field maps which they carried, while at the same time a continuous hourly reading of a mercurial barometer was recorded at "Mesaba* station," by means of which the simultaneous aneroid readings of the different parties could be corrected and reduced to a uniform basis, and referred to the sea level. In this way a large mass of data was obtained which, when corrected and platted, will result in contour lines, 50 feet separate, over a large area in the northern part of the state. This will give an expression of a preliminary topographical reconnaissance, and will serve as an introduction to the topographical map which it is hoped may yet be constructed. At the same time it is an in-

* There having been great diversity in the spelling of this word, the matter was brought before the *United States Board of Geographical Names*, of which the Superintendent of the Coast and Geodetic Survey is president. On consideration of the various spellings, numbering about half a dozen, it was decided by the Board that the correct orthography is *Mesabi*.

dispensable aid in the understanding of the geological maps and descriptions. Simultaneously with this system of hypsometric readings, a line of levels was run by means of a surveyor's level by Mr. L. A. Ogaard, in company with Mr. Berkey, from Grand Marais across the country to the International boundary, designed to cross what was supposed to be some of the highest land in the state. Many hills, lakes and streams were thus accurately ascertained. This series of levels was widened out to the right or left whenever opportunity occurred so as to include important adjoining points. The highest point found was at the summit of the Misquah hills, 2,230 feet above tide, in the N. E. part of sec. 35, town. 64, range 2 W. The region about is made up of the well-known "red-rock." This range of hills, in its extension some miles further east and west, has nearly as great altitude. The examinations of the season have also demonstrated that the actual water-divide from this place southwestward to Duluth is essentially composed of the same rock, variously mingled with the gabbro of the Mesabi range. The general results of some of these examinations are given in the accompanying reports of the assistants mentioned. More of the details and the final conclusions will be set forth in the final report.

While the accompanying reports give, in the main, the general results of the various field parties, in the words of the assistants themselves, that of Mr. Spurr, who was occupied on the productive portion of the Mesabi range, in the vicinity of Biwabik, McKinley and Virginia, and who has supplemented his field-work by a careful investigation in the laboratory, reaching highly interesting and important results as to the origin of the ores of the range, has been published as a separate document (Bulletin X). The 21st report of the survey has also been issued and distributed. Volume III, of the final report, is still in press. Only a part of the paleontology of the Lower Silurian can be included in the volume. The gasteropods and cephalopods, which the volume had been intended to cover, and for which preliminary contracts had been executed, have to be omitted These chapters, however, will be published at some future date, as now planned, and probably as bulletins of the survey. Of the volume, however, the following chapters were issued since the last report:

Chapter VI. The Lower Silurian Lamellibranchiata of Minnesota. By *E. O. Ulrich*. Pp. 475-628, 8 plates. Published June 16, 1894.

Chapter VII. The Lower Silurian Ostracoda of Minnesota. By *E. O. Ulrich*. Pp. 629-693, 4 plates. Published July 24, 1894.

Other papers by members of the Minnesota geological corps have been published, as follows, elsewhere. These have a bearing on the geology of the state and of the Northwest.

Volcanic Rocks in the Keewatin of Minnesota. *U. S. Grant.* Science, vol. xxiii, p. 17, Jan. 12, 1894.

Note on the Keweenawan rocks of Grand Portage Island, north coast of Lake Superior. *U. S. Grant.* American Geologist, vol. xiii, pp. 437-439, June 1894.

Epeirogenic Movements associated with Glaciation. *Warren Upham.* American Journal of Science, III, vol. xlvi, pp. 114-121, Aug., 1893.

Altitude as the Cause of the Glacial Period. *Warren Upham.* Science, Aug. 11, 1893.

Beltrami Island of Lake Agassiz. *Warren Upham.* American Geologist, vol. xi, pp. 423-425, June, 1893.

Englacial Drift. *Warren Upham.* American Geologist, vol. xii, pp. 36-43, July, 1893.

Early Man in Minnesota. *Warren Upham.* Am. Geologist, vol. xiii, pp. 363, 364, May, 1894.

Causes and Conditions of Glaciation. *Warren Upham.* Am. Geologist, vol. xiv, pp. 12-20, July, 1894.

The Niagara Gorge as a Measure of the Postglacial period. *Warren Upham.* Am. Geologist, vol. xiv, pp. 62-65, July, 1894.

The Madison Type of Drumlins. *Warren Upham.* Am. Geologist, vol. xiv, pp. 69-83, with pl. iii, Aug., 1894.

Evidences of the Derivation of the Kames, Eskers, and Moraines of the North American Ice-sheet chiefly from its Englacial Drift. *Warren Upham.* Bulletin of the Geological Society of America, vol. v, pp. 71-86, Jan., 1894.

The Succession of Pleistocene Formations in the Mississippi and Nelson river basins. *Warren Upham.* Bulletin of the Geol. Soc. of America, vol. v, pp. 87-100, Jan., 1894.

How Old is the Earth? *Warren Upham.* Popular Science Monthly, vol. xliv, pp. 153-163, Dec., 1893.

Increase Allen Lapham. *N. H. Winchell.* American Geologist, vol. xiii, pp. 1-38, Jan., 1894.

Pebbles of Clay in Stratified Gravel and Sand. *N. H. Winchell.* Glacialists' Magazine, vol. i, pp. 171-174, March, 1894.

Note on Cretaceous in northern Minnesota. *H. V. Winchell.* American Geologist, vol. xii, pp. 220-223, Oct., 1893.

Additional Facts about Nicollet. *H. V. Winchell.* Am. Geologist, vol. xiii, pp. 126-128, Feb., 1894.

A Bit of Iron Range History. *H. V. Winchell.* Am. Geologist, vol. xiii, pp. 164-170, March, 1894.

The Discovery of Mineral Deposits in the Lake Superior region. *H. V. Winchell.* Proc. Lake Superior Mining Inst., vol. ii, 1894.

False Bedding in Stratified Drift Deposits. *J. E. Spurr.* Am. Geologist, vol. xiii, pp. 43-47, Jan., 1894.

Oscillation and Single Current Ripple-marks. *J. E. Spurr.* Am. Geologist, vol. xiii, pp. 201-206, March, 1894.

The Iron Ores of the Mesabi Range. *J. E. Spurr.* Am. Geoligist, vol. xiii, pp. 335-345, pl. viii, May, 1894.

The Stratigraphic Position of the Thomson Slates. *J. E. Spurr.* Amer. Jour. Sci., III, vol. xlviii, pp. 159-166, Aug., 1894.

II.

LIST OF ROCK SAMPLES COLLECTED TO ILLUSTRATE THE NOTES OF N. H. WINCHELL, 1893.

1786. Coarse diabase, from a branching conspicuous dike, or bleb, which crosses, in part at least, the town site of Ely. It is seen on the highest portion of the town, cutting the bouldery graywacke, near the Catholic church.

1787. Amygdules, or pipe-like tubes, in the boulders or bombs of the agglomerate at Ely, filled with silica which appears to be "chalcedonic" or minutely granular. This new feature is found sparsely in the rock toward the southwest from the cut at the railroad already described. (Specimen lost).

1788. The diabasic rock mentioned under 1786 appears southwestward from the railroad cut, toward the Lockhart property (at Ely), and where it abuts against a bouldery mass of the graywacke or agglomerate, its grain and substance seem to enter the bouldery mass, at the same time becoming finer, and to surround the bombs, forming the dark-green scale which envelops them. This number, 1788, is a sample of the massive rock which enters, apparently, the graywacke and surrounds the boulder-like masses.

1789. An irregular, irruptive, siliceous rock, a kind of quartz porphyry. appearing in the midst of the greenstone on a knob about three-fourths mile west of the depot at Ely.

1790. Finely porphyritic or amygdaloidal diabase, like 1788, the amygdules (?) filled with a dark green mineral (chlorite ?), north from the Chandler mine, at Ely.

1791. In the conglomeritic portions of this greenstone, particularly in the matrix surrounding the boulders, is coarse silica, with calcite crystals, mingled in which are also isolated pieces of some green shale or scale, seen north from the Chandler mine.

1792. In some places the foregoing minerals (silica and calcite) become abundant, though very fine-grained, forming lenticular masses of siliceous marble, which stand vertical. These are white, and from two to four inches thick and three or four feet long.

1793. Basal conglomerate, from the bottom of the supposed preglacial gorge, at Virginia. This is of ferruginous pebbles, mingled with dust and dirt of the iron bearing rocks. It may be of Cretaceous origin. It has a later infiltration of white silica which now forms its principal cementing bond.

1794. Forms of taconyte, showing transition from rock to ore, Moose mine near the line of separation from the Ohio, Virginia.

1795. Forms of the ore, Lone Jack mine, Virginia.

1796. Dark, diabasic rock which blends with the gabbro as if only a phase of the gabbro, at Duluth.

1797. Gabbro embracing small masses of augite-syenite, at Duluth, and containing as a result, numerous crystals of orthoclose as a constituent of itself.

1798. Siliceous pebbles or claystones from the Keewatin schists or slates about a mile and a half northeast of Otter Creek station, at the highway north of the St. Paul & Duluth railroad.

1799. Pebbles of disintegration from the gabbro at 1013 Michigan St., Duluth.

1800. Diabasic structure in the gabbro, thin plagioclase crystals lying parallel over large areas making a lath-shaped marking when weathered; same place as the last.

1801. Gneissic structure in the gabbro (rather a dioryte), taken at the point where the grand boulevard (running approximately on the upper beach) crosses a small creek back from Rice's point.

1802. Gabbro containing dark-green inclusions. These small dark-green masses are rather fine-grained and they seem to have affected the gabbro surrounding them by disseminating an element which, entering among the gabbro elements, has given rise to a red weathering feldspar and hornblende, along with some epidote. These dark-green spots, with the accompanying discoloration impart a noticeable spottedness to the gabbro mass wherever they occur.

1803. A fine-grained rock from the gabbro near the dam of the little creek where it is ponded above the grand boulevard, at Duluth.

1804. At a point midway between the dam and the elevated station of the elevated railroad, Duluth, is a large surface exposure of some old metamorphic rock, some of it being brownish-red, and some of it gray. It is below the crest of the gabbro range, and on the southern slope, but is embraced within the general gabbro area. The red areas somewhat embrace the gray or blue. This number represents the red rock.

1805. Is the fine-grained gray rock. This is sometimes apparently a conglomerate, holding boulders of quartz and of granite, but in general it is a uniform rock. In some cases the red rock shades into the blue, even on the surface.

1806. Both of the above sometimes are amygdaloidal—at least are flecked with rounded dark-green spots about which are reddened areas resembling the inclusions in the gabbro, (1802).

1807. Samples from the sedimentary patches embraced in the amygdaloidal parts at Cow Tongue point, north shore of lake Superior.

1808. Pebbles from the hard fine grained, gray sedimentaries, got on the beach one mile west of Brulé river. They vary from blue to reddish, and one is white.

1809. Red rock pebble, from the same beach. These are usually amygdaloidal, and sometimes also porphyritic.

1810. Green doleritic trap pebbles from the same beach. These are very rare, although the rock outcropping on the shore, at all the points, consists of such trap.

1811. From the vertical cliff forming the west shore of Sickle bay—a rather fine-grained gabbro.

1812. Showing contact of this gabbro with a very fine-grained black rock, from a pebble on the beach.

1813. Poikilitic gabbro, from the west side of Double bay, at the point. The pyroxene shows its own sheen in the sunlight over large crystal surfaces.

1814. Gabbro from the hill range at Double bay, at the west end of the near hills.

1814A. White-weathering lumps and patches in 1814.

1815. In descending the hill again we encountered a slightly different phase, being very coarse with dark crystals of pyroxene and light-weathering large crystals of same plagioclase.

1816. Coarsely rough gabbro, at one mile east of Cannon Ball bay.

1817. Coarse gabbro, with poikilitic crystals of pyroxene, at a point two miles west of the west side of Red Rock bay.

1818. From the southern (basaltic) dike of the two trap dikes cutting the "red rock" on the eastern side of Red Rock bay.

1819. From the northern (non-basaltic) of the two dikes cutting the "red rock," at the same place, two feet from the contact with the other.

1820. Of the northern dike at the contact with the southern. These dikes are nearly parallel (east and west), but interfere with each other, the northern dike being the later.

1821. From a branching dike of diabase, or "black trap," at the extremity of Red Rock point. It has a pitted surface, from the decay and removal of some soft mineral.

1822. Quartz porphyry, Red Rock point.

1823. Sample from low rocky knob rising but little above the water, near the shore, within the bay next east of Red Rock point, but near Red Rock point, apparently underlying all the quartz porphyry.

1824. A curious, shaly-looking rock within the bay next east from Red Rock point, cut by conspicuous dikes that appear to be of the same age as those that cut the quartz porphyry.

1825. The same, having a spotted appearance.

1826. Amygdaloidal phases of 1824.

1826A. Agates from 1826.

1827. A metamorphic quartzyte, evidently some of the Wauswaugoning quartzyte, from the southern face of Mt. Josephine, about 500 feet above the lake.

1828. Basic irruptive rock concerned in the metamorphism of 1827.

1829. Average rock of the top of Mt. Josephine.

1830. "Red rock," kind of quartz porphyry, from a hill northwestward from Mt. Josephine, where it forms an irregular patch elongated about east and west, visible on the southern slope of the gabbro range.

1831. Conglomerate, from the east side of Grand Portage island.

1832. Darker and finer-grained sandstone(?), same place.

1833. From the very top of 1832, where it is in contact with an overlying trap sill.

1834. A peculiar, nearly black, amygdaloidal rock found on the very top of the island and extending westward gradually descending to the water level.

1834A. A lot of balls from 1834.

1834B. Series of red pebbles, from the beach of Grand Portage island.

1834C. Fine red granite, porphyritic with quartz, from a hill rising about 600 feet above the lake, about a mile and a half from Grand Portage, on the west of the Grand Portage trail. It is on one of the highest cliffs on the southern side of the hill, but forms only a small part of the hill, which consists rather of the gabbro of the region, being a part of the great dike range of which Mt. Josephine is a spur.

1835. Same contorted slate, from the low hill of slate, cut by numerous dikes, which rises near the lake at Grand Portage.

1836. A possible organic impression, from the slates of 1835.

1837. Upper portion of the Wauswaugoning quartzyte. It is gray, somewhat colored like the slates, spotted with light red, pink, or even green; from the foot of Mt. Josephine at the head of Wauswaugoning bay.

1838. The same, sub-crystalline, fine-grained.

1839. The same, having the form of quartz porphyry, appearing in patches in 1838, and also largely.

1840. The same, spotted with red and green.

1841. Plumbaginous quartzyte, from the old graphite mine on Pigeon point.

1841A. Spotted gray quartzyte, from the beach near the head of Morrison bay.

1842. At one-half mile west of Little Portage bay (*i. e.*, where Pigeon point is norrowest), the axis of Pigeon Point peninsula is composed of a dark-greenish but spotted modified quartzyte, the spots being coincident with or caused by poikilitic crystals of some rock-making mineral, apparently some feldspar.

1843. Gabbro, extremity of Pigeon point.

1844. Red rock, near the extremity of Pigeon point.

1845. Modified Wauswaugoning quartzyte, from the knob rising near the south shore of Pigeon point a little west of Little Portage bay—a quartz keratophyre, according to Bayley. This knob consists of various conditions of this quartzyte.

1846. Possible organic impressions in a limestone, septaria-like mass, weathered from the slates on the south side of the tongue which divides Pigeon bay into north and south arms.

1847. An amygdaloid with green fillings, at the eastern end of the outer and eastern of the Lucille islands.

1848. Massive pyroxenic rock, apparently in form of a dike, cutting 1847, same place.

1849. Porphyritic gabbro running diagonally, like a dike, across the same island.

1850. Red rock attached to 1849.

1851. Ore, from the Susie Island shaft, Pigeon Point Silver and Copper Mining company, an ill-starred enterprise inspired by the late T. M. Newson.

1852. Quartzyte and black slate, showing contact of sedimentary sequence in the shaft. It is apparent that while the shaft started in hardened slate at the surface, the excavation struck red quartzyte and finally red granite.

1853. Red granite from the bottom of the shaft.

1854. Black slate, at the Susie Island works, becoming crystalline with orthoclase and turning red on weathering.

1855. Sample of dike forming a little point about one mile west of the west point of Grand Portage bay.

1856. Amygdaloid cut by this dike.

1857. Amygdaloid, center of sec. 20, first point west of the last.

1858. Supposed sedimentary material containing laumontite, from the western side of Cow Tongue point.

1859. Red rock, not quartz porphyry, from the west side of Cow Tongue point.

1860. Quartz porphyry of the red rock series, on the S. town line of 62-1 E., where the new road from Grand Marais crosses it. This is also amygdaloidal, which is a new point in the petrology of this series.

1861. Coarse poikilitic gabbro, from the hills next north of the Brulé lakes, on the Iron trail.

1862. Finely granitic red rock, on the portage south from Misquah lake.

1863. Dark gray, or reddish-weathering fine-grained rock holding porphyritic crystals of feldspar, from the north side of Brulé lake at the portage north to Lost lake.

1864. Porphyritic orthoclase gabbro, S. W. ¼ sec. 13, T. 63-3 W., south shore of Brulé lake.

1865. A dark gray, rather fine-grained rock which is supposed to be derived from the porphyry series, S. W. ¼ sec. 14, T. 63-3 W. south shore of Brulé lake.

1866. Red rock porphyry. Probably S. E. ¼ sec. 15, 63-3, W.

1867. Orthoclase gabbro, S. E. ¼, S. W. ¼, sec. 24, T. 63-3 W.

1868. Red rock forming the hill in W. ½, N. E. ¼, sec. 25, T. 63-3 W.

1869. Fine grained orthoclase gabbro, south side of the island in N. E. ¼, S. W. ¼, sec. 24, 63-3 W.

1870. Peculiar gabbro, east end of the island, S. W. ¼, N. E. ¼, N. E. ¼, sec. 13, 63-3 W.

1871. Fine grained gray rock, with spots resembling amygdules. No structure made out in this rock; eastern point of the large island, N. E. ¼, S. W. ¼, sec. 18, T. 62-2 W.

1872. A phase of the same. These two specimens well represent the rock of this point.

1873. Red rock, fine grained and dark colored, N. E. ¼, S. E. ¼, sec. 18, T. 63-2 W. This is the eastern end of a range of red rock hills that lies on the south of Brulé lake in this $\frac{1}{16}$ section and S. ½, N. W. ¼, sec. 17.

1874. Dark porphyry, intermediate between the gabbro and the reddish porphyry (1863) seen about Brulé lake. South side of a small lake in the N. E. ¼, N. E. ¼, sec. 17, T. 63-2 W. The same is seen along the south shore ¼ mile further east.

1876. Dark, compact, fine grained rock, with a tendency to a reddish color. Small dark areas of crystalline material, surrounded by a vein of red which grades into the rest of the rock, are common, N. E. ¼, N. E. ¼, sec. 20, 63-3 W.

1877. Quartz porphyry, with black groundmass, in which are small quartzes and feldspars, the latter redish to flesh-color, and frequently having the outer part redder than the interior, N. E. ¼, N. W. ¼, sec. 20, T. 63-3 W.

1878. Quartz prophyry with dull red groundmass, small quartzes and red feldspars, which latter are not usually very distinct, as they are of about the same color as the ground mass, N. W. ¼, N. W. ¼, sec. 20, T. 63-3 W.

1879. "Black rock," so-called, on a small island in the N. W. ¼, S. E. ¼, sec. 18, T. 63-3 W.

1880. Spotted phase of the same, at the western outlet of Brulé lake, N. E. ¼, S. W. ¼, sec. 18, 63-3 W.

1881. Rather fine grained "pepper-and-salt" rock, in a low ridge crossing the trail from Brulé lake, S. W. ¼, N. W. ¼, sec. 18, T. 63-3 W., apparently in form of a dike.

1882. Fine grained red rock, from the precipitous cliff on the eastern side of the hill rising at the S. W. corner of sec. 8, T. 63-3 W.

1883. Hard "black rock," N. E. ¼, N. E. ¼, sec. 17, 63-3 W.

1884. Red "black rock," N. W. ¼, N. E. ¼, sec. 16, 63-3 W.

1885. Amygdaloid-like porphyry, from a reef-like island just off the eastern most point in S. E. ¼, S. W. ¼, sec. 10, 63-3 W. The amygdaloidal spots are sometimes ½ inch in diameter.

1886. Black rock from the hills in the N. part of sec. 18, T. 63-3 W. at the west end of Brulé lake.

1887. A slaty fragment from the "black rock" forming a part of one of the hills in N. E. ¼ sec. 18, 63-3 W.

1888. Black rock, apparently with fine quartz grains. Same place as the last.

1889. Pseud-amygdaloid in the black rock, at the Temperance river outlet of Brulé lake.

1890. Apparently a coarse diabase, or a fine gabbro, possibly a derivative of the black series, cut by veins of red granite. Same place.

1891. Graphic granite, from veins and patches in the gabbro cut on the spur of the railroad near Paulson's camp.

1892. From an eighteen inch dike cutting the gabbro, seen on the railroad about a mile east of Paulson's camp.

1893. Fair sample of the iron ore at Paulson's, sec. 28, 65–4W.

1894. Pyrite, thought to contain nickel. Paulson's.

1895. An unknown mineral connected with the pyrite, from the quartzyte at Paulson's. This mineral is cinnamon colored.

1896. Average sample of an isolated ridge of Animikie saparated by a range of greenstone from the main mass of the Animikie, lying in S. W. ¼ sec. 21, 65-4 W., near Paulson's camp.

1897. Some of the finest portion of a singular slate-and-quartzyte breccia occurring in a low ridge by the railroad (south side), at the peat swamp crossing, about 1 mile west of the narrows of Gunflint lake.

1898. From the center of the conspicuous vertical dike which cuts the trap hill at the west side of the outlet of South Fowl lake.

1899. From the same dike from its contact with the trap forming the hill.

1900. Fair sample of the gray trap of the hill, remote from the dike.

1901. The trap near the dike, apparently changed to a greater denseness through the action of the dike.

1902. Fine quartzose conglomerate, overlying the next, dipping southward, toward the hill-range, from about the center of the N. W. ¼ of sec. 25, 64–4 E., southward from South Fowl lake.

1903. Lower portion of the conglomerate represented by 1902. These are each visibly about 18 feet thick, and grade into each other. The upper mass resembles the finer portions of the gritstone seen at the east end of Grand Portage island, and the lower one is like the coarse quartz-pebbly conglomerate seen near Fond du Lac in the valley of the St. Louis river.

1904. From the bottom of the perpendicular escarpment forming the top of the same hill. The hill rises about 350 feet above the country immediately north. This represents the top of the gritstone, and is similar to 1902. The gritstone has a thickness of about 126 feet, although it cannot all be seen exposed.

1905. From the top of the same hill, a non-descript rock resembling some Keewatin.

1906. A fine-grained member of the gritstone, from an exposure further east.

1907. Slate, south of the Millie mine, Iron Mountain, Mich.

1908. Limestone, "the limestone," same place.

1909. "Potsdam sandstone," unconformable over the limestone, same place.

1910. Typical jaspilyte of the Chapin mine region.

1911. Ore of the Chapin mine region, with "carbonate" interbedded.

1812. Rhodochrosite (?), Chapin mine ore dump.

1913. The conglomerate supposed to lie between the Millie and the Chapin, from the Quinnesec ore dump, from an old pit.

1914. Same of the schistose and calcareous portions of the greenstone, on the Wisconsin side, Lower Quinnesec falls, Menominee river.

1915. Some of the massive, ditto.

1916. Green schist, with quartz and carbonate of lime.

1917. Finely laminated, apparently sedimentary structure, in the green schists on the Michigan side, Lower Quinnesec falls.

1918. Coarsely crystalline, apparently gabbro-like rock thrown out in the excavation for the channel for running logs, Lower Quinnesec falls.

1919. "Actinolite-magnetite schist" and hematite, from the "lower Huronian," at a point in the first hill just south of the Republic mine, Michigan. Structure dips N. about 75 deg.

1920. Quartzyte, supposed to belong below the last, a little further south. The visible stratification here dips N. about 50 deg.

1921. Fine quartzose mica schist, in a narrow band visible about 18 feet, running in the granite, a little further south.

1922. Fine mica schist holding quartz pebbles, at the base, as supposed, of the "lower Huronian," lying on a granite which appears to be irruptive, and from which it is supposed to have derived boulder masses, about half a mile further south.

1923. Breccia of jaspilyte, cemented by dark jaspilyte, and by iron, Republic mine.

1924. Quartzyte, from the Republic ridge, at the point where the evident discordance occurs.

1925. From the same quartzyte, becoming sericitic, from an old mining location on the opposite side of the lake.

1926. Garnetiferous mica schist, from the same side of the lake but further west, a surface exposure thought to be from the top of the "upper Huronian."

1927. A much changed large dike of basic rock, running parallel with the strata in the "upper Huronian" at the railroad cut, west side of the lake.

1928. Conglomerate containing copper, Calumet and Hecla mine.

1929. A boulder-like mass, containing a large amount of copper, apparently a boulder of amygdaloid or other porous rock which has received copper into its interstices, same place.

1930. "Shot copper," originally an amygdaloidal fragment of some eruptive rock embraced in the general conglomerate, has been permeated by metallic copper from solution, same place.

1931. String copper, with a little silver, from which the associated boulders have been separated.

1932. Calcite crystals, containing interleaved copper; same place.

1933. "Half breed", i. e. mass of metalic copper containing some silver, found under the stamps. Calumet and Hecla.

1934. "Baby ingot" of metallic copper. Calumet and Hecla.

1935. Sandstone having a matrix of metallic copper. Calumet and Hecla.

1936. "Melaphyr" trap, taken from the Tamarac shaft, near the Calumet and Hecla mine, the most abundant rock passed through in the 3,000 ft. New shaft.

1937. Variation of this trap rock, with some epidote.

1938. Carbonate, supposed to be that from which the iron ore of the Palms mine (near Ironwood, Mich.), and of the Gogebic range in general, is derived. From near the Palms mine.

1939. Tufaceous material, in the "upper Huronian", interbedded with the iron-bearing rocks. From the dump at the Palms mine.

1940. The siliceous slate south of the Aurora mine, involved in the granite, whether by irruptive contact or by sedimentary non-conformity, is a point of difference.

1941. The granite here contacting.

1942. Some of the poikilitic, most coarsely crystalline portion of the gabbro at the first railroad cut (most westerly) near Short Line park, on the St. Paul & Duluth R. R. From the east end of the cut. Much of this rock at the first cut is amygdaloidal, especially toward the western end of the cut, and on the western face of the hill, and most of it is rather a green trap or diabase, when not amygdaloidal.

1943. Very fine-grained, dense, olivinitic gabbro, weathers greenish. From the second cut east of Short Line park, (on the E. line of S. E. $\frac{1}{4}$ sec. 33).

1944. The usual black irony belt in the gabbro hill at the same place, visible on the west face of the hill.

1945. Coarse olivinitic, magnetited gabbro. Same place.

1946. Underlying coarse gabbro, same place.

1947. From veins, or seams, in 1946. same place.

1948. Highly blackened gabbro, from another cut further east, probably in the east side of sec. 34. This is rather fine grained but not observably magnetic. It constitutes but a small part of the prevailing rock.

1949. From a detached amygdaloidal mass between the depot and the river at Cloquet.

1950. Average type of the gabbro of the first (westerly) hill range, in sec. 33, near Short Line park.

1951. Three samples showing the average amygdaloidal structure in the same hill.

1952. One of the narrow amygdaloidal dikes cutting this hill, with contact on the gabbro, same place.

1953. From a large dike running N. 15 deg. E., same place.

1954. Massive homogeneous, irruptive rock mingled with the bombs and graywacke in the "greenstone formation" near (but north from) the depot at Ely. (Specimen lost.)

1955. Concretionary, rounded small masses, resembling those figured on p. 318 of the 16th annual report, from the ambiguous greenstone at Ely, near the Catholic church. (Specimen lost.)

1956. A breccia embracing some green fragments of the schist.

1957. Sub-crystalline porodyte, or feldspathic quartzyte, north side of Ely island, Vermilion lake. With the exception of a little argillyte at the west end of this island the whole north shore consists of rock of this kind.

1958. Apparently burnt jaspilyte, from the mainland southeast from Ely island. This appears as a black, slaty argillitic jaspilyte, in the midst of porodyte, and runs at least one-fourth mile, with the usual strike, standing nearly vertical, or dipping 85–90 deg. toward the north.

1959. Three pieces showing the south contact of this on the porodyte. No effect, so far as can be seen, is produced on either; but the porodyte simply becomes some finer and greener. We subsequently noted the same contact on the north side of a jaspilyte belt, with the same result.

1960. Some squeezed masses of jaspilyte showing the changed forms of pebbles of different colors. North side of the north ridge, at Soudan.

1961. Apparently pebbles, pressed, enclosed in hematitic jaspilyte, but on close examination they appear to be remnants of reddish jaspilyte replaced otherwise by hematite.

1962. A form of the greenstone which appears on the north slope of the "north ridge." It has an approach toward argillyte.

1963. A black slaty jaspilyte is seen near the limonite locality, where a large amount of limonite was taken out by the Minnesota Iron company but not shipped, north from Soudan. Is it carbonaceous?

1964. Another coarse, siliceous grit, or quartzose graywacke, weathering light-colored, embraced in the argillytes, and interbedded with them, yet owing to upheaval and fracture now forming all manner of contact with them, from the west side of a point within the bay about a mile and a half west of Stuntz island, south shore of Vermilion lake.

1965. Similar to the last, but also resembling much of the rock on Stuntz island, from the same point, but a little nearer the extremity of the point.

1966. A typical homogeneous specimen of the "black rock," so-called, at the crossing of Lake street and Piedmont avenue, Duluth.

1967. A sample of the conglomerate-appearing portion of the same black rock near the same place.

1968. Red rock, associated with this black rock near the creek crossed by Piedmont avenue, a short distance further west.

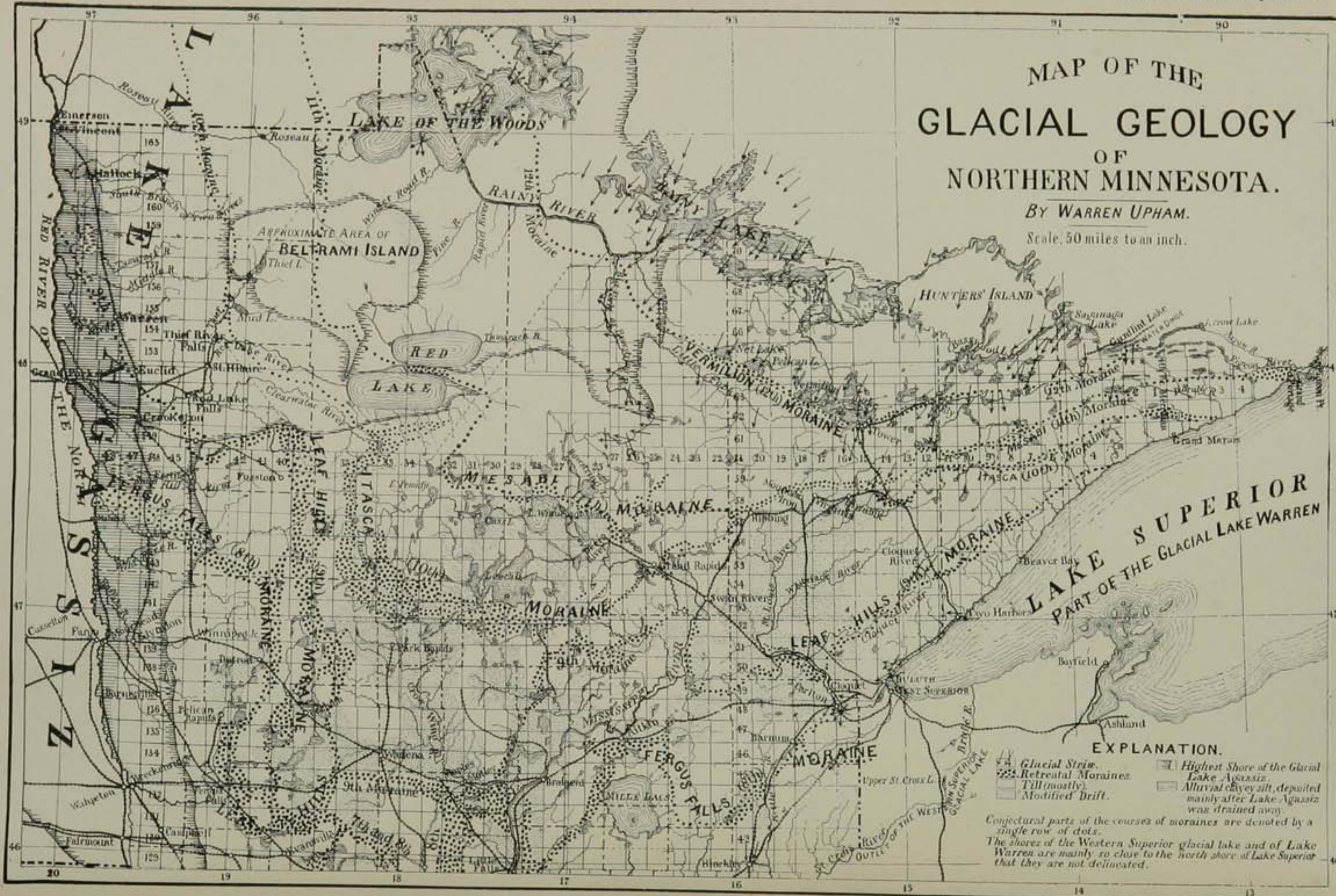
[NOTE. The descriptive observations and diagrams accompanying these specimens, as made in the field, are reserved for use in the final report.]

III.

PRELIMINARY REPORT OF FIELD WORK DURING 1893 IN NORTHEASTERN MINNESOTA, CHIEFLY RELATING TO THE GLACIAL DRIFT.

By WARREN UPHAM.

CONTENTS.


MAP OF THE
GLACIAL GEOLOGY
OF
NORTHERN MINNESOTA.
BY WARREN UPHAM.
Scale, 50 miles to an inch.
LAKE OF THE WOODS
RAINY RIVER
RAINY LAKE
APPROXIMATE AREA OF BELTRAMI ISLAND
RED LAKE
HUNTERS' ISLAND
VERMILLION (12th) MORAINE
MESABI (11th) MORAINE
LEAF HILLS (9th) MORAINE
ITASCA (10th) MORAINE
FERGUS FALLS (8th) MORAINE
LAKE SUPERIOR
PART OF THE GLACIAL LAKE WARREN
LAKE AGASSIZ
RED RIVER OF THE NORTH
EXPLANATION.
Glacial Striæ.
Retreatal Moraines.
Till (mostly).
Modified Drift.
Highest Shore of the Glacial Lake Agassiz.
Alluvial clayey silt, deposited mainly after Lake Agassiz was drained away.
Conjectural parts of the courses of moraines are denoted by a single row of dots.
The shores of the Western Superior glacial lake and of Lake Warren are mainly so close to the north shore of Lake Superior that they are not delineated.

AREAS EXAMINED.

From June 6th to November 2d, the writer was engaged in field work in the north central and northeastern portions of Minnesota, excepting absence during the second half of August in attendance at the sessions of the Geological Society of America and the American Association for the Advancement of Science, in Madison, Wis., and of the World's Congress on Geology, auxiliary with the Columbian Exposition, Chicago. The areas specially assigned to me for examination and report comprise (1) Aitkin county; (2) Cass county (excepting the small part north of Hubbard county, assigned to Prof. J. E. Todd); and (3) the large tract of Crow Wing county lying northwest of the Mississippi river (which at the time of the writing of chapter XXII in volume II of the Final Report of this Survey, treating of Crow Wing and Morrison counties, was included in Cass county, being transferred thence to Crow Wing by the state legislature in 1887).

After the examination of these areas, which occupied the summer months, my work during September and October consisted of observations of the glacial and modified drift in the vicinity of Moose Lake, Barnum, Carlton, and Duluth; southwestward from Duluth and West Superior to Holyoke, on the Eastern branch of the Great Northern railway; northwestward along the Duluth and Winnipeg railroad from Duluth to Grand Rapids; along the Duluth and Iron Range railroad for the entire extent of its main line from Duluth to Two Harbors, Tower, and Ely, and on its Western Mesabi branch from Allen Junction to Biwabik; and along Vermilion lake, from Tower to its outlet and western end.

MAPPING ACCOMPLISHED.

Having the township plats of the government surveys as the basis for topographic (or hypsometric) and geologic mapping, the delineations to be added were (1) lines of contour, showing the form of the land surface in undulating or rolling tracts, hills, valleys, and plains, with the altitudes of all portions above the level of the ocean; and (2) the location of rock outcrops, and the extent and boundaries of the diverse drift deposits.

I. TOPOGRAPHY.

For the reference of the contour lines to the sea level, the hights determined by the surveys for the railroads of this part of the state, all of which north of Duluth and the Northern Pacific railroad have been recently constructed, were obtained by copying from the profiles of these surveys. Every facility for this was courteously granted by the officers and engineers of the several railroad companies, namely, the Duluth & Winnipeg, the Duluth, Missabe & Northern, and the Duluth & Iron Range; and likewise of the shorter railroads used chiefly or wholly for lumbering purposes, namely, the Brainerd & Northern Minnesota railway, the Mississippi & Northern railroad (running northward from Cross lake, Crow Wing county), and the Duluth, Mississippi River & Northern railroad (running northward from Hiawatha, at the mouth of the Swan river). Previously I had similarly obtained and published the altitudes determined by the Northern Pacific railroad; the St. Paul & Duluth railroad; the Eastern railway of Minnesota (operated by the Great Northern railway company); and hights of the Mississippi and St. Louis rivers, and of lakes about their sources, as shown by these various railroad lines and by surveys of U. S. Engineers for the purpose of constructing reservoirs on the upper Mississippi and its tributaries.*

Using these altitudes, exactly ascertained by levelling, as data for reference, careful observation and barometric readings have sufficed for the drafting of the lines of contour, 50 feet apart vertically, upon the areas here reported. Mainly the surface is nearly level or only moderately undulating, but in certain belts it rises prominently in hills 50 to 200 feet or more in hight, consisting of marginal morainic drift accumulations which mark the boundaries of the ice-sheet at stages of pause or slight re-advance interrupting its general retreat at the close of the Glacial period. The valleys of the rivers are seldom very deeply eroded below the general level, their depths ranging from 10 or 20 feet to 100 feet or rarely more. Similarly shallow or sometimes deep depressions in the general sheet of drift hold the numerous or often very abundant lakes, which lie commonly 10 to 40 feet below the surrounding country, and have depths of 10 to 50 or 75 feet or rarely more.

In Aitkin, Cass, and Crow Wing counties, outcrops of the bed rocks are very rare. The thickness of the overlying drift is believed, from its known depths in other parts of the state, to vary from 50 or 75 feet to 150 or 200 feet, or perhaps

* "Altitudes between Lake Superior and the Rocky Mountains," forming Bulletin No. 72, U. S. Geol. Survey, 1891, pp. 229.

occasionally more, being spread as a somewhat uniform sheet over that region. The general altitude and slopes of the land are therefore due to the form of the rock floor on which the drift rests. In the neighborhood of Carlton and Duluth, however, and on many large tracts of the country farther north and northeast, the bed rocks have abundant exposures, and bold rock hills and cliffs often show more evidently the part which the rocky foundation takes in all the grand topographic features.

The following table contains altitudes of the more important railroad stations, lakes, rivers, and hills, in the region of this report, noted in feet above mean tide sea level.

Altitudes above the Sea Level.

RAILROAD STATIONS (track).

St. Paul & Duluth Railroad.

	Feet.
Duluth	608
Short Line Park	875
Thomson	1055
Carlton	1083
Otter Creek station	1150
Summit of grade, about 1 mile north of Mahtowa, highest on this railroad	1170
Mahtowa	1147
Barnum	1105
Moose Lake station	1063

Great Northern Railway.

West Superior	631
South Superior	672
Boylston	687
Dedham	802
Foxboro	956
Rhodes' Mill	1025
Holyoke	1100

Northern Pacific Railroad.

	Feet.
Duluth	608
South Superior	672
Pokegama	682
Walbridge	815
Barker	953
Wrenshall	1044
Summit of grade, 1½ miles southeast of Carlton, in a rock cut 18 feet deep	1098
Carlton	1083
Pine Grove	1237
Sawyer	1317
Cromwell	1306
Wright	1309
Tamarack	1271
McGregor	1228
Kimberly	1237
Rossburg	1222
Aitkin	1208
Cedar Lake station	1222
Deerwood	1277
Jonesville	1238
Brainerd	1209
Baxter	1205
Gull River station	1191
Sylvan Lake station	1207
Pillager	1203
Wheelock	1214
Motley	1227
Hayden	1255
Staples	1274

Duluth & Winnipeg Railroad.

Cloquet	1191
Nagonab	1214
Stony Brook station	1230
Stony Brook Junction	1226
Catlin	1237
Floodwood	1255
Island	1267
Wawina	1268
Swan River station	1293
Blackberry	1300
La Prairie	1283
Grand Rapids	1287

	Feet.
Cohasset	1284
Deer River station	1291

Duluth, Missabe & Northern Railway.

Shops	1230
Pine	1358
Grand Lake siding	1332
Burnett (at the Cloquet river)	1295
Columbia	1267
Albert	1301
Birch	1320
Kelsey (at the Whiteface river)	1302
Wallace	1316
Morrell	1333
Shaw (at the St. Louis river)	1339
Iron Junction	1379
Wolf	1402
Mountain Iron	1450
Hibbing	1565
Virginia	1439
Eveleth	1505
Biwabik	1455

Duluth & Iron Range Railroad.

Main Line.

	Feet.
Duluth	608
Lester Park	651
Clifton	661
Arthur	663
Two Harbors	692
Waldo siding	1057
York siding	1450
Highland	1709
Summit of grade, highest on this railroad, about 1 mile north of Highland, in a cut of morainic till 20 feet deep	1744
Thomas siding	1610
Cloquet River station	1504
Breda siding	1580
Bassett Lake station	1636
Reno siding (summit of grade)	1676
St. Louis River station	1584
Allen Junction	1508
Mesaba	1513
Hinsdale siding (summit of grade)	1596
Embarras River station	1426
Norway siding	1472
West Two Rivers siding	1426
Tower Junction	1381
Tower	1367
Armstrong Lake siding	1475
Robinson Lake station	1482
Ely	1417

Western Mesabi Branch.

Allen Junction	1508
Biwabik	1458
McKinley	1436
Virginia station (½ mile east of the town and about 115 feet higher)	1555

LAKES.

Lake Superior, low and high water, 600-603; mean 1870 to 1888	601.56

*Along the International Boundary.**

South Fowl lake	1436
North Fowl lake	1440
Moose lake	1492
Mountain lake	1652
Rove lake	1667
Watershed on the boundary, between sources of the Pigeon and Arrow rivers, about	1715
Rose lake	1528
South lake	1558
North lake	1550
Gunflint lake	1547
Pine lake	1465
Granite (or Banks' Pine) lake	1448
Saganaga lake	1434
Swamp (or Oak) lake	1435

*From the profile, principally based on levelling, of the "Route by the Grand Portage and Pigeon River from Lake Superior to Rainy Lake," in S. J. Dawson's "Report on the exploration of the country between Lake Superior and the Red River settlement, and between the latter place and the Assiniboine and Saskatchawan," Toronto, 1859 (pp. 45, with two maps and two profiles); corrected approximately to accord with the recent survey of the Port Arthur, Duluth & Western railway, giving the altitude of Gunflint lake, and with the altitudes of Knife, Carp, Sucker, and Basswood lakes, which, as given in this series, besides many others south and southeastward to the Devil's Track lake, were determined in 1893 through levelling by L. A. Ogaard and Alex. N. Winchell for the Geological and Natural History Survey of Minnesota.

Feet.

Watershed between Saganaga and Otter Track lakes, crossed by a portage of ¼ mile, the only exception to a complete circuit of lakes and streams enclosing "Hunters' Island," about....1475

Otter Track (or Cypress) lake....1387

Knife lake....1382

Carp (or "Pseudo-Messer") lake....1355

Sucker (or Birch) lake....1330

Basswood lake....1300

Crooked lake....1245

Lac la Croix (Nequauquon lake)....1186

Crane, Sand Points, and Namekan lakes....1127-1126

Rainy lake, low and high water, 1115-1120; mean....1117

Lake of the Woods, low and high water, 1057-1063; mean....1060

South of the International Boundary.†

Red lake....1172

Lake Itasca....1464

Lake Pemidji....1355

Cass lake....1300-1302

Lake Winnebagoshish, formerly, 1290-1293; as raised by dam of reservoir system....1298

Bow String lake, head of the Bow String river (or Big Fork of Rainy river)....1321

Ball Club lake....1281

Bass lake....1275

Leech lake, formerly 1293-1295; as raised by dam of reservoir system....1297

Kabecona lake....1302

Pokegama lake, formerly 1271; as raised by dam of reservoir system....1275

Feet.

Sandy lake, formerly 1211; proposed highest flowage by dam of reservoir system....1220

Mille Lacs, low and high water, 1249-1254; mean....1251

Cross and White Fish lakes, as raised by dam of reservoir system....1231

Maximum capacity of this dam....1236

Little Boy lake....1309

Wabado lake....1312

Woman and Girl lakes....1324

Ten Mile lake....1378

Fourteen Mile lake....1375

Crow Wing lake, at the head of Crow Wing river....1390

Eighth or Prairie lake, Crow Wing river....1385

Seventh, Sixth and Fifth lakes of this river, respectively 1382, 1379 and 1378.

Elbow lake....1426

Long lake, Hubbard county....1364

Sylvan lake....1201

Lower and Upper Gull lakes, as flowed by dam....1200

Lake Hubert....1199

Long lake, Crow Wing county....1198-1200

Pelican lake, Crow Wing county....1211

Embarras lakes....1380-1353

Vermilion lake....1357-1360

Trout lake, close north of last, about....1370

Burnt-side lake, also about....1370

Long lake,* Ely....1337

Fall lake*....1313

Newton lake*....1307

Garden or Eve lake‡....1384

Farm lake....1386

White Iron lake....1395

†These altitudes from Red lake to Vermilion lake, inclusive, are from levelling, mostly by railroad surveys, but along the upper Mississippi by United States engineers for the system of reservoirs, and, in the case of lake Itasca, by J. V. Brower, Commissioner of the Itasca State Park (to whose published altitude seven feet are here added, as required by the corrected elevation of the Great Northern railway at Park Rapids).

*From levelling for this Survey in 1893, by L. A. Ogaard and U. S. Grant. The altitudes of Trout and Burnt-side lakes, and of others following, when not specially indicated, are from barometric readings by Prof. N. H. Winchell, Dr. U. S. Grant and Mr. A. H. Elftman, referred to sea level approximately by comparison with the hights ascertained by levelling.

‡From surveys for extension of the Duluth & Iron Range railroad.

	Feet.
Birch lake	1410
Slate lake (T. 60, R. 10)	1640
Greenwood lake (T. 58, R. 10)	1705
Seven Beaver lake	1675
Gabbro lake	1464
Bald Eagle lake	1468
Lake Isabelle	1570
Snowbank lake†	1424
Wilder lake	1540
Lake Alice	1544
Thomas lake	1534
Fraser lake	1535
Kekequabic lake*	1497
Syenite lake (T. 62, R. 6 W.)	1777
Lake Polly (T. 63, R. 6 W.)	1617
Little Saganaga lake*	1600
Gabemichigama lake*	1587
Ogishke Muncie lake*	1488
Sea Gull lake	1440
West Sea Gull lake	1455
Lake Ida Belle*	1793
Kiskadinna lake*	1767
Mayhew and Iron lakes*	1853
Loon lake*	1745
Brulé lake*	1851
Winchell lake*	1910
Gaskanas lake*	1878
Meeds lake*	1879
Lake Abita, probably the highest in the state, on the southern slope of Brulé mountain*	2048
Devil's Track lake*	1636

Rivers.

Mississippi river.

NOTE.—See lakes Itasca, Pemidji, Cass, and Winnebagoshish, in the preceding list.

	Feet.
Head and foot of Pokegama falls, as raised by dam	1275-1254
Head and foot of Grand rapids, ½ mile long	1253-1248
Mouth of Split Hand river	1236
Mouth of Swan river	1226
Mouth of Sandy river, low and high water	1210-1224
At Aitkin, low and high water	1190-1200
Mouth of Pine river, ordinary low stage	1177
At Rice lake, two miles northeast of Brainerd, held by dam	1172
At Brainerd, low and high water	1150-1167
Mouth of Crow Wing river, low and high water	1145-1163
At Little Falls, above and below the dam	1099-1079
At St. Cloud, above and below the dam	975-960
At Minneapolis, above and below St. Anthony's falls	794-738
At St. Paul, low and high water	683-702

Crow Wing river and its tributaries.

NOTE.—The hights of Crow Wing and lower lakes, forming a series on the head stream of the Crow Wing river, are given on page 23.

The survey of the Great Northern railway branch to Park Rapids supplies the following altitudes of tributaries of the Crow Wing river at the bridges of this railway:

	Feet.
Leaf river	1293
Blueberry river	1372
Shell river	1379
Straight river	1402
Fish-hook river	1424
Crow Wing river at Motley	1208
Junction of Crow Wing river with the Mississippi, low and high water	1145-1163

St. Louis river and its tributaries.

	Feet.
Embarras river at bridge of the D. & I. R. railroad	1410

*From levelling for this Survey in 1893, by L. A. Ogaard and U. S. Grant. The altitudes of Trout and Burnt-side lakes, and of others following, when not specially indicated, are from barometric readings by Prof. N. H. Winchell, Dr. U. S. Grant and Mr. A. H. Elftman, referred to sea level approximately by comparison with the hights ascertained by levelling.

†From surveys for extension of the Duluth & Iron Range railroad.

	Feet.
Lakes of this river, extending in a series about 12 miles, where it passes through the Giant's (or Mesabi) range and southward	1380–1353
Cloquet river at bridge of the D. & I. R. railroad	1479
Small lakes forming the head of the St. Louis river, in the west part of T. 59, R. 11 W., about	1685
Expansion of this river in Seven Beaver lake	1675
St. Louis river at bridge of the D. & I. R. railroad	1584
At bridge of the D., M. & N. railway	1300
At mouth of Floodwood and East Savanna rivers	1234
At Stony Brook Junction	1211
At Cloquet, head of rapids above Knife falls	1178
Foot of Knife falls	1160
At bridge of the D. & W. railroad	1120
Top of dam at Thomson, about	1040
At bridge of the St. P. & D. railroad, close below the last, low and high water	997–1020
At Fond du Lac, level with lake Superior, about seven miles east of Thomson	602

Hills and Mountains.

	Feet.
Highest point on the road from Brainerd to Leech lake, about seven miles south of the Indian Agency	1500
Summit of ridge southwest of Pokegama lake, in the south part of T. 54, R. 26, the highest point in Itasca county	1617
Poquodenaw mountain, sec. 25, T. 52, R. 26, the highest hill in Aitkin county, about	1525
Hills in secs. 26 and 28, T. 59, R. 17, about four miles northeast and three miles N. N. E. from Virginia, forming the highest land in St. Louis county, respectively, about	2025 and 2150
Summits of the Giant's (or Mesabi) range, in T. 59, R. 16, a few miles north of Biwabik	1800-1900
Summits of this range near Hinsdale, where it is crossed, in a gap, by the D. & I. R. railroad	1850-1950
Hill close north of Tower (South ridge), about	1560
Soudan hill (North ridge), one mile northeast from the last, about	1600
Jasper peak, 2½ miles east of Tower, about	1650
Ridge close southeast of Syenite lake, in the east part of T. 62, R. 6 W., probably the highest in Lake county, about	2100-2200
Misquah hills, Cook county, the highest in Minnesota, in the south edge of Ts. 64, Rs. 1 and 2 W., comprising several summits about 2200 feet above the sea along a distance of eight miles from east to west, with their highest point about a half mile southeast from the east end of Winchell lake, determined by levelling	2230
Brulé mountain (T. 63, R. 1, W.), by levelling	2170
Top of bluffs (600 to 700 feet above lake Superior) close north of Duluth	1200-1300
Sawteeth mountains, near the shore of lake Superior, from Temperance river and Carlton's peak to Grand Marais	1300-1700

II. GEOLOGY.

In the areas assigned to me for geologic mapping and report, namely, Aitkin and Cass counties, and the northwestern part of Crow Wing county, the tracts covered by the several varieties of the glacial and modified drift have been delineated approximately. The few and small outcrops of the bed-rocks have also been shown on the maps; but, in a region so almost universally drift-covered, it is impossible to trace with certainty, or perhaps even with demonstrable probability, the limits of these Archean and Taconic formations. Under many portions of the drift-sheet here Cretaceous beds, though not observed in outcrops, are doubtless still thinly represented in place. On a map of the formations underlying the drift, the northwestern part of Cass county is best shown as Cretaceous, and this may also extend eastward through Aitkin county; for it is known that much of the drift of these counties has been derived from contiguous and underlying Cretaceous shales by glacial erosion.

SKETCH OF RESULTS OF GEOLOGICAL WORK.

I. ARCHEAN OUTCROPS IN AITKIN AND CASS COUNTIES.

A considerable tract in the southeastern part of Aitkin county is probably occupied by Archean rocks, which extend thence east and south into Pine and Kanabec counties. Between the Snake river and Cowan's brook, in the south edge of Aitkin county, the glacial drift in the S. E. ¼ of sec. 34, T. 43, R. 23, has in some places very plentiful blocks of a fine-grained, gray granite, containg black mica. This Archean formation is doubtless the bed-rock there at a little depth below the surface. Within a mile southwestward, and thence for nearly three miles down the Snake river, past its Upper and Lower falls in northern Kanabec county, Archean granites, schists, and gneiss, have many and extensive outcrops.

In the most southwestern township (T. 134, R. 32) of Cass county, the east half of sec. 28, about five miles northwest from Motley, comprises an area of frequently outcropping hornblendic granite, extending a half mile from south to north, with a width of twenty to forty rods. These rock exposures rise five to eight feet above the adjoining general surface of moderately undulating drift, being twenty to forty feet above the Crow Wing river, which lies about three-fourths of a mile to the southwest. Two wide dikes of dark, tough diabase intersect the granite, following the course of nearly vertical joint planes. In the Eleventh Annual Report (pages 87, 88), these rocks are described in detail, and a figure is given showing a part of one of the dikes, with narrow branches running from it. Some portions of this granite may be found valuable for quarrying, which, though several times contemplated, has not yet been undertaken.

II. QUARTZYTE AND DIABASE IN AITKIN COUNTY.

Quartzyte forms a slightly projecting point of the northwestern shore of Dam lake, near the center of the west half of sec. 35, Kimberly (T. 47, R. 25), about three miles south from Kimberly station and eleven miles east of Aitkin. Its outcrop has a length of about 250 feet along the shore and varies in width from 15 to 50 or 60 feet, rising to a hight of four or five feet above the lake. Through all its extent the rock is much fractured into separate boulder-like masses from one or two feet up to ten or rarely twelve feet in diameter, lying in close contact, with only very scanty foreign drift boulders of granitic, trappean, and other crystalline rocks such as abound in the drift of all this district, and even in the immediate vicinity of the outcrop. Boulders of the quartzyte, however, are very rare in the drift, and the great abundance of its masses at this locality shows unquestionably that it is here the bed-rock, although no compact ledge is seen. The shattered condition of its whole observable extent seems probably attributable to preglacial weathering of the rock at and near this place to form low cliffs with many boulders due to gradual disintegration along crevices and joint planes. During the Glacial period some or perhaps all of these quartzyte masses may have been transported short distances, but the very small proportion of boulders of other rocks mingled with the quartzyte indicates that its blocks are in or near their preglacial position.

In its original condition this rock was a sandstone of well-rounded white quartz grains mostly from a thirtieth to a tenth of an inch in diameter. The spaces between the grains have become filled with similar white quartz, and the rock is now a very compact light gray quartzyte, varying rarely in superficial portions to a partially reddish color where iron peroxide coats the sand grains and stains the interstitial quartz.

Apparently the most probable hypothesis that we can assume, in attempting to correlate this Aitkin county quartzyte with the stratigraphic sequence of rock formations ascertained elsewhere in all the surrounding country, is to suppose it to be a part of some area, very probably a belt having a general east-northeast to west-southwest extension, of the Pewabic formation, which is regarded as the basal member of the Taconic series. There may be, according to this hypothesis, a wide and shallow synclinal trough of the quartzyte with its northern border on the southern slope of the Giant's (or Mesabi) range, with western continuation to Pokegama falls on the Mississippi, and its southern rim represented by the locality here described. The dip and strike of the strata, however, were not determinable in this place, since no distinct lines of bedding were observed in any of these quartzyte masses; and their irregular forms, although evidently due to joint structure, indicate that the formation here is not traversed by any regular systems of parallel and intersecting joints.

About three miles southwest from this exposure of quartzyte, two outcrops of nearly black, rather coarse-grained, very hard and tough diabase occur in the S. W. ¼ of sec. 9, T. 46, R. 25, within about a fourth of a mile west from the south end of Long lake and some 20 or 25 feet above it. A foot trail leading from Rabbit lake northeasterly to Dam lake passes over the western and larger outcrop, which has a smooth and somewhat flat extent of about 100 feet from southwest to northeast, with a maximum width of 30 feet, rising only one to two feet above the general surface of the glacial drift. This trap rock shows no traces of flow or shear structure, nor any noteworthy variation in the degree of coarseness of its crystalline texture, throughout its visible area. It belongs doubtless to the central portion of a dike of undetermined but probably not very great width, whose borders and contact with the country rock on each side, presumably quartzyte, are hidden by the drift.

The course of the dike is probably from southwest to northeast, for a second exposure of the same rock is found at a distance of about twenty rods farther northeast, divided from the foregoing by a slight depression of five feet in which there is a grove of several large poplars. The length of this outcrop is about 30 feet, also trending northeastward, and its width 15 feet. Both outcrops are cut in many directions by numerous joints, nearly vertical or steeply inclined, among which no prevailing system is observable. Slight weathering of these rock surfaces has removed their glacial striation; but the diabase appears to have been more durable to resist decay than the enclosing strata of the country rock, for which reason the dike remains with a greater hight and projects through the drift sheet. A wooded hill of the drift rises within a distance of about a quarter of a mile northeastward to a hight of 40 feet or more above the trap outcrops, which lie in a tract having only bushes and scattering small trees. An examination for a considerable distance around failed to discover other rock exposures, but very probably some of small extent will be found if the land should be cleared for cultivation or pasturage.

The time of the volcanic or more deeply seated plutonic intrusion of the trap rock here cannot be definitely stated. Quite probably it may have been contemporaneous with the intrusive laccolitic sills of diabase in the Animikie and Keweenawan (or Nipigon) sedimentary formations on the northwest coast of Lake Superior. Dr. A. C. Lawson concludes that those trap sheets and dikes, mostly similar to the diabase in Aitkin county, are of some undetermined age subsequent to the Keweenawan period, which was in the later part of the Taconic or Algonkian era.* They may belong, however, to a very late stage of this era, before its great upper series of detrital and volcanic rocks was completed.

III. EVIDENCE OF CRETACEOUS BEDS UNDERLYING THE DRIFT.

Although no outcrops or natural exposures of Cretaceous strata have been found in Aitkin and Cass counties, it seems highly probable that shales of this age remain in many places, perhaps upon the greater part of this area, beneath the drift. Fifteen years ago Prof. N. H. Winchell wrote:

> A line drawn from the west end of Hunters' Island, on the Canadian boundary line, southward to Minneapolis, and thence southeastwardly through Rochester to the Iowa state line, would, in general, separate that part of the state in which the Cretaceous is not known to exist from that in which it does. It is not here intended to convey the idea that the whole state west of this line is spread over with the Cretaceous, because there are many places where the drift lies directly on the Silurian or earlier rocks; but throughout this part of the state the Cretaceous exists at least in patches, and perhaps once existed continuously.†

This opinion has been well confirmed by the subsequent work of this Survey, and notably by Mr. H. V. Winchell's recent discoveries of Cretaceous shales at several places 35 to 45 miles northeast of Aitkin county, along the elevated Mesabi range.‡ The Cretaceous marine submergence of this region

*Bulletin No. 8, of this Survey.

†Bulletin of the Minnesota Academy of Natural Sciences. vol. i, p. 348.

‡Am. Geologist, vol. xii, pp. 220-223, Oct., 1893.

appears thus to have extended eastward at least to the present site of lake Superior. A large part of the clay of the glacial drift here was doubtless derived by erosion from Cretaceous shales, and their calcareous matter supplied to the drift may principally account for its small amount held in solution by wells and springs in these counties, making their water somewhat "hard" and unfit for washing with soap.

On the site of the Sandy lake dam an excavation about ten feet square, made in the summer of 1893, encountered in the modified drift, at a level a few feet below the river bed, a gravel layer enclosing abundant water-worn and partially rounded lumps of lignite. These masses vary in size from one or two inches to six inches or more in length, and are mostly flattened in parallelism with their bedding planes. It was estimated by Mr. Archibald Johnson, in charge of the construction of the dam, that about two bushels of lignite fragments were thrown out from this small excavation. They are of quality similar to the lignite coal found in thin layers enclosed in Cretaceous shales near Richmond, Ft. Ridgely, and Redwood Falls in Minnesota, and to the thicker Cretaceous lignite beds which are mined on the Souris or Mouse river and west of Bismarck in North Dakota. Small fragments of lignite are found very rarely in the till of all the western two-thirds of Minnesota, including Aitkin county, in which Sandy lake is situated; and gravel layers in wells near Aitkin occasionally contain smoothly rounded pebbles of very compact, nearly black, carbonaceous shale, somewhat resembling graphite. Occurring so plentifully at Sandy lake, this lignite gravel must have been derived from the erosion of some layer of lignite in Cretaceous shales not far distant northward or northeastward.

Only very scanty Cretaceous shale gravel, however, is found in the till and in nearly all the modified drift of this region. The greater part of the Cretaceous beds here may be too soft to yield pebbles, the product of their glacial erosion being principally an indistinguishable part of the fine rock flour or clay in the till. The lignite fragments at Sandy lake are not sufficient, according to the opinion of the writer, to indicate the existence of workable layers of lignite; for they more probably came from thin seams like those known elsewhere in Minnesota, which are mostly about one foot or less in thickness and nowhere exceed three or four feet, being inadequate for profitable mining. Little or no encouragement can be given to prospecting in this thickly drift-covered region with the hope of finding valuable beds of this brown coal.

IV. GLACIAL DRIFT AND MORAINES.

(Mapped in Plate I, facing page 18, at the begining of this chapter.)

Nearly all of Minnesota is covered by a mantle of drift that averages from 100 to 150 feet in thickness, almost everywhere concealing the bed-rocks, which generally had been subaërially eroded in preglacial times to an approximately flat or only moderately hilly surface. Small knobs and hills of rock which had been spared by the preglacial erosion were doubtless in many places worn down and levelled by the ice-sheet, and its drift was filled into the preglacial valleys, so that the contour of the drift-enveloped country is now more uniform than it was before the Ice age. But on certain belts the drift was left in hills and ridges, accumulated along the margin of the ice where it paused or somewhat reädvanced, apparently because of secular fluctuations of climatic conditions, at successive stages which interrupted its general retreat during the closing part of the Glacial period. Numerous belts extending across areas which have a nearly plane surface of the underlying rocks are thus occupied by drift amassed in prominent hills. Upon the greater part of Minnesota the only hills are formed of this morainic drift, ranging in hight commonly from 25 to 75 or 100 feet, but occasionally attaining much greater altitude, as in the Leaf hills, which rise from 100 to 350 feet above the moderately undulating country on each side. These characters of the bed-rock contour, and of the overlying drift surface, prevail through Cass, Crow Wing, and Aitkin counties, and the region thence north to the international boundary, as also upon most of the area eastward to the sources of the St. Louis, Whiteface, and Cloquet rivers.

Farther northeastward, a region of comparatively scanty drift, with plentiful rock outcrops, begins upon Rainy lake, Net, Pelican, and Vermilion lakes, in the Giant's or Mesabi range (a high granite ridge), and along the bold highland which forms all the northwestern shore of lake Superior. This region, reaching thence northward and eastward into Canada, presents very remarkable contrasts with the other and far greater portion of Minnesota before described; for it has frequent steep rock hills 100 to 200 or 300 feet above the neighboring lakes and streams, and its drift averages probably only from 10 feet or less to 25 or 50 feet in thickness, often giving, even on the lowlands, ample opportunities for examination of the older geologic formations, and for accurate tracing of their boundaries. Yet this hilly and rocky district is quite surely less uneven than before its glaciation, which in general tended to reduce the hights of the hills and to fill the hollows with drift, or to bar them with drift accumulations whereby most of the very abundant lakes of the district are partially enclosed. In many instances it may be shown here that glacial erosion produced rock basins that are filled by lakes; but more commonly some part of the lake shores consists of drift whose removal would open avenues through which the water could mostly or wholly flow away.

Transportation of Boulders.

The boulders of the drift in northeastern Minnesota have been mostly transported toward the west, southwest, and south, from their parent ledges. In the northwestern part of the state, however, the glacial currents flowed and carried their boulders from the Silurian limestone region of lakes Winnipeg and Manitoba, and from the Archean gneiss and granitic rocks east and north of lake Winnipeg, southward and southeastward into western and southern Minnesota, and thence continued across Iowa to the drift boundary in Missouri and northeastern Kansas. These two fanlike outflows from the farther north and thicker central portions of the ice-sheet were confluent, pushing against and uniting with each other from the northeast and northwest, along a belt which extends southward from near the mouth of Rainy lake and Winnebagoshish and Leech lakes to the vicinity of Brainerd and to Minneapolis, coinciding approximately, for this distance of about 250 miles, with the courses of the Big Fork (or Bow String) and Mississippi rivers.

Throughout the district of this field work and report the drift is mainly derived from the rock formations outcropping and underlying it within distances from a few miles up to fifty miles in the directions whence the glacial outflow advanced. Upon an area of gabbro, or of granite or schists, or slate, or other rock, and for some miles onward, many of the boulders, large and small, and much of the gravel in the till and modified drift, consist of the same kind of rock. The glacially eroded grist comprises frequent boulders up to 5 feet in diameter, usually very few up to 10 feet, and exceedingly rare blocks of larger size, excepting near to prominent and favorably jointed rock outcrops. A much larger proportion of the drift occurs as small boulders and fragments, gravel, sand, and rock flour, the fine detritus making nearly everywhere the far greater part of the whole mass.

Only where rock formations of restricted area have peculiar characters by which their boulders can be identified with certainty, as distinct from all similar boulders supplied by other formations and districts, is it possible to affirm positively the distance of their transportation. Thus, we find rarely in Big Stone and Otter Tail counties, of western Minnesota, granite boulders with included fragments of hornblende schist,* like much of the granite forming the Giant's or Mesabi range, which was probably their source. These boulders appear to have been carried about 200 miles southwest and west-southwest. A mass of native copper weighing more than thirty pounds, found in Lucas county, southern Iowa,† had been doubtless borne by the currents of the ice-sheet about 600 miles, from the present copper mining region south of lake Superior, or from Isle Royale, first southwestward and then southward through eastern and southern Minnesota, passing west of the Wisconsin driftless area.

The farthest known transportation of rock-fragments in the drift, recorded in part by Dr. Robert Bell, of the Canadian Geological Survey, whose observations are supplemented by my own, is from James bay southwest to North Dakota and Minnesota. The rock thus recognized is a "dark grey, granular, siliceous felsite or greywacke,...... characterized by round spots, from the size of a pea to that of a cricket ball or larger, of a lighter color than the rest of the rock, which weather out into pits of the same form." It occurs *in situ*, as reported by Dr. Bell, on Long island, off Cape Jones, on the east coast of Hudson bay, where it is narrowed to form James bay, having there a southwestward strike, and probably continuing under the sea for some distance in that direction. He notes that the abundance of pebbles and boulders of this rock is the most remarkable feature of the drift on the west coast of James bay and along the Attawapishkat, Albany and Kenogami rivers, and that its fragments have been found by him as far west as Lonely lake, and southward to lake Superior.‡ Farther to the southwest and south I have observed fragments of it, usually

* Final Report, vol. i, p. 626; vol. ii, p. 551.

† C. A. White, Geology of Iowa, 1870, vol. i, p. 96.

‡ Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, vol. ii, for 1886, p. 36G; compare Report of Progress for 1878-79, pp. 22, 23C.

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only a few inches, but in some instances, a foot or more in diameter, occurring very rarely in the drift in the northeastern part of North Dakota, where the largest piece ever found by me was about thirty miles south of the international boundary and fifty miles west of the Red river, and at numerous localities in Minnesota, where it extends at least as far south as Steele county, seventy-five miles south of St. Paul, and a thousand miles southwest of its outcrop north of James bay.

GLACIAL STRIÆ.

While the most distantly derived boulders of the drift bear testimony of the sum of all the movements of the glacial currents, during the entire Ice age, upon the area across which they came, it is to be remarked that the glacial striæ, or furrows and scratches on the bed rocks engraved by boulders, pebbles, and sand grains frozen in the base of the moving ice-sheet record only the course of the latest glacial current there, excepting such striated rock surfaces as became drift-covered and thus protected from the latest ice abrasion. Probably the average glacial erosion of our rock surface, for different parts of Minnesota, varies from 10 or 20 feet to 50 or 100 feet or more, approaching, but not generally equalling, the depth of the drift. Nearly all of the striæ produced during the early and middle portions of the Glacial period have therefore been erased and their places taken by the later markings. Even where one set of striæ was protected by a drift covering until a considerably divergent set was engraved on adjacent parts of the same ledge, as has been observed at some localities in southwestern Minnesota,* and in many places near Duluth, noted in the following table, it is far more probable that both belong to successive late stages of the glaciation than that any long fraction of the Ice age intervened. When several courses intersect each other on the same rock surface, differing 30°, 60°, or even 90°, in their extremes of deflection, as in numerous instances near Carlton, Thomson and Duluth, these variations seem referable to the closing scene of the glacial retreat when the ice border, irregularly indented in its process of melting and consequently having sudden and great deflections of its marginal currents, was being withdrawn across these striated rock exposures.

Generally outcrops that have been long exposed to the disin-

*Final Report, vol. i, pp. 505 and 549, with figures 35 and 44.

tegrating action of the weather, having been undoubtedly in many instances bare ever since the departure of the ice-sheet, show few remnants, or only here and there faint traces, of their originally abundant striæ. These long weathered rock surfaces have suffered a slight loss, estimated to vary commonly from a sixteenth of an inch or less to a half inch or sometimes more, worn away, with the delicate glacial striæ, by the rains of many centuries, while yet the planed or rounded forms of the ledges due to their glaciation are unchanged. That so little subaërial erosion has taken place since the end of the Ice age is a sure evidence of the geological brevity of this Postglacial or Recent period, agreeing with the conclusion reached by Prof. N. H. Winchell from his investigations concerning the rate of recession of the Falls of St. Anthony, by which he estimated the length of postglacial time to be about 8,000 years.†

Wherever the ledges have been covered by drift and so protected from weathering, they retain their glacial marks in perfection; and on tracts of plentiful rock outcrops, such striated surfaces are frequently exposed by excavations for streets, cellars, etc., and by the removal of the drift on the borders of quarries. Though most of the striæ of naturally exposed ledges have become effaced, usually a careful search will detect some portions where they remain; and occasionally, even on surfaces evidently exposed during all the Postglacial period, the striation is still very distinct upon spaces 10 to 20 feet or more in extent.

Courses of Glacial Striæ in northeastern Minnesota,
referred to the true or astronomic meridian.

FROM NOTES BY COL. CHARLES WHITTLESEY.*

Vermilion lake............S. 15° W.
Sand Points lake..........S. 55° W.
Namekan lake. also..... S. 55° W.
Rainy lake.......S. W. to S. 75° W.
Big fork of Rainy river at "a fall of six feet over trappose rock," estimated 82 miles by the stream from its mouth ....N. 80° W.

FROM NOTES BY PROF. N. H. WINCHELL, in former annual reports of this survey.

Otter Track lake.............S. W.
Knife lake...............S. 48° W.
Island in Carp lake.......S. 40° W.
Sucker lake...................S. W.
Basswood lake, Northeast cape ....S. 15° W.
Ima lake, north shore.......... ....S. 36° W. and S. 23° W.
Island in Thomas lake....S. 25° W.
Sec. 11, T. 64, R. 7 W......S. 30° W.
Delta lake, sec. 28, T. 65, R. 6.. ....S. 25° W.
Sec. 30, T. 63, R. 8 ....S. 8° E.
Sec. 35, T. 63, R. 9........S. 12° W.
Sec. 27, T. 63, R. 10.......S. 15° W.
Birch lake..S. 12 °W. and S. 22° W.

†Final Report, vol. ii, pp. 314-341, with maps and plates.

* Report of Explorations in the Mineral Regions of Minnesota during the years 1848, 1859, and 1864.

Vermilion lake, twenty localities.................S. 17°-24° W., and three other localities.... ....S. 28° W., S. 10° W. and S.
Pike river, tributary to Vermilion lake, two places.......... ....S. 10° and 20° W.
Duluth....................W. S. W.
Prairie river, lower falls, sec. 34, T. 56, R. 25 W...........S. 10° E.

From notes by Mr. Horace V. Winchell, in the Sixteenth and Seventeenth Annual Reports of this Survey.

Little fork of Rainy river, five localities............S. 10°-42° W.
Rainy river, 3½ miles below Ft. Francis..................S. 32° W.
Rainy lake, nine localities...... ....S. 32°-64° W.
North fall on outlet from Namekan lake to Rainy lake..S. 30° W.
Bow String river (Big fork of Rainy river), probably in T. 63, R. 26, intersecting striæ, mainly.....S. 10° W. and S. 30° E.
do., a short distance above the last, very distinct glaciation.....................S. 60° E. [or, more probably ....N. 60° W.]
Deer river, at dam about a half mile above its junction with the Big fork, probably in T. 62, R. 25.......S. 80° E. to due E. ....[or, N. 80° W. to due W.]
Big fork, about three miles above the mouth of Deer river......................Due E. ....[or more probably, W.]
do., in or near sec. 35, T. 150, R. 25......S. 52° E. [or N. 52° W.]

The cause of the foregoing remarkable deflections will be considered on a following page.

Net lake, in the Bois Fort Indian Reservation....S. 20°-24° W.
Pelican lake, mostly in Ts. 64 and 65, R. 20, four localities ....S. 24°-36° W.
Elbow lake, T. 64, R. 18, two localities..S. 26° W. and S. 28° W.
Trout lake, north of Vermilion lake, two localities...... ....S. 16° W. and S. 36° W.
Summit of the Giant's range at Hinsdale................S. 22° W.
Sec. 32, T. 60, R. 13, about..S. S. W.
Sec. 35, T. 61, R. 12, south of Birch lake, about...S. 12°-30° W.
Sec. 10, T. 64, R. 8, south of Ensign lake................S. 24° W.
Sec. 27, T. 64, R. 8, northeast end of Disappointment lake.. ....S. 34° W.
Sec. 36, T. 62, R. 8, south of lake Isabelle................S. 24° W.
Sec. 15, T. 59, R. 6, southwest of Crooked lake............S. 6° W.

From notes by Dr. U. S. Grant, 1892–93.

N. W. ¼ of sec. 27, T. 65, R. 2 W., north shore of lake Louise... ....S. 16° W.
S. E. ¼ of sec. 28, T. 65, R. 2 W., north shore of lake Emma ....S 7° W.
N. W. ¼ of sec. 35, T. 65, R. 2 W., north shore of No-name lake.......................S. 2° W.
S. W. ¼, sec. 10, T. 63, R. 3 W., reef in Brulé lake.......S. 18° W.
S. E. ¼, sec. 20. T. 65, R. 4, north shore of a small lake......S. 4° E.
N. W. ¼, sec. 13, T. 64, R. 6. S. 28° W.
N. E. ¼, sec. 3, T. 65, R. 6, on an island....................S. 50° W.
N. E. ¼, sec. 7, T. 65, R. 6, island in Amœba lake........S. 30° W.
S. W. ¼, sec. 35, T. 66, R. 6, north end of island in lake Avis. S. 30° W.

From notes by Prof. G. E. Culver, 1893.

Pokegama falls, Mississippi river.....................S. 50° E.
Prairie river, lower falls. S. 4°-10° E.

On the Bow String river (Big fork of Rainy river):

First rock outcrop observed in descending this stream...S. 5° E., and nearly due E. [more probably W.]
"Another exposure of diorite some five miles down the stream"...S. 70° E. [or N. 70° W.]
Foot of Rice River rapids, on the "upper exposure of greenstone"..................S. 35° E.; and on its second exposure.. ....S. 65° E. [or N. 65° W.]
A few miles below the last.... ....S. 70°-80° E. [or N. 70°-80° W.]
A short distance farther down the river S. 70° E. [or N. 70° W.]
About halfway between the mouths of Rice and Deer rivers ...S. 70°-80° E. [or N. 70°-80° W.]
An eighth of a mile above the Little falls................S. 2° E.
Little falls..............S. 2°-8° E.

Rock gorge of river, ⅛ mile long, estimated 12 miles below the Little falls.................... ....S. 58°-70° E. [or N. 58°-70° W.]
Big falls.....S. 80° E. [or N. 80° W.]
1½ miles below the mouth of Sturgeon river (which comes in from the west 5 miles below the Big falls) ....S. 24° E.
About 12 miles below the Big falls.S. 58°-62° E. [or N. 58°-62° W.]
About 25 miles below the Big falls, on the lowest rock outcrop observed on the Big fork....................S. 44° W.
Little fork of Rainy river, 4 miles from its mouth...S. 50° W.
Rainy river, 2¾ miles below Ft. Francis..................S. 40° W.
do., 1½ miles below Ft. Francis, also.....................S. 40° W.
Near the head of Black bay of Rainy lake............. S. 52° W.
West end of Namekan lake. S.40° W.
Sand. Points lake.10 miles from the mouth of the Vermilion river....................S. 22° W.

FROM NOTES BY MR. W. H. C. SMITH.*

Near Sand Points lake....S. 28 °W.
Knife and Carp lakes..S. 10°-38° W., averaging about........S. 23° W.
Otter Track (Cypress) lake and Cache bay at west end of Saganaga lake.........S. 10°-28° W.; most commonly about..S. 20° W.
Extreme limits of all the observations of glacial striæ on Hunters' Island.......... ... .S. 2° W. and S. 43° W., with average general direction about........ ......S. 20°W.

FROM NOTES BY DR. A. C. LAWSON.†

Rainy lake, east arm (upon the international boundary),from its east-southeast extremity to Brulé Narrows, twenty-four localities.......S. 28°-73° W.
do., East arm, from Brulé Narrows and the Seine river to the mouth of the lake, forty localities.............S. 28°-61°W.
Canadian portions of Rainy lake, with its many bays and several canoe routes northward, 137 other recorded localites....... ....S. 18°-63°W.

Rainy river, island four miles above the Manitou rapids.S. 38° W.
do., one mile below the Long Sault, and at the first and second rapids of Pine river, three localities, alike....S. 24° W.
do., one mile above the mouth of Rapid river...........S. 38°W.

FROM NOTES BY DR. A. C. LAWSON‡ AND DR. G. M. DAWSON.§

Around the Lake of the Woods, observations in about 180 localities by Dr. Lawson and assistants, and in about 60 localities reported by Dr. Dawson, "the great majority", i. e., 82 per cent.........S. 35°-55° W.; but 13 per cent. are..S. 10°-34° W.; and 5 per cent. are...S. 56°-83° W. Only four localities showed courses more westerly than S. 65° W., as follows:
On the southeast side of Big island, striæ bearing....S 75° W. intersect others bearing.S. 37° W.
On the west side of Bigsby island, which, like the preceding, lies near the middle of Sand Hill lake (the southern and largest part of the Lake of the Woods), double sets of striæ were observed in two places, respectively.......... ....N. 80° W. and S. 20° W. and......N. 83° W. and S. 33° W.
On a point projecting from the Minnesota shore in the southwestern part of this Sand Hill lake, striæ bear.......... ....S. 70° W. and 65°W., with others....S. 35° and 33° W.; also.....................S. 10° E.

NOTES BY WARREN UPHAM, 1893.

Vermilion lake, west part of Pine island, S. W. ¼, sec. 34, T. 63, R. 16, three places..... ....S. 15°-20° W.
Tower, near the school house, mostly..................S. 10° W. with variation to..S. and S. S. W.
A half mile southwest of Tower ...S. 5° and 15° E., and S. 10° W.
On the south ridge, close to Tower:
At Lee's mine, about.....S. 15° W.
Southeast summit, also about.. ....S. 15° W.

*"Report on the Geology of Hunters' Island and adjacent country," Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, vol. v, for 1890-'91.

†Geol. and Nat. Hist. Survey of Canada, Annual Report, vol. iii, for 1887-'88.

‡Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, vol. i, for 1885.

§Report on the Geology and Resources of the Region in the Vicinity of the Forty-ninth Parallel, from the Lake of the Woods to the Rocky Mountains, 1875.

Southwestern slope of this hill, several places, about 100 feet above Tower.. Due S.-S. 15° W., with rare deflected striæ. S. 10° E.
Greenstone knoll, ¼ mile northeast of Tower Junction, beside branch railroad to Soudan, mostly..........S.-S. 5° W.; with other courses.......... S. 15° E., S. 20° W., and S. 35° W.
Soudan, street car depot....... ....S. 10°-15° W.
do., southwest edge of village ....S. 30° W.
North ridge, close to Soudan, ⅛ mile west of summit and 30 feet lower.......S. 20° and 30° W. also, a few striæ...............S.
do., at west end of the old open mine..............S. 15° W.
Jasper peak, three places near top, each having two sets of striæ........................ ..S. 10°-15° W., and S. 30°-35° W.
Ely, many places on top of hill in village, two slightly varying sets (the second most abundant).................... ...S. 20°-25° W., and S. 30°-35° W.
do., ⅓ mile farther east, two courses, both plentiful, intersecting. ....S. 15-20° W., and S. 45°-50° W.
Hinsdale, close west of D. & I. R. railroad, several places.... ...S. 10°-20° W., and S. 25°-30° W.
do., above the old quarry, several places........S. 15°-20° W.
Nearly one mile northwest of Allen Junction, many striæ in two sets, intersecting..... ....S. 35° W., and S. 50° W.
Allen Junction, two places, abundant...........S. 45°-50° W.
About two miles southeast from last.................S. 30°-35° W.
Close west of railroad 1 mile south of Little Cloquet river bridge..................S. 35° W.
Rock cut 50 rods long, ¾ mile north of Two Harbors, nine places, mostly.........N. 80° W.; with variations to........... ....W. and N. 70° W.
Top of hill in S. E. ¼ of sec. 27, T. 53, R. 11, 1½ miles west of the last, at hight of about 500 feet above lake Superior. N. 75° W.
Lighthouse point, ⅓ mile southeast of Two Harbors village, two places.................. ...N. 85° W., and (mostly) due W.
Lester Park, at east side of mouth of Lester river, three places, mostly......S. 50°-60° W; also on same rock surfaces... ..S. 70° W., due W., and S. 30° W.

The magnetic needle is deflected here to the N. E. and E. N. E., but these bearings were determined by comparison with the trend of the north coast of lake Superior, and with the direction to elevators in Duluth, 6 to 7 miles distant. All the following observations of glacial striæ in and near Duluth likewise depend not only on compass readings (corrected for average magnetic variation, about 10° east of north), but also on the simultaneously observed courses to prominent buildings or land marks or to the sun. The needle in numerous places varied 10° to 60° or more and occasionally even 180° (pointing to the south instead of north), on account of the influence of the magnetite-bearing gabbro of this area. In many other places, however, the magnetic courses were nearly correct.

In Duluth and its vicinity (with figures in parentheses noting the approximate hights in feet above lake Superior):

East Superior street, east end of rock cut (200), about ⅓ mile northeast from the Endion school house (which is at 180 feet) ....S. 75° W.
Crest of this cut (250).....S. 70° W.
⅛ mile N. E. from Endion school house (225). S. 85° W. and S. 40° E.; both courses being represented by long and deep, clearly glacial furrows on a somewhat weathered rock surface.
20 rods north of this school house, at a hight of nearly 50 feet above it (225)..S. 70° W., ..S. 85° W., due W., and N. 65° W.
A few feet west of last (225).... .... S. 80° W. and S. 60° W.
Again, about 5 feet farther west ....N. 50°, 55°, and 60° W.
50 feet west of last, on a grandly furrowed surface 20 feet long (225)..........S. 75°-85° W.; with broad glacial grooves ¼ to ½ inch deep, from which any intersecting finer striæ that may once have existed are lost by weathering.
About 15 rods N. N. W. from the Endion school house (200), in two places, mostly. S. 80°-85° W.; also, on the same surfaces.... ....N. 80°-85° W.

On Woodland avenue (490), about ½ mile south of the Hardy school house (which is at 510 feet) .... W.

Near Buena Vista street (450), ¾ mile east of the great bend of Chester creek ....S. 75° W.

1⅓ miles W. S. W. of the Endion school house, near Brewery creek (425), about 30 rods east of Piedmont avenue bridge.. ....S. 85° W.

15 rods west from the last, on ledges in the bed of this brook (425). W., N. 80° W., and S. 80°-85° W.

About 6 rods S. W. from the last, at a small quarry (460)..N. 85° W.

Extensive smooth ledges ⅛ mile S. S. E. from the last (425), mostly effaced by weathering N. 85° W., due W., and S. 80° W.

Thence, on continuation of these ledges ¼ mile southward (400-325), distinct glacial striæ were seen in many places, occasionally accompanied with large "chatter marks" which are convex eastward, respectively in order from north to south: (1) W.; (2) N. 75° and 65 °W.; (3) N. 80° W., crossed by others bearing S. 20° W., which curve within an extent of four feet to a course due S.; (4) S. 50° W.; (5) N. 80° W.; (6) W., S. W., S., and S. E., all clearly glacial and crossing on the same surface; (7) S. 70° W.; (8) N. 80° W., S. 70° W., S. 60° W., S. 50° W. and curving in two feet to S. 30° W.. with others S. 30° W. and curving in six inches to S. 10° W., all on a space of about four feet square, intercrossed; (9) S. 70° W., many parallel striæ, crossed by a few others, N. 80° W.; (10) S. 70° W., S. W. (many), and S. 30° E., the last being surely glacial and extending straight 3 to 4 feet. [This tract is about ½ to ¾ mile N. N. W. of the High School building (which is at 125 feet).]

On the Boulevard near Third and Fourth avenues W. (½ mile S. W. from the foregoing) and thence southwesterly to the Seventh avenue inclined railway, striæ plentiful in many places (all about 475 feet)............S. 50°-60° W., with occasional deflections to.........S. 75° W. and S. 30° W.

On and near the Boulevard for a half mile southwest from the inclined railway, several places (all about 475 feet), mostly.............S. 50°-60° W., with deflections to........... ..S. 70° W., S. 85° W., and due W.

Above the Boulevard ¼ to ⅓ mile N. E. from the inclined railway, many places (525-550)... ....S. 70°-80° W.

30 rods W. (555) from the top of this railway (which is at 535 feet)....................S. 65° W.

About 15 rods S. W. (575) from the last..S. 80° W. and N. 80° W.

About 50 rods W. (590) from the top of the inclined railway .. .. S. 80° W.

¼ mile N. W. from this railway (590-600) .... S. 85° W.-W.

⅓ to ½ mile N. W. from the railway, three places (about 600 feet), successively............ (1) N. 75°-80° W.; (2) N. 75° W.; (3) N. 85° W.

¾ mile farther N. W., near Highland Park village (675). N. 75° W.

Piedmont avenue, between Seventh and Eighth streets (375), extensive rock exposures, with very distinct glaciation in many places, all... .... S. 65°-70° W.

About ⅛ mile west of last, close below the Boulevard, on large outcrops (425), striæ remaining in many places........... S. 60°, 65°, 70° and (rarely) 80° W., crossed in one place by striæ S. 20° E., which curve within 18 inches to S. 10° E.

It is noteworthy that such curving striæ, seen elsewhere in twenty places or more, are in all cases deflected to more southward courses, when traced forward as the ice currents moved. At this locality the curving marks are rather broad and deep gouges, far more so than any of the prevailing W. S. W. striæ.

Fifth avenue W. (at hight of about 300 feet), 20 rods west of the Institute of the Sacred Heart, mostly......S. 55°-65° W.; crossed by a few deep glacial furrows ....S. 25° W.

Lake shore, 10 to 15 rods N. E. from mouth of Chester creek, striæ most abundant...S. 50° W.; also common, S. 60° W.; with a few deflections to.......... .... S. 30° W. and S. 70° W.

Lake shore, about 30 rods S. W. from Chester creek .... S. 40° W., S. 55° W. and S. 70° W.

Superior street ⅛ mile N. E. from the city hall and public library (40), several places, mostly ....S. 60° W. with others.................. ..... S. 45° W., and S. 70°-80° W.
Michigan street, near Twelfth avenue W. (50)..........S. 45° W.
do., between Fourteenth and Fifteenth avenues (25) .... S. 55°-60° W.
do., within ⅛ mile S. W. from the last (at hight of 20-30 feet) to Garfield avenue (which leads over Rice's point to West Superior), mostly.S. 40° W. but intersected by........... .... S. 65° W. and due W.

In West Duluth.

At quarry about ⅛ mile N. E. from the Longfellow school house (75)..............S. 70° W.
10 rods W. of last (100)......... .... S. 65°-70° W.
About 15 rods farther W. N. W. (100) ....S. 68° W.
⅛ mile north of the foregoing, on the D., M. & N. railway near Fourth avenue W. (175) ....S. 75°-80° W.
15 rods E. of last, at the intersection of this railway and State street (175)...N. 80°-85° W.

In Carlton and its vicinity.

Thomson, 15-20 rods S. E. of the depot..............N. 80° W.
3 to 6 rods east of the last..... ....N. 52°-55° W.
About 10 rods west of the Thomson dam.........N. 70° W.
Beside the St. P. & D. railroad ⅛ mile west of St. Louis river, mostly.................N. 70° W. intersected by.............. .....N. 55°-60° W. and N. 80° W.
About 15 rods west of the last, mostly ....N. 80° W.; with others, equally distinct, crossing on the same surface ..S. 60° W., S. 35° W., S. 10° W., S. 20° E. and S. 30° E.
Northeast edge of Carlton village, on street leading to Thomson .... N. 80° W.

The very prominent and plentiful slate outcrops at and near Carlton, and northward to Cloquet, have almost completely lost their glacial marks by weathering. In searching several hours, both at Carlton and Cloquet, I was unable to find any striæ surely referable to glaciation.
Close north of the N. P. railroad about 1 mile west of Carlton, a few glacial striæ.. .... S. 50°, 55° and 65° W.

Within 1½ miles southeastward from Carlton the N. P. railroad has five rock cuts, at four of which I searched in vain for glacial marks. The fifth cut, however, about 30 rods long and 15 feet deep, 1½ miles from Carlton, shows on the recently uncovered slate of its edges at each side of the railroad very interesting glacial striæ, as follows:
On the southwest side, near the northwest end of the cut..... ....N. 65° W., and N. 45° W.
Two rods S. E. from the last. plentiful striæ.........N. 45° W.
Again, two rods farther S. E., abundant................S. 80° W. intersected by........ ....S. 15° W., due S., and S. 45° E., each of these courses being represented by only two or three glacial gouges.
About three rods farther S. E., many very clear striæ.....due W.
25 feet onward S. E...S. 85° W., and partly S. 80° W. and due W.
The same westward striation is also well shown on this southwest side of the cut in other places within two rods southeastward.
On the northeast side, at the crest of the cut, about 10 rods S. E. from the last, plentiful ....N. 80° W.; crossed by short glacial gouges ....S., S. 20° E., and S. 45° E. These cross markings are two to six inches long, numerous.
About 25 feet N. W. from the last, the well preserved main striation is.........W.-S. 85° W; crossed by a few short glacial marks.....S. 20° E., and S. 45° E.

Deflections of Glacial Currents.

During the time of maximum extent and thickness of the ice-sheet, its currents doubtless flowed southward upon all the northern part of Minnesota, but with considerable variation on one side to the west and on the other to the east of due south. In the region bordering lake Superior, and thence south and southwest to the Mississippi, the currents were turned southwesterly, for the driftless area of Wisconsin, whose margin extends also into southeastern Minnesota, indicates that the glacial outflow from the western part of the lake Superior basin moved in a curving course successively to the southwest, south, and east of south, in its passage through Minnesota. Uniting with this flow the more western part of the ice-sheet above the Manitoba lake region and the Red river valley moved nearly due south as the axial portion of the great ice-lobe which stretched across Minnesota and Iowa, becoming at the culmination of the Glacial period confluent south of the driftless area with the ice that moved southwestward from the region of lakes Michigan, Huron, and Erie. During the departure of the ice-sheet, however, when its latest currents were recorded by the striæ which remain for our inspection, the inequalities in the rates of melting of different portions of the retreating ice border shaped it often into minor lobes and deep embayments, very unlike its outlines at the time of greatest extent, and continually changing in form as the process of the melting and recession pushed the ice boundary back. In general this retreat was from south to north, but the courses of the moraine belts show that on some tracts it was from west to east, and less frequently, at least in this state, from east to west. Everywhere the outermost few miles of the vanishing ice-sheet had its currents turned strongly toward its boundary, since on that side there was a steep slope of the ice surface.

In the vicinity of Duluth, where the foregoing notes show an unsurpassed complexity of divergent and intersecting glacial striæ, we may generally refer the courses between S. 30° W. and S. 60° W., inclusive, to the main current of the ice-sheet here previous to any great deflections by the irregularities of the final melting. Occasionally, however, local southward deflections were doubtless of much later date, being due to indentations of perhaps only a few rods extent in the retreating ice border. The more common directions, ranging from S. 70° W. to W. and N. 80°–70° W., belong to the time of glacial recession and imply that the withdrawal of the ice boundary here was from west to east.

Similar westward deflections of the glacial currents crossing the shores and islands of the Lake of the Woods and on the Big fork of Rainy river are likewise referable to the closing stages of the glaciation. When the ice was thickest and during its retreat nearly to this region, the currents of ice flow from the area of Paleozoic limestones west of the Lake of the Woods and lake Winnipeg passed south and southeast, carrying their limestone drift to the mouth of Rainy lake and the basin of the Big fork, becoming there or close eastward confluent with the ice flow from the north and northeast, which overspread all of the country north of lake Superior. But during the recession of the ice the laving action of lake Agassiz appears to have caused exceptionally rapid melting along the Red river valley and upon the whole area covered by this glacial lake east to the Big fork, so that the ice currents there were shifted from southeastward to westward and even northwestward courses, being turned toward the open and lower lake expanse. In a former report,* I supposed these striæ on the Big fork to represent an increasing eastward deflection of the previous southeasterly current; but it now seems to me more reasonable, from consideration of the courses of moraines and of the extent of lake Agassiz in northern Minnesota, to attribute their deflection to the somewhat earlier melting of the ice from the part of the lake Agassiz area crossed by the Rainy river than from the upper part of the Big fork basin, whereby the latest ice currents on the Deer river and contiguous parts of the Big fork were almost reversed from their former direction.

The changes in the directions of the ice-flow near Duluth were more remarkable in their abundant evidence by glacial striæ than I have anywhere else found; but observations comparable with these were recorded on the quartzyte ridge in Cottonwood county, southwestern Minnesota,† and I have seen almost equally interesting and plentiful deflected glacial striæ in Somerville, Mass.‡ It is also to be noted that the overlapping of northeastern drift by northwestern drift in Wright county, Minnesota, and thence eastward to the St. Croix river

*Geol. and Nat. Hist. Surv. of Canada, Annual Report, new series, vol. iv, for 1888-89, pp. 119, 120 E.

†Geology of Minnesota (Final Report), vol. i, pp. 503-505.

‡Proc., Boston Society of Natural History, vol. xxvi, pp. 33-42, March 15, 1893.

on the boundary of Wisconsin,§ proves for that large district during the closing stages of the Glacial period a reversal of the direction of glacial currents far more extended in space and time and more important in their deposition of drift than in the Big fork district.

TILL.

Unstratified glacial drift, called till, or boulder-clay, which was laid down directly by the ice-sheet without modification by water transportation, assorting, and deposition in beds, occupies probably two-thirds, or a larger part, of northeastern Minnesota. It consists of boulders, gravel, sand and clay, mingled indiscriminately together in a very hard and compact formation, which therefore is frequently called "hardpan." In this part of the state, the boulders of the till are usually so plentiful that they are sprinkled somewhat numerously on its surface; yet there are seldom more, on the large portions of the country which are adapted for agriculture, than the farmer needs to use, after clearing them from his fields, for the foundations of buildings and for walling up his cellar and well. They are rarely abundant enough to make walls for the enclosure of the fields, as in New England.

Three kinds of till occur in this region, each being mainly restricted to its distinct geographic limits; but on the belts containing their general boundaries, there is often an overlapping of one on another, or successive alternations of two interbedded. Adjoining portions of the ice-sheet have won and lost once or repeatedly in pushing against each other.

1. On the west, the till brought by the southward and southeastward glacial currents contains plentiful boulders, not only of Archean and Taconic rocks, but also of the Paleozoic magnesian limestones which are the bed-rocks of a large part of Manitoba.

2. Over the greater part of the country eastward from the Big fork, and from Winnebagoshish and Leech lakes, the till was derived from the north and northeast and contains still more plentiful Archean and Taconic boulders, as granites, gneiss, schists, gabbro, quartzyte, slate, etc., while boulders of limestone are exceedingly rare or altogether absent, their only source being Paleozoic formations in the basin of James and Hudson bays.

§Proc., Am. Assoc. for Adv. of Science, vol. xxxii, for 1883, pp. 231-234. Geology of Minnesota, vol. ii, pp. 254-256, 409-413.

3. The third kind of till is that which was brought by the ice-flow from the lake Superior basin. It is characterized by comparative scantiness in the supply of granite, gneiss, crystalline schist and gabbro boulders, by the absence of limestone, and by the large proportion of fine detritus of dull reddish color from the erosion of the Cambrian red sandstones and shales, and of the partly sedimentary and partly igneous Keweenawan series, which form the shores and bed of lake Superior. This red till, with few boulders, has its typical development about Duluth and Superior, and forms the flat expanse which gradually rises from the west end of lake Superior along the Nemadji river and the lower part of the St. Louis river. Thence, with slow decrease of the prevailing deep redness of its color, it extends northward to Biwabik, westward into the southeastern part of Aitkin county, and southward to St. Paul and Minneapolis, though on a large region from southern Pine county nearly to St. Paul, it is covered, as was before noticed, by overlapping northwestern till.

Along the Duluth & Iron Range railroad from Highland station to the St. Louis river, and in the excavations for working the Biwabik iron mine, I observed many very interesting sections of alternating and often interbedded till deposits of the second and third kinds here described, derived respectively from the north or northeast and from the basin of lake Superior on the east. Plate II shows four of these sections. Though found abundantly in this belt, such alternating till accumulations, attributable to changes of glacial currents, are very rare in most drift-bearing regions. They here belong probably to the time of the final recession of the ice-sheet, when, as we have seen by the deflected courses of striation, its currents were far more liable to changes than during the previous time of greater extent and depth, and resulting generally steady flow, of the ice. These alternations of till deposition seem to me well accordant with the view which I have elsewhere presented,* that the drift during its transportation was englacial, and that its deposition, excepting on a broad marginal portion of the drift sheet, was chiefly reserved until the time of glacial recession. Much of the previously englacial drift appears then to have become amassed beneath the ice as a ground moraine of subglacial till. Probably in these sections no more than 1 to 3 feet, or at the most 5 to 10 feet, in the latter case comprising the two upper

*Bulletin, Geol. Soc. of America, vol. v, pp. 71-84, Jan. 1894.

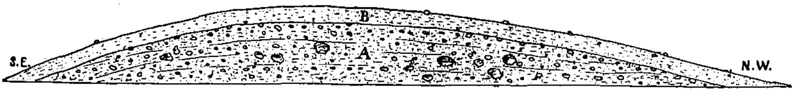

FIG. 1. SECTION ON THE DULUTH & IRON RANGE RAILROAD, IN THE NORTH PART OF SEC. 1. T. 54, R. 12, THREE MILES NORTHWEST OF HIGHLAND STATION. *Length, ¼ mile; hight, 25 feet.*

FIG. 2. SECTION ON THE DULUTH & IRON RANGE RAILROAD, IN THE SOUTH PART OF THE S. W. ¼ OF SEC. 23, T. 55, R. 12, ½ TO ¾ MILE NORTH OF THOMAS SIDING. *Length, ¼ mile; hight, 6-15 feet.*

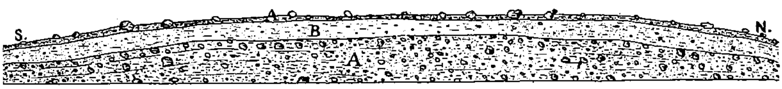

FIG. 3. SECTION ON THE DULUTH & IRON RANGE RAILROAD, IN THE SOUTHEASTERN PART OF SEC. 15. T. 55. R. 12, TWO AND ONE-HALF MILES SOUTHEAST OF CLOQUET RIVER STATION. *Length, ¼ mile; hight, 20 feet.*

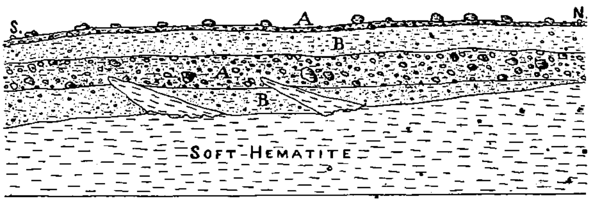

FIG. 4. SECTION OF PART OF THE WEST SIDE OF THE BIWABIK IRON MINE, OCT. 18, 1893; SHOWING IN THE BASAL PART OF THE DRIFT TWO LARGE MASSES OF THE RED IRON ORE WHICH WERE GLACIALLY UPLIFTED AND PROBABLY TRANSPORTED VERY SHORT DISTANCES. *Length of section, 150 feet; hight of drift above the ore deposit, 15 to 25 feet.*

A. Till of yellowish gray color, but bluish at considerable depths, containing plentiful and often very abundant boulders, derived from the north and northeast.

B. Till of somewhat reddish gray color, containing few or often rare boulders, derived from the east.

layers of the till, can have remained as englacial and finally superglacial drift when the ice boundary was withdrawn across this area.

RETREATAL MORAINES.

Northeastern Minnesota is crossed by several belts of knolly and hilly till, with far more abundant boulders than are found on its more extensive comparatively smooth tracts. These belts of somewhat thicker, more rocky, and prevailingly ridged drift were accumulated along the border of the ice-sheet during stages of halt or slight reädvance interrupting its general retreat at the close of the Glacial period. Wherever the vicissitudes of the wavering climate caused the chiefly waning border to remain nearly stationary during several years the outflow of the ice to its melting steep frontal slope brought much drift which had been englacial and on account of the ablation had largely become superglacial, being exposed on the surface of the departing ice-sheet. As these marginal accumulations of drift record the position of the terminal line of the ice-sheet when they were formed, the name terminal moraines has been usually applied to them, but they also may be called, perhaps more properly, retreatal or recessional moraines.

Four moraine belts have been traced in the part of Minnesota northwest of lake Superior, and another, lying next south and formed before any considerable part of the area of this lake was uncovered from the ice-sheet, is also included in the following descriptions. In their order from south to north, these are the Fergus Falls, Leaf Hills, Itasca, Mesabi, and Vermilion moraines, being the eighth to the twelfth and most northern in the series of moraines whose courses have been mapped in this state. A map showing these moraines, the directions of glacial striæ, the areal distribution of the glacial and modified drift, and the extent of the glacial lake Agassiz in northern Minnesota, forms Plate I, facing page 18, at the beginning of this chapter.*

Fergus Falls Moraine.

A belt of morainic drift, chiefly till with many boulders, amassed in hills and irregular ridges 50 to 100 feet above the

*On a smaller scale, the courses of the moraines and other features of the glacial geology of the entire state of Minnesota are mapped in Wright's "Ice Age in North America," 1889, p. 546. They are shown in detail for the southern half of the State by the maps in volumes I and II of the Final Report of this Survey. Many details of their mapping and correlation throughout the northern half of Minnesota remain yet to be supplied.

intervening hollows and frequent lakelets, enters Aitkin county at the northwest side of Mille Lacs. Thence it extends with a width of five to ten miles northward to Cedar lake and to the lakes surrounding Deerwood in Crow Wing county, having in this part an unusual expansion and probably marking a north-westwardly re-entrant angle of the ice-border. Passing from Farm Island and Cedar lakes eastward, the moraine has a width of about five miles. In the southern part of this hilly belt lie Hanging Kettle, Diamond, and Mud lakes, the northern part of Elm Island lake, and Cranberry, Rabbit, Long and Dam lakes. At the northeast corner of Kimberly township the moraine has a fine development in many bouldery hills upon a width of two or three miles next northwest and north of Portage lake, being there crossed by the Northern Pacific railroad.

If my correlation is correct, the vicinity of Portage lake belongs to a second re-entrant angle, with its apex pointing northeastward, from which the moraine, mostly less conspicuous, turns back and passes by the east side of Dam lake, forms high hills south of Sugar lake, and thence approximately coincides with the eastern watershed of Mille Lacs, until in the southern edge of Aitkin county it curves around to an east and northeast course, passing into Pine county as the hilly belt enclosing the Pine lakes. The series of low drift hills thus traced is provisionally regarded, in the descriptions of its portions in Crow Wing and Pine counties*, as the continuation of the Fergus Falls moraine, which is the eighth of the moraines recognized and mapped in their geographic and chronologic succession, crossing the southern and western part of Minnesota.

In northwestern Pine county this moraine is well developed from the Pine lakes northeast to the Kettle river; and farther northeastward I believe that it is represented by a belt of somewhat hilly drift extending along the east side of the Moose Horn river in southern Carlton county, through T. 46, R. 19, and into Mahtowa (T. 47, R. 18); but thence probably it turns back from a re-entrant angle of the ice front and runs southward through T. 46, R. 18, and eastward past Oak and Net lakes in the north edge of Pine county, to cross the state line nearly on the watershed between the Nemadji and St. Croix basins. A tract of moderately hilly till which I observed one to three miles east of Barnum, and its extension southward by Bear, Hanging Horns, Moose Horn, Long, and Moose lakes, belong

*Final Report, vol. ii, pp. 605, 642.

to this looped morainic belt; and another portion, consisting partially of till with a somewhat rolling surface, but in larger part of low kame-like accumulations of sand and gravel, is crossed by the Great Northern railway in its first three miles southwest of Holyoke.

Such correlation of these morainic tracts seems to be harmonious with the course of the outer moraines in northwestern Wisconsin west and north of the driftless area, as mapped by Chamberlin.† It also accords well with the directions of glacial striæ found very abundant and distinct on the plentiful rock outcrops in the vicinity of Carlton, Thomson, Duluth, and Two Harbors, which, as before noted, run prevailingly west-southwestward, but in very many places also display wide deflections to the southwest and south and to the west and even north-northwest. The divergent and variable glacial currents by which these striæ were made doubtless belonged mostly to the time of recession of the ice border across that district. We thus learn that the rapidly wasting ice in its departure from the western end of the lake Superior basin had a definitely lobate front similar to the looped course assigned to this moraine in Aitkin, Carlton, and Pine counties. Between the times of formation of the eighth and ninth or Fergus Falls and Leaf Hills moraines, as these names are here used, the area of these extraordinary divergent and often intersecting striæ was uncovered by the glacial retreat.

Leaf Hills Moraine.

The next halt or reädvance of the chiefly receding ice-border was at the belt of prevailingly knolly and ridged and in part prominently hilly drift, with many boulders, which extends from the west side of Gull lake, in southern Cass county, northeastward past White Fish lake in northwestern Crow Wing county, and north of lake Washburn in eastern Cass county, to Hill or Poquodenaw lake and "mountain" (an especially prominent morainic hill which rises about 250 feet above the surrounding country), in northwestern Aitkin county. This belt is probably the representative of the ninth or Leaf Hills moraine, which in Otter Tail county is partially united with the Fergus Falls moraine, the two together making the conspicuous Leaf hills (or "mountains," as they are commonly called), 100 to 350 feet high. Beyond Poquodenaw the moraine has a low and inconspicuous development east-northeasterly to the

†U. S. Geol. Survey, Third An. Rep., for 1881-82, Plates xxviii and xxxv.

Mississippi river; but near the east bank of the river, about a mile north of Aitkin county, it again forms a high hill, known to lumbermen and log-drivers as the "Grub Pile," in the southeast part of sec. 25, T. 53, R. 24, rising about 200 feet above the river.

From this hill as the apex of a re-entrant angle of the ice-sheet, the moraine turns back and extends nearly twenty miles southward to Sandy lake. Along the first six miles of this course it is mainly covered by level or only moderately undulating stratified drift, but in the south edge of T. 52, R. 23, it rises very prominently in Bald bluff, close east of the Mississippi, and in a series of irregular hills continuing thence eastward through the south part of secs. 33 and 34 of this township and the north edge of secs. 4 and 3, T. 51, R. 23. The crests of these hills are 150 to 200 feet or more above the Mississippi, and afford a wide view, the Poquodenaw hill being visible about fifteen miles distant on the west, and the hills of the tenth or Itasca moraine, bordering Pokegama lake, twenty miles away at the northwest. Moraine hills 75 to 150 feet high stretch from Bald bluff southward along the east side of the Mississippi to Sandy lake. Thence this belt, lower and less distinct, consisting partly of kame-like deposits of modified drift and partly of till, curving southeastward, makes the shores and islands of Sandy lake and bounds the northeastern arm of Rice lake, beyond which it passes eastward by Round and Big Island lakes and through T. 49, R. 22, where its low swells, hillocks, and ridges project only 20 to 40 feet above the many tamarack swamps.

Eastward from Aitkin county this moraine is narrowly and scantily developed in the northwest corner of Carlton county, but becomes more prominent and broader in the vicinity of Prairie lake, beyond which, as I am informed by Mr. J. E. Spurr, its hills and ridges occupy a width of five to six miles along the south side of the St. Louis river to Stony Brook and Nagonab. Curving northward beyond the St. Louis, it borders both sides of the Cloquet river for several miles, passing northwest of Grand lake. The same belt probably continues east-northeast to a morainic tract, observed by Mr. A D. Meeds, adjoining the Cloquet river and Island and Boulder lakes in the southern third of T. 53, R. 14, and to the narrow but typically hilly moraine which is crossed by the Duluth & Iron Range railroad a mile north of Highland station. It is supposed to reach the north shore of lake Superior about midway between Duluth and Pigeon point. Its course beyond Highland station, however, has been definitely ascertained for only about thirty miles. Along this extent, passing east-northeast to the middle of the east side of T. 57, R. 8, the moraine has been mapped by Mr. Arthur H. Elftman in his exploration for this Survey during the summer and autumn of 1893, who reports it admirably represented by a belt of very irregular drift hills from a half mile to two miles wide, with summits 50 to 75 feet above the land on each side.

Itasca Moraine.

Extending eastward from lake Itasca, this tenth moraine attains a grand development along the south side of Leech lake, being there about ten miles wide. In the southern half of its width it encloses Ten Mile and Fourteen Mile lakes, and Woman, Wabado and Little Boy lakes. Thence it continues east-northeasterly across Itasca county, where its abundant knolls and hillocks of drift, as described by Prof. G. E. Culver in another part of this report, lie on the northern slope of a high Cretaceous ridge in T. 54, R. 26, cover much of the lower country bordering the shores of Pokegama lake within the next ten miles, occupy considerable tracts a few miles north and east of Grand Rapids (attaining a maximum altitude of 300 feet), and reach from near the falls of the Prairie river east-northeast past the Diamond iron mine and along the watershed between the Prairie and Swan rivers to Hibbing.

Along the next thirty miles, to the Embarras lakes, Mr. Spurr's descriptions and mapping indicate that the Itasca and Mesabi moraines are united in a belt mostly two to three miles wide, which coincides closely with the granite ridge known as the Mesabi or Giant's range. East of the gap in this range through which the Embarras river flows (expanding along the greater part of its valley in a series of beautiful lakes), both these moraines veer to the south of the granite ridge. On the Duluth & Iron Range railroad the exceedingly knolly and confusedly ridged but low belt of the Itasca moraine, strewn with a countless profusion of boulders of all sizes up to ten feet in diameter, is crossed from about a half mile to two and a half miles northwest of St. Louis River station. For observation of the rough contour and abundant boulders which are usually the two chief characteristics of these retreatal moraines, I know of no other more impressive view than is seen here from the passing train, although none of the elevations rise more than 50 or

75 feet above the adjoining tamarack swamps and the plentiful bowl-like hollows which are enclosed by the morainic accumulations.

In Lake county the moraine varies from one to two or three miles in width, and crosses ranges XI to VIII (the belt of Mr. Elftman's exploration in 1893) along the line dividing Ts. 59 and 60. His descriptions show that the moraine along this extent of twenty-four miles is typically developed in very irregular low hills and ridges, mostly between 50 and 75 feet in hight. Eight to ten miles farther on, taking an east-northeast course, its hills of drift, heavily covered with white pine, are reported by Mr. H. V. Winchell as surrounding lake Harriet, at the head of the Isabelle river, with ridges of very abundant boulders close northward. Its course thence eastward to the coast of lake Superior, which it may reach in the vicinity of Grand Marais or near the mouth of Brulé river, has not been traced.

Mesabi Moraine.

The most northwestern of the morainic tracts in Minnesota which are here correlated together as the Mesabi or eleventh moraine lies between the south and north divisions of Red lake and consists of a high till ridge, with many boulders, some two miles wide and extending about ten miles east from the Narrows, with a continuous altitude 150 to 200 feet above the lake. Forty to fifty miles southeast from this tract, lower drift hills, referred to the same moraine, border the north side of lake Winnebagoshish, and reach thence southeastward to Deer and Bass lakes, near which they occasionally rise to hights of about 200 feet above the general level. Along a distance of twenty miles to the north from the last named lakes, Prof. Culver reports irregular groups and short series of drift hills, mostly less than 100 feet high, which seem to represent the complex accumulations of a re-entrant angle of the ice-border. From Spider, Trout and Wabano lakes, this moraine passes eastward, and appears to be merged with the Itasca moraine to form a compound hilly belt along the Mesabi range from close north of Hibbing to the upper Embarras lake northeast of Biwabik. At Mesaba station on the Duluth & Iron Range railroad, and within a mile southeastward, this Mesabi moraine comprises many hillocks and short ridges 20 to 40 or 50 feet high. Thence continuing northeast, it is represented by characteristic knolly and hilly drift deposits and abundant boulders on the south side of the western part of Birch lake, and through the northern part of Ts. 60 in Rs. XI to VIII, where it is mapped by Mr. Elftman, lying two to five miles north of the Itasca moraine, and occupying a width of one to two miles. It probably comes down to the lake Superior shore about 70 miles farther east, in the Pigeon River Indian reservation, passing thence beneath the lake level.

Vermilion Moraine.

A twelfth moraine, named from Vermilion lake, along whose southern side it is well exhibited, as also south of Pelican and Net lakes, was first carefully studied and mapped during my field work in 1893. The portion of its course which I have examined reaches about 40 miles, from the west extremity of Vermilion lake east-southeast to Tower and thence east-northeast to Ely. In total, its whole extent yet known is nearly 75 miles, beginning at the west on the south side of Net lake, where Mr. C. L. Chase, engaged during the past summer in government township surveys, reports a belt of irregularly grouped drift hills, 50 to 100 feet high, with very abundant boulders. Next south of Pelican lake it occupies a width of one to two miles, and it averages about one mile wide in its course skirting the southern shores of Vermilion lake for the distance of twenty miles from its west end to Tower. This belt in most portions is distinguished more by its wonderful profusion of boulders, ranging in size up to 5 or 6 feet and occasionally 10 or 15 feet in diameter, than by its large amount of drift amassed in hillocks and ridges. Its multitudes of boulders strow the surface of the Tower town site, and are conspicuously piled upon the southern slope of the high rock hill called the South ridge, just north of this town; but they are absent from the top of this ridge and from its northern slope, which are chiefly bare rock. Turning northeasterly for the next one and a half miles, this moraine thinly caps the North ridge at Soudan, above its iron mines. Thence it runs to the east and skirts the northern and eastern base of Jasper peak, which, like the top of the ridge near Tower, has almost no drift.

Six to ten miles farther east, this belt is crossed by the Duluth & Iron Range railroad, on which its bouldery drift knolls and ridges are cut through in many places within two miles west and an equal distance east of Robinson Lake station. At Ely its boulders are very abundant in and near the village. Less than a mile to the south, associated with the morainic belt, is an irregular esker ridge of sand and gravel, often very coarse, trending from west to east and here and there expanding into small plateaus, with altitudes mostly 50 to 75 feet above the railroad and iron mines. Four to seven miles east of Ely, plentiful low drift hills, with many boulders, were observed by Mr. Elftman adjoining the north end of White Iron lake, southeast of Garden or Eve lake, and north of Farm lake. The extent of this belt beyond its limits as here described remains unexplored; but it is doubtless traceable west at least to the area of lake Agassiz, and much farther eastward.

Although this morainic belt is very distinct and certainly records a nearly stationary stage interrupting the retreat of the ice-sheet, I estimate its volume of drift added above the average of the surrounding region to be only 5 to 10 feet on its variable width of a half mile to two miles. A half, or at least a third, of this added volume consists of boulders from six inches to ten feet in diameter.

For the region of Ely and Vermilion lake I estimated the volume of all the drift thus: bare ledges of rock, with no drift or too little to be worth consideration, about a tenth of all the surface; ledges thinly drift covered, probably four-tenths, with an average of about 5 feet of drift; while the remaining half of the country, having diverse deposits of sand and gravel, retreatal moraines, or smoother tracts of till, may have an average depth of 40 feet of drift. By this estimate the mean thickness of the drift there, if uniformly spread, would be about 22 feet.

V.—MODIFIED DRIFT.

The deposits included under this title are waterworn and stratified gravel, sand and clay or silt, which were washed away from the drift upon and beneath the retreating ice-sheet by the streams due to its melting and to accompanying rains. Kames, eskers, sand and gravel plateaus and plains, the valley drift (varying from very coarse gravel to very fine loess and clay, often eroded so that its remnants form terraces), are the principal phases of the modified drift. In being derived directly from the ice-sheet, these deposits had the same origin as the glacial drift forming the common till and the greater part of the retreatal moraines; but they were modified, being separated from the coarser portions, further pulverized or rounded, and assorted in layers, by water.

Kames and Eskers.

Associated with the till in the moraines, a considerable part of these accumulations of marginal drift often consists of irregularly stratified gravel and sand in knolls and short, irregular ridges, which are called kames. Such stratified deposits are also occasionally found on the general till expanse between the morainic belts. In both situations they are attributable to deposition by small streams descending from the melting surface of the ice-sheet, being accumulated in the short cañon-like gorges which were melted into the ice-border at their mouths. The slackening of the steep and rapid descent of the streams there emerging upon the land in front of the ice caused them to deposit the coarser part of their load of gravel, sand, and clay, which was left in these hillocks and ridges when the enclosing ice-walls melted away.

Plateaus of gravel and sand, deposited similarly as kames but filling broader indentations of the retreating ice-front, have a considerable development in the vicinity of Sandy lake, with altitudes 50 to 75 feet above the lake level. They also occur west of Carlton and close southeast of Cloquet, and in numerous other localities. Within one to two miles south of White Iron lake, they are described by Mr. Elftman as forming flat-topped hills about 100 feet high.

Eskers, which are also the deposits of glacial streams but differ from kames in forming prolonged, narrow ridges, a half mile to one mile or sometimes several or many miles in extent, are infrequent in this state. Only a few examples have been noted in the large northeastern region which is here reported, and none has been traced along a distance of more than one or two miles.

Valley Drift and Plains.

Moderately undulating or nearly level tracts of sand and gravel, spread on the land in front of the retreating ice-sheet by streams which had gathered this modified drift from the melting ice surface, are found extensively developed in Wadena, Hubbard, Cass, Crow Wing, and St. Louis counties, and to less degree in many other portions of northeastern Minnesota. Areas reaching ten to twenty miles on each side of the Crow Wing, Pine, and St. Louis rivers, consist of these plains, often bearing chiefly jack pine (Pinus banksiana), but in their more rolling and ridgy portions also commonly bearing the red or Norway pine. Where these lands are very moist, lying only a few feet above the stream courses, and especially, as in parts of the St. Louis basin described by Mr. Spurr, where thin deposits of till are spread like a veneer above the modified drift, the larger and more valuable white pine grows. The soil preferred by this tree, however, is the till or boulder-clay, which generally rises higher than these areas of modified drift and bears a heavy growth of hardwood (species of poplar, birch, oak, elm, ash, maple, basswood, and other deciduous trees), interspersed with white pine, sometimes only seen here and there as scattered trees, but frequently occurring in small or large groves, from a few rods to several miles in extent.

VI. THE WESTERN SUPERIOR GLACIAL LAKE, AND THE LATER GLACIAL LAKES WARREN AND ALGONQUIN.

If the courses of the Fergus Falls and Leaf Hills moraines are rightly traced as noted in the foregoing pages, the earliest outlet from the Western Superior glacial lake, held by the barrier of the waning ice-sheet still occupying the central and eastern part of that lake basin, probably flowed across the divide between the head streams of the Bois Brulé and St. Croix rivers, where a remarkable eroded channel is found.* The indentation of the ice-front north of the Wisconsin driftless area at the time of formation of the first or Altamont moraine points decisively to the melting backward of a great re-entrant angle in the ice boundary upon the country between Duluth and Ashland, including the place of the Bois Brulé-St. Croix outlet, at a time previous to the melting of the ice upon the district reaching west from that outlet to Aitkin county. The correlations of retreatal moraines given here and in the second volume of the Final Report imply the probable beginning of existence of the Western Superior ice-dammed lake between the times of formation of the seventh and eighth or Dovre and Fergus Falls moraines. But after the accumulation of the latter and before the time of the next or Leaf Hills moraine, the ice-melting in the western portion of the lake Superior basin and thence west to the Mississippi river was very rapid, so that the greater part of Aitkin county, the whole of Carlton county, and the country from Duluth north to Grand, Wild Rice, and Island lakes, and from Two Harbors north to Highland station, were uncovered from the departing ice-sheet. According to the probable duration of the glacial lake Agassiz, estimated to have been only about 1,000 years†, in which the stage between

*Geology of Minnesota, Final Report, vol. ii, pp. 642, 643.

†Geol. and Nat. Hist. Survey of Canada, An. Rep., new series, vol. iv, for 1888-'89, pp. 50, 51 E.

the Fergus Falls and Leaf Hills moraines was a small fraction, this retreat of the ice from Aitkin and Carlton counties and the west end of lake Superior appears to have occupied no more than a century or perhaps only half a century.

The old channel of outflow to the St. Croix river has a width of about a fifth of a mile in its narrowest place. Its bed is 1,070 feet above the sea, or 468 feet above lake Superior; and it is bordered by bluffs about 75 feet high, showing that when the course of outflow began here the Western Superior glacial lake was about 550 feet above the present lake level. Probably the highest part of the swamp now forming the watershed in the channel has been filled twenty to twenty-five feet since the lake forsook this mouth, which was thus lowered by erosion some 100 feet, from 1,150 to 1,050 feet, approximately, above the present sea level. Beaches and deltas referable to this glacial lake are found, as described by Dr. A. C. Lawson,* in Duluth and its vicinity and on Mt. Josephine, near Grand Portage, showing that the lake while outflowing to the St. Croix had been extended, by the recession of the ice-sheet, along all the northwestern shore of lake Superior in Minnesota; but it may well be doubted whether it continued far into Canadian territory. Before the recession of the ice-sheet had uncovered the country about Port Arthur and farther eastward, probably its departure from Wisconsin and Michigan had permitted the glacial representatives of lakes Superior and Michigan to become confluent over the low divide of the Au Train and Whitefish rivers, the latter of which is tributary to the Little bay de Noc. The Western Superior glacial lake, suddenly falling about 60 feet, as is shown by the hights of successive beaches and deltas, then became merged in the glacial lake Warren,† outflowing at Chicago to the Des Plaines and Illinois rivers.‡

Dr. Lawson, in his report before cited, has not discriminated between the traces of the earlier lake outflowing to the St.

*"Sketch of the Coastal Topography of the North Side of Lake Superior, with Special Reference to the Abandoned Strands of Lake Warren," Minnesota Geol. Survey, Twentieth An. Rep., for 1891, pp. 181-289, with map, profiles, and figures from photographs.

†Named by Prof. J. W. Spencer in honor of Gen. G. K. Warren, Science, vol. xi, p. 49, Jan. 27, 1888; Proc. A. A. A. S., vol. xxxvii, for 1888, pp. 197-199; Trans., Roy. Soc. of Canada, vol. vii, for 1889, sec. iv, p. 122.

‡For my former discussions of the later stages of the glacial lakes and retreat of the ice-sheet in the St. Lawrence basin, see "Glacial Lakes in Canada," Bulletin, Geol. Soc. of America, vol. ii, for 1890, pp. 243-276; and "Relationship of the Glacial Lakes Warren, Algonquin, Iroquois and Hudson-Champlain," Ibid., vol. iii, for 1891, pp. 484-487.

Croix and those of lake Warren; but this seems desirable for convenience and definiteness in description and discussion. Many small glacial lakes, and a few as here attaining large size, became finally merged, by the retreat of the ice, in the single vast expanse of lake Warren, which stretched from Duluth eastward and southeastward to the west end of the basin of lake Ontario, covering the whole or the greater part of the four higher Laurentian lakes. In the western part of the lake Superior basin the ancient high shore lines, with their evidences of wave erosion and deposition, belong, from hights (above the present lake) of 450 or 475 feet up to 607 feet, the highest observed by Dr. Lawson, to the Western Superior lake. Below these hights, the numerous lower shores mark successive stages of lake Warren, which were due only in very slight measure to erosion of its outlet, but which the present writer confidently believes to have been caused almost entirely by a progressive uplift of this region, elevating the northern and northeastern parts of the area of the great glacial lake, while its outlet and some southwestern portions of its area remained with little or no change of hight.

A quite different view is given by Dr. Lawson, who thinks that lake Warren was not held in by the retreating ice-sheet, but by land barriers, the country on the south and east having been relatively higher than now, and that the differential subsidence of the land there and contemporaneous uplifting of the country about Hudson bay went forward without disturbance of the horizontality of the old shore lines enclosing lake Superior. On the west, however, I have ascertained for the southern half of the area of the glacial lake Agassiz, in the basin of the Red river and of lake Winnipeg, that it experienced a differential uplift increasing about one foot to the mile from south to north during the departure of the ice-sheet. On the east, Mr. Frank Leverett has demonstrated that the beaches of lake Warren south of lake Erie were contemporaneous with the accumulation of adjacent moraines;* and the basin of lake Iroquois, the glacial expansion of lake Ontario, according to levelling by Gilbert and Spencer, has been uplifted like that of lake Agassiz, but with a greater northward ascent of the old Iroquois beach, amounting to five feet per mile for fifty miles from Rome to near Watertown, N. Y. It seems therefore improbable, in the first place, that lake Warren occupied a land-

*Am. Journ. of Science, III, vol. xliii. pp. 281-301, with maps, April, 1892.

locked instead of an ice-dammed basin, and, secondly, that these recent differential epeirogenic† movements on each side failed to extend across the area of lake Superior.

The great Pleistocene lakes Agassiz, Warren, Algonquin, and Iroquois, were probably due alike to the barrier of the waning ice sheet; and their basins appear to have shared in a general epeirogenic uplift of the whole drift-bearing area of our continent, when it was relieved from its ice burden. Under this view, the highest shores at Duluth and on Mt. Josephine seem readily referable to an ice-dammed lake in the western part of the Superior basin outflowing in the eroded channel at the head of the St. Croix river, from which there is an ascent of about 140 feet in a distance of 120 miles northeast to the 607 feet shore terrace noted by Lawson on Mt. Josephine. Later, for the earliest and highest stage of lake Warren, likewise ice-dammed, with outlet to the Mississippi across the low divide at Chicago, about 595 feet above the sea, we have now an ascent of 420 feet in about 350 miles to the highest shore found by Lawson near the Sault Ste. Marie, at a hight of 414 feet above lake Superior. The differential uplifts thus indicated for both of these old lake shores are similar in their vertical amount and geographic extent with the fully known epeirogenic uplift of the lake Agassiz area.

BEACHES.

The upper limit of lacustrine action in Duluth and its vicinity is marked by discontinuous beach deposits on the upper part of the steeply ascending bluffs at an altitude of 535 feet to 540 feet above the lake. In the recess between two projections of rock at the top of the Seventh Avenue inclined railway, where the hight of this shore was determined by Dr. Lawson, it appears as a small terrace of sand and fine and coarse gravel, 12 to 15 rods long and about 5 rods wide. The verge of its flat surface is on the level of the railway station floor, and thence the terrace rises four or five feet to where it adjoins the till and rock slopes. In front the same gravel and sand fall off about 20 feet within a few rods, and then spread out again in a similar lower and longer terrace, eight to ten rods wide, with its surface gently inclining lakeward at 515 to 505 feet, approximately. These

†The terms *epeirogeny* and *epeirogenic* (continent-producing, from the Greek *epeiros*, a mainland or continent) are proposed by Mr. G. K. Gilbert (in "Lake Bonneville," Monograph I, U. S. Geol. Survey, 1890, p. 340), to designate the broad movements of uplift and subsidence which affect the whole or large portions of continental areas and of the oceanic basins.

deposits were brought partially by inflowing waters from above, being so far of delta character, and partially by shore currents from wave erosion of the adjoining bluffs on each side, being for such portion more strictly beach accumulations. They mark stages of the Western Superior lake when its mean levels here were about 535 and 510 or 515 feet above lake Superior.

Next below these shore lines is the most definite and persistent beach of the entire series, both of the Western Superior lake and the ensuing lake Warren. This was generally represented along the bluff face by a narrow beach terrace or slight shelf, less steep than the slopes below and above it, so that its contour line, 470 to 475 feet above the present lake, has been used as the course of a driveway, known as "the boulevard," which has been graded and is much used for pleasure driving, along an extent of four miles, above the principal part of the city of Duluth, from Miller's creek to Chester creek. Beyond these limits the boulevard is planned to be extended for distances of four miles more, both to the southwest and northeast, following the same altitude and shore line, giving a total length of twelve miles. Its hight is only a few feet above the water divide in the old channel of outflow from the Western Superior lake to the St. Croix; but, if we make due allowance for the partial filling of that channel with postglacial alluvium and peaty swamp deposits, it seems probable that this latest shore of that glacial lake has now an ascent of 15 or 20 feet in the distance of about 25 miles from its outlet north-northwest to Duluth. The earlier and higher shores here were made when the erosion of the outlet lacked successively about 65 and 30 or 35 feet of its final depth; but a certain part of its earliest erosion had been done before the retreat of the ice extended the lake to this northwest coast. These three beaches of the Western Superior lake may be conveniently designated as the First and Second Duluth beaches and the Boulevard beach.

Between the neighborhood of Duluth and Mt. Josephine, no definite observations of the Western Superior glacial lake shore lines have been obtained, although there can be no doubt that they extend continuous along this distance, which is about 130 miles in a nearly direct northeastward course. When the woods of this high coast shall be cleared off, as will probably sometime be done in many places for farming and pasturage, the beach levels will be observed, especially the highest and lowest of the three noted at Duluth. Attempting to correlate these beaches with those found by Lawson on Mt. Josephine, I identify the 535 feet and 510 to 515 feet Duluth shores as respectively his 607 and 587 feet shores; and the 475 to 470 feet beach of the Duluth boulevard becomes apparently the conspicuous 509 feet beach of Mt. Josephine. The total differential uplifting of the two upper shores between these localities has been about 70 feet, of which about half had been accomplished previous to the time of the Boulevard beach. This progressive uplifting of the land soon after the recession of the ice, while indeed the ice barrier yet remained in the eastern part of this lake basin, is in full parallelism with the epeirogenic movements which gave their northward ascents to the beaches of lakes Agassiz and Iroquois, and, as Prof. J. W. Spencer and Mr. F. B. Taylor have shown, to the beaches of various portions of lakes Warren and Algonquin.

During the past season's field work I obtained numerous observations of the beaches of the Western Superior lake near Thomson, and between Carlton and Wrenshall, some 15 miles southwest of Duluth, and in the vicinity of Holyoke, a station of the Great Northern railway, 15 miles south of Carlton. Near Holyoke, which is about 30 miles west of the outlet at the head of the Bois Brulé and St. Croix rivers, the successive lake levels indicated by the beach ridges observed and provisionally referred to the Western Superior lake are about 520, 500, and 455 feet above lake Superior, corresponding well with the slightly inclined planes of the Duluth and Mt. Josephine shores, and indicating a lowest water surface of about 455 feet at the outlet.

Eight beaches of lake Warren, mostly on the same levels with its well defined deltas, were also observed in the vicinity of Duluth, on the Northern Pacific railroad from West Superior to Wrenshall, and on the Great Northern railway to the vicinity of Rhodes' Mill, four miles northeast of Holyoke. The highest three of these shore lines bear conspicuous deposits of beach sand and gravel which are cut by the railroad, the first being one and a half miles southeast of Wrenshall, the second nearly a mile farther east, and the third close west of Barker station, about a half mile east from the last. The altitudes of their crests at the railroad cuts are respectively 427, 401, and 361 feet above lake Superior; and the mean water levels of lake Warren while these deposits were being accumulated appear to have been approximately at 410, 385, and 350 feet. Of these the first, which was the highest level of lake Warren, held during only a very short stage, is represented by the fourth in the series of deltas of Chester creek in Duluth; and the second and third have their representation in the fifth of those deltas, while apparently the second is the Nelson beach, and the third the McEwen beach, of Mr. F. B. Taylor's observations along the south side of lake Superior, north of lake Huron, and in the vicinity of lake Nipissing.* The Nelson beach, generally marking the highest well defined shore of lake Warren, is 410 feet above lake Superior at Houghton, Michigan; 414 feet near the Sault Ste. Marie; and 538 feet, or 1,140 feet above the sea, near North Bay, lake Nipissing. The McEwen beach, supposed to have been formed when lake Warren at Duluth stood about 350 feet above lake Superior, is identified as the 365 feet shore terrace at Ste. Marie, while near lake Nipissing its hight from the same plane is 488 feet, being 1,090 feet above the sea level. In Dr. Lawson's series of observations, the higher and earlier shore of 410 to 415 feet near Wrenshall and at Duluth seems to be probably represented by the 440 to 458 feet plain and terrace at Grand Portage, and by the 455 feet terrace of an old delta plain on the Kaministiquia river; and near lake Nipissing, according to my correlation with Mr. Taylor's notes, it is found about 1,205 to 1,220 feet above the sea.

To present concisely the results of my studies of the whole series of lake shores observed by me at and near Duluth, in their probable correlations with the shores observed farther eastward by Dr. Lawson, Mr. Taylor, and Prof. Spencer,† notes of the twelve lake levels found here are successively presented as follows, in descending order, their altitudes being given in feet above lake Superior. On northern portions of the lake Superior coast several of these seem to be each represented by two or more shores, separated by distinct vertical intervals of 10 feet or more. Most of the beaches, it should be remarked, are very feebly developed, even in the most favorable situations for their formation, and are not discernible along the far greater part of all the lake borders. During all the time of uplifting of the basin and sinking of the water surface by its finding successively lower outlets and by their erosion

*Bulletin, Geol. Soc. America, vol. v, pp. 620-626, with maps, April, 1894. Am. Geologist, vol. xiii, p. 220, March, 1894; and 316-327 and 365-383, with maps, May and June, 1894. Am. Jour. Sci., III, vol. xliii, pp. 210-218, March, 1892.

†J. W. Spencer, Am. Jour. Sci., III, vol. xli, pp. 12-21, with map, Jan., 1891; same vol., pp. 201-211, with map, March, 1891. Bulletin, Geol. Soc. of America, vol. ii, pp. 465-476, with map, April, 1891.

from higher to lower levels, whenever the diminishing lacustrine area was nearly unchanged for a few years or longer, the erosion and deposition effected by the great waves of storms, and the tribute of streams forming deltas, recorded these shore lines.

BEACHES OF THE WESTERN SUPERIOR GLACIAL LAKE.

First Duluth beach: at Duluth, 535 feet above lake Superior; on Mt. Josephine, 607 feet; at Kimball, Wis., 570 feet; at L'Anse and Marquette, Mich., about 590 feet.

Second Duluth beach: at Duluth, 510 or 515 feet; on Mt. Josephine, 587 feet.

Boulevard beach: at Duluth, 470-475 feet; on Mt. Josephine, 509 feet.

BEACHES OF THE GLACIAL LAKE WARREN.

Belmore beach (name given by Prof. N. H. Winchell to the corresponding earliest shore line of lake Warren in Ohio†): near Wrenshall and in Duluth, 410-415 feet; at Grand Portage, 440 feet; on the Kaministiquia river, 455 feet; at Mackenzie, on the Canadian Pacific railway 13 miles northeast of Port Arthur, Dr. Lawson's descriptions indicate that this lake level, at about 475 feet, adjoined the melting ice-sheet (l. c., p. 264); eight miles east of Cartier, about 600; southeast of lake Nipissing, 605-620. The "Ridgeway beach" of Prof. Spencer.

Nelson beach (named by Taylor in the vicinity of North Bay, lake Nipissing; probably united with the Belmore beach in Ohio and northward to Mackinac island): at Duluth, 385 feet; at Mackenzie, a morainic terrace, 420 feet; at Jackfish bay, 418; Sault Ste. Marie, 414; Houghton, 410; North Bay, 538. · The "Algonquin beach" of Mr. Taylor on Mackinac island, at 185 feet; near Petoskey, about 80 feet; and at Traverse City, 60 feet. The hights (likewise above lake Superior) of this shore about Green bay of lake Michigan are noted by Mr. Taylor as follows: at Green Bay, 0; six miles north of Menominee, 30 feet; South Bay hill, 115 feet; Cook's Mill, near the head of Big bay de Noc, 150 feet.

McEwen beach (named by Taylor near North Bay): at Duluth, 350 feet; Schreiber and Terrace bay, 391-2; Sault Ste. Marie, 365; North Bay, 488.

Thibeault beach (also named by Taylor near North Bay): Great Northern railway, about 2½ miles northeast of Foxboro, 290-300 feet; Mt. Josephine, 313; Mackenzie, 327; Sault Ste. Marie, 311.

Double Bay beach: at Duluth, 255-260 feet; at Double bay, 279 feet; on Isle Royale‡, about 270; Carp river, 288.

First Beaver Bay beach: at Duluth, 155–160 feet; at Beaver bay, 173 feet; eastward represented by two beaches:—*a*, at Grand Portage, 232 feet; at Carp river and Pie island, 222; at Terrace bay, 243; at Sault Ste. Marie, 224; on the Keweenaw peninsula, 220;—*b*, at Mazokamah, 214; Terrace bay, 228: Dog river, 216; Sault Ste. Marie, 208; on the Keweenaw peninsula (Taylor and Lane), about 200.

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†Proc. Am. Assoc. for Adv. of Sci., vol. xxi, for 1872, pp. 171-179. Geology of Ohio, vol. ii, 1874, pp. 56, 418, 433.

‡Altitudes of this and other lower shore lines on Isle Royale are kindly supplied by Dr. A. C. Lane, from unpublished observations for the Geol. Survey of Michigan.

Second and Third Beaver Bay beaches (becoming three northeastward): at Duluth, 85-90 feet; Beaver bay, 126 and 115; Pigeon river (third), 134; Isle Royale, about 130; shore above Carp river, 164, 128, and 122; Port Arthur (third), 149; Silver Islet, 168, 161, 149; Jackfish bay, 176, 158: Sault Ste. Marie, 150; Keweenaw peninsula, 170, 150, 145–125 (delta of Huron creek, A. C. Lane).

Chester Creek beach: at Duluth, 45-50 feet; Beaver bay, 80; Isle Royale, 90; McKellar's point, 101; Port Arthur, 118; Nipigon, 132; Montreal river, 135; Mamainse, 122.

BEACH OF THE GLACIAL LAKE ALGONQUIN.

Algonquin beach (named by Prof. Spencer, in Proc. A. A. A. S., vol. xxxvii, p 199): at Duluth, united with the present lake beaches; at Beaver bay, 20 feet; Good Harbor bay, 27; Grand Portage, 38; McKellar's point, 48; Carp river, 52; Pie island, 43; Port Arthur, Nipigon, and Montreal river, 61; Sault Ste. Marie, 49; Houghton and Marquette, about 25; near Algoma, 60-80; near North Bay, on lake Nipissing, 140. The Nipissing beach of Mr. F. B. Taylor; but not his "Algonquin beach" on Mackinac island (Am. Jour. Sci., III, vol. xliii, pp. 210-218), which is the highest of the lake Warren shores, being apparently the compound representative of the Belmore and Nelson beaches.

The front of the departing ice-sheet was the barrier of the Western Superior glacial lake while the one receded and the other advanced from Duluth northeastward to Mt. Josephine and the most northeastern point of Minnesota, and eastward to Marquette. When the farther glacial recession opened the space for this lake and the similarly expanding lake Warren to be merged together above the low land of the eastern part of the Michigan upper peninsula, the Western Superior waters fell about 60 feet below their former outlet to the St. Croix, and thenceforward the outlet of lake Warren past Chicago carried away the drainage from the glacial melting and rainfall of the Superior basin. At a time that was probably somewhat later than the end of the Western Superior lake, its analogue, the Western Erie glacial lake, which had outflowed past Ft. Wayne, Indiana, to the Wabash, Ohio, and Mississppi rivers, became likewise lowered and merged in lake Warren, which in its soon ensuing maximum stage stretched from the south end of lake Michigan to the north side of lake Superior, northeast to lake Nipissing, and eastward to the east end of lake Erie and the southwestern limits of the lake Ontario basin. While the outlet continued at Chicago, all the northern part of the area of lake Warren, extending about 600 miles from Duluth to lake Nipissing, was uplifted hundreds of feet.

The uplifting was approximately uniform for this entire extent, and indeed for the whole width of the Superior basin, reaching 150 miles from south to north; so that the present altitudes of the elevated beaches, while somewhat inclined, are yet through long distances so nearly horizontal that they partially and in a remarkable degree justify Dr. Lawson's opinion that the ancient lake levels remain parallel with that of to-day. The sum of all the epeirogenic movements since the formation of the Belmore and Nelson beaches, along a nearly due north line measures as follows, in comparison with the Chicago outlet: from Chicago for about 185 miles north to the southern end of Green bay, very little, the old shore still being nearly unchanged; about the north end of Green bay, at the head of the Big bay de Noc, 150 feet; at Houghton, on the Keweenaw peninsula, 410 feet; and at the north side of lake Superior, 420 feet, or more probably 475 feet. Along a west to east belt 50 to 100 miles wide, including the upper peninsula of Michigan, the rate of differential uplifting ranged from one to five feet per mile from south to north; while on a large area farther north there was little differential movement, but in general a surprisingly uniform and regular elevation of the lake Superior district.

When the glacial melting and retreat at length permitted an outflow from the St. Lawrence basin over a lower pass, which was through central New York to the Mohawk and Hudson, the water surface of the basins of lakes Michigan, Huron, and Superior, fell only some 50 or 75 feet, from the latest and lowest stage of lake Warren to its short-lived successor, lake Algonquin. This lake was ice-dammed only at low places on its east end, as at or near the heads of the Trent and Mattawa rivers, lying respectively east of lakes Simcoe and Nipissing, where otherwise its waters must have been somewhat further lowered to outflow by those passes. A careful study of the late glacial epeirogenic uplifting of all portions of the St. Lawrence drainage area, as known by the present inclinations of its many shore lines, convinces me that Gilbert* and Wright† have overestimated the importance of the outflow, if any such took place, from lake Algonquin past the present lake Nipissing to the Mattawa and Ottawa rivers. Professor Spencer's Algonquin beach is very clearly the Nipissing beach of Mr.

*Proc. Am. Assoc. for Adv. of Science, vol. xxxv, for 1876, pp. 222, 223. "The History of the Niagara River," Sixth An. Rep. of the Commissioners of the State Reservation at Niagara, for the year 1879, pp. 61-84, with maps and sections (also in the Smithsonian An. Rep. for 1890, pp. 231-257).

†Bulletin, Geol. Soc. of America, vol. iv, pp. 423-5; with ensuing discussion by Dr. Robert Bell, pp. 425-7.

Taylor; and this earliest and principal stage of lake Algonquin is shown by these beaches to have coincided closely in area with lakes Michigan and Superior, but to have been considerably more extensive eastward than the present lake Huron and Georgian bay. It held a level which now by subsequent differential epeirogenic movements is left probably wholly below the present level of lake Michigan by a vertical amount ranging from almost nothing to about 40 feet. Its shores were nearly coincident with the western shore of lake Huron, but eastward they are now elevated mostly 150 to 200 feet above that lake and Georgian bay; and in the lake Superior basin they vary from about 50 feet above lake Superior at its mouth, and along its northeastern and northern shores, to 25 feet at Houghton, and to a few feet or none at Duluth. The earliest outflow of lake Algonquin doubtless passed southward by the present course of the St. Clair and Detroit rivers; thence it ran east as a glacial River Erie, following the lowest part of the shallow bed of the present lake Erie, which then had an eastward descent of probably 200 feet, allowing no lake or only a very small one to exist in the deepest depression of the basin; and north of Buffalo it coincided with the course of the Niagara river.

The Niagara gorge has since been eroded by the recession of its waterfall; and the outflow from the upper Laurentian lakes has been constantly pouring over the receding cataract, excepting possibly (but improbably) that it may have been diverted for some very short time, as less than a century, to the Mattawa. It seems to me far more probable that the epeirogenic uplift of the Nipissing region, which had elevated it about 450 feet during the existence of lake Warren, continued so fast that both the Trent and Nipissing–Mattawa passes were raised above the level of lake Algonquin before the glacial retreat uncovered the country east of them so that outlets could be obtained there.

With the continuance of the uplift of the lake Superior basin after the formation of the Algonquin beach, the mouth of lake Superior and the Sault Ste. Marie came into existence; and this movement allowed the lake level at Duluth to fall probably 40 or 50 feet beneath the Algonquin and present shore line. Subsequent differential elevation of the eastern and northern parts of the basin, as compared with Duluth, has again brought the west end of the lake up to the Algonquin shore; but not until the St. Louis river, while the water surface stood considerably lower than now, had deeply eroded its broad channel through the very gently sloping expanse of till from Fond du Lac to the harbor of Duluth and Superior.

It would be very interesting to trace the relationship of the epeirogenic uplifting of the lake Warren basin with those of the contemporaneous lake Agassiz on the west and the slightly later lake Iroquois on the east, but the limits and scope of the present report forbid this. Nor can we here consider what these glacial lakes teach concerning the recession of the ice-sheet from New York and New England, which are thus clearly shown to have been the last portion of the United States, at least eastward from the Rocky mountains, to be uncovered from the fast waning continental glacier. The retreatal moraines of all the drift-bearing area east of the great angle of the drift boundary in southwestern New York appear, in the light of these studies, to be somewhat (though not many hundreds of years) newer than all the series of moraines within the limits of the United States west from that angle to Minnesota and North Dakota.

DELTAS.

Not only the St. Louis river, but also many small streams in the vicinity of Duluth, brought noteworthy deltas of gravel and sand into the formerly much higher glacial lakes which represented lake Superior. The largest delta plain which I observed reaches about a mile eastward from the St. Louis river at Thomson and has an altitude of 455 to 460 feet above the present lake. It was probably formed nearly at the old lake level or within a few feet below it, contemporaneous with the formation of the Boulevard beach. Still water deposits, laid down at a short distance off shore, swept by the prevailing winds and shore currents southward from the mouth of the St. Louis, as it then was, are now found as the beds of stratified clay worked for brick-making at and near Wrenshall, three to four miles south of this delta. Numerous other sand and gravel deltas of the St. Louis, mostly of small extent, will doubtless be easily recognized by adequate search; and the corresponding finer silts borne southward thinly cover many tracts of the wooded Nemadji drainage area, above its much greater thickness of till.

On Tischer's creek, in the northeastern suburbs of Duluth, large terrace remnants of a delta which was brought in during the stage of the First Duluth beach are found at 540 to 550 feet, about a quarter to a third of a mile north of the Hardy School. Other and lower deltas of this stream lie west of this school house and within a quarter of a mile south.

The most interesting series of deltas, however, which I examined in Duluth is situated along the course of Chester creek. Besides its present course, this creek sent a part of its waters into the Western Superior glacial lake by a more western channel, occupied by a very small brook, there depositing the conspicuous gravel and sand banks above and below the boulevard a half mile southwest of Chester creek, which are now being extensively excavated by the city street department and in part for use as masons' sand. Along Chester creek I noted nine successive delta terraces or small plains, usually well represented on each side of the creek, which has cut deeply through them to the underlying rock or steep till slope. In their descending order, these have the following altitudes:

1. About 540 to 530 feet; belonging to the First Duluth stage.
2. About 510 to 490 feet; representing the Second Duluth beach.
3. At 480 to 460 feet; deposited during the time of the Boulevard lake level.
4. At 420 to 410 feet; the Belmore level.
5. From 380 to 350 feet; representing together the Nelson and McEwen beaches.
6. From 260 to 230 feet, including the former site of the Forest Hill cemetery; the Double Bay beach. (Probably a delta deposit may be found nearly midway between the last two, at the Thibeault shore line.)
7. At 160 to 150 feet; on the first Beaver Bay shore line.
8. At 90 to 75 feet; corresponding to the Second and Third Beaver Bay beaches.
9. At 50 to 45 feet, close to the mouth of this creek, and rising immediately on the north side of the Duluth & Iron Range railroad. From this delta is derived the name of the Chester Creek beach.

After examining this series of deltas and mapping their locations, the altitudes here noted were obtained from a large scale contoured map of Duluth in the office of Mr. D. A. Reed, the city engineer.

IV.

PRELIMINARY REPORT OF FIELD WORK DURING 1893 IN NORTHEASTERN MINNESOTA.

BY ULYSSES SHERMAN GRANT.

CONTENTS.

ITINERARY.

During the last week in June and the first in July the writer accompanied Prof. N. H. Winchell on a trip along the north shore of lake Superior from Grand Marais to the end of Pigeon point and return. Quite a number of the more important localities along this shore were examined, an account of which will be given by Prof. Winchell. After returning to Grand Marais another trip of ten days was made northward and northwestward, by what is known as the "Iron trail," to Brulé lake and thence to Gunflint lake, where a week was spent in examining the iron-bearing rocks in T. 65-4.* In the first part of August the writer participated in the excursion of the Geological Society of America through the mining regions of Michigan. On returning to the field in the last part of August the region of Gunflint lake and that west, south and east of this lake was examined, and data were obtained for a geological map of this region. This work continued until the early part of October, when a few days were spent in company with Messrs. N. H. and H. V. Winchell in visiting some of the critical exposures near Tower.

MAPPING ACCOMPLISHED.

At the beginning of the season the writer was assigned that part of Minnesota lying in ranges 2-7 west of the Fourth principal meridian to map geologically and topographically. Of course it was impossible, with the time and assistance allowed, to cover all this area (over 1500 square miles) much more carefully than already had been done; consequently that part lying between T. 63 and lake Superior was neglected and the work was concentrated on the rest of the area.

The part of the Mesabi range in this portion of the state was divided into three divisions (plates), in which more detailed work was done than on the rest of the region, and in each division the vicinity of the outcrop of the iron-bearing rocks received more attention than the rest of the plate. These plates and their approximate areas are as follows:

Plate 80.—Ts. 63-64, Rs. 6-7; 144 square miles; Fraser Lake plate.
Plate 81.—Ts. 64-65, Rs. 4-5; 143 square miles; Akeley Lake plate.
Plate 82.—Ts. 64-65, Rs. 2-3; 101 square miles; Gunflint Lake plate.

The amount of mapping accomplished is outlined in the two following sections.

I. TOPOGRAPHY.

This part of the work was done under the direction of the writer by Messrs. C. P. Berkey, L. A. Ogaard and Alex. N. Winchell. Mr. Berkey, who was in charge of this work during July and August, was in the field from June 26th to September 2d;† Mr. Winchell from June 26th to August 26th; Mr. Ogaard from June 26th to October 5th, but during September and October considerable of his time was devoted to other duties.

The altitudes of all the principal lakes, and of a large num-

*In this paper the "Range" is always *west* of the Fourth principal meridian.

†Mr. Berkey has written an account of his work on the topography, which appears later in this volume.

ber of the smaller ones, were ascertained accurately by levelling from lake Superior.* By means of aneroid barometers and hand levels data were obtained for the drawing of contour lines, which are fifty feet apart. The topographical work on that part of the Mesabi range mapped by the above mentioned party is much more accurate than that done by parties of the survey further west, for two reasons; first, the levels of the lakes were accurately determined, and second, these lakes were used as checks on the aneroids every few hours. The results of the work of 1893 and that of the writer for 1892 are as follows:

Plate 80.—Levels of most of the lakes by barometrical readings; location of the prominent hills; very little accurate contouring. This, however, is an unimportant sheet.

Plate 81.—Practically complete, excepting some of the northwestern part.

Plate 82.—Practically complete.

In the region south of these plates, except in the vicinity of Brulé and Ida Belle lakes where the contouring is nearly complete, very few data have been obtained. To the north of these plates the levels of almost all the lakes are known, mostly by aneroid readings, and some contouring has been done. The hights of the lakes between Gabemichigama lake and Ely (by way of Knife and Basswood lakes) were obtained by level.†

II. GEOLOGY.

In the mapping of plates 80, 81 and 82 the writer found it necessary to go over the entire ground anew and depended but very little on the mapping of former parties of the survey, as their work was more in the nature of a reconnaissance than of accurate mapping. In addition to a careful survey of the lake shores, with very frequent trips inland, nearly all north and south section lines were followed in the vicinity of the iron-bearing rocks and the Animikie, and occasionally sections were crossed one to four times. The mapping done during the last two seasons and some in 1891 is as follows:

Plate 80.—Practically complete, but less time was devoted to

*The levelling was done by Mr. L. A. Ogaard, assisted by Alex. N. Winchell. The writer can vouch for the care and accuracy with which this work was done, sometimes under decidedly embarrassing circumstances.

†The hights of many of the lakes and points in the area here reported on can be found on pages 22-25 of Mr. Warren Upham's report in this volume; also in the report of Mr. C. P. Berkey.

this plate than to the others as it is very largely covered by gabbro.

Plate 81.—Practically complete.

Plate 82.—Practically complete.

In the region south of these plates, except around Brulé and Ida Belle lakes and in T. 62-6, nothing has been accomplished since the publication of the geological map in bulletin number 6. The mapping of the region north of these plates is practically complete. Special attention has been given to the vicinity of Kekequabic lake, of which a map has been published (see the 21st Ann. Rept., pl. I), and to the outlines of the Saganaga granite (see the 20th Ann. Rept., pp. 83–95). The lakes lying between Ogishke Muncie and Ottertrack lakes have been examined and work supplementary to that of the former parties of the survey in this region has been done.

SKETCH OF RESULTS OF GEOLOGICAL WORK.

While opportunity has not been had for a careful examination of the specimens collected during the last two years, and for the preparation of a report on this region, still there are some points, which were brought out by the field work and some little study since, that are sufficiently clear to warrant a preliminary statement of the results reached.

I. THE KEEWATIN.

The lakes south of Ottertrack lake in T. 66–6 and the north half of T. 65–6 have been examined and the rocks found to be of the usual Keewatin strata with some areas that consist of volcanic tuff. Large and beautiful exposures of Ogishke conglomerate occur on the shores of the lake in S. W. ¼ sec. 36, 66–6.

The Keewatin in the northern part of the southern half of Ts. 65–4 and 65–5 is composed almost entirely of greenstone and greenstone schists. Some of these greenstones show fragmental materials and are probably of the nature of volcanic tuff, while other parts are undoubtedly massive eruptives.

The outlines of the Saganaga granite in Minnesota have been traced, and abundant evidence has been found to show the eruptive nature of this granite in the Keewatin rocks. Part of this evidence has been published* for the western edge of this granite area, and during the last two years facts pointing the same way have been noted along the southern edge of this

* U.S. Grant. 20th Ann. Rept., pp. 83-95, 1893. Amer. Geol., vol. x, pp. 4-10, 1892.

granite where it comes in contact with the greenstone. The proofs of the eruptive nature of the granites of Saganaga, Kekequabic and Snowbank lakes and of the Giant's range have been stated before by the writer,* and in the case of the Kekequabic lake granite the matter has been treated in some detail.† Mr. J. E. Spurr, who has been at work for the survey on the Mesabi range west of the Duluth and Iron Range railroad during the last summer, also states that there is abundant evidence of the intrusive and metamorphosing nature of the granite of the Giant's range in that district.‡

It frequently happens, that, where these granites come in contact with the surrounding rocks, schists more crystalline than those of the usual Keewatin occur. To these more crystalline and completely crystalline schists the Minnesota survey has applied the term *Vermilion*, which is regarded as a synonym of Dr. A. C. Lawson's *Coutchiching*. The Vermilion rocks have been supposed to occupy a distinct stratigraphical position below and older than the Keewatin. The writer has already called attention to the fact that in the region of the Kawishiwi river (Ts. 63–9, 63–10 and 63–11 W.) there seem to be good reasons for not separating the rocks mapped as Vermilion from the Keewatin.§ During the field work of the past two seasons additional facts have been collected concerning these more crystalline rocks (Vermilion), facts sufficient to justify the statements (1) that the rocks called Vermilion in the region of the writer's field work are not necessarily lower in the geological scale than the Keewatin, but that they occur at various horizons in the Keewatin, (2) that they are only a more crystalline condition of these same Keewatin rocks, and (3) that they probably owe their more crystalline nature largely to their close proximity to areas of intrusive granite. It will be noticed that the Vermilion rocks as mapped usually occur between areas of Keewatin and granite; in this connection consult especially plates 10 and 11 of Bulletin No. 10 and the geological map accompanying Bulletin No. 6. And, as stated above, some of these granite areas are known to be intrusive, and very probably others not mentioned above are of the same nature. The gradual transition from the Keewatin to the Vermilion rocks has been described by Messrs. N. H., A. and H. V. Winchell in

* 20th Ann. Rept., pp. 37-38, etc., 1893.

† 21st Ann. Rept., pp. 37-38, 50-54, 1893.

‡ Bull. No. X. p. 2, 1894.

§ 20th Ann. Rep., p. 59, 1893.

the more recent and annual reports of the survey and more especially in Bulletin No. 6. The same conclusions in regard to the relations and position of the "Vermilion" rocks of the western Mesabi iron range were reached independently by Mr. J. E. Spurr† during the last summer.

It would be unwise to extend these conclusions concerning the "Vermilion" rocks in the areas studied by the writer to all similar rocks in northeastern Minnesota and western Ontario; but it does not seem improbable that these conclusions will in the future be found to apply to a large part, if not to the whole, of the so-called "Vermilion" rocks of the northeastern part of this state.

II. IRON-BEARING ROCKS OF AKELEY LAKE.

These rocks lie upon the Keewatin greenstone to the north and on the south are overlain by the great gabbro mass. They extend in a narrow belt from near the center of the N. ½ sec. 27, 65–4, westward nearly to the western edge of the N. ½ sec. 34, 65–5 (a distance of about six and a half miles). West of this they are met with in a few isolated outcrops near the northern edge of the gabbro, or included in the gabbro, and at Birch lake (T. 61-12) apparently the same rocks reach a considerable development and have been exploited for iron ore. In Ts. 65-4 and 65–5 these rocks outcrop in a belt from 300 to 1300 feet in width, and the dip varies from almost vertical to 20 degrees toward the south, the average dip being 45–50 degrees. Where the belt is the widest the dip averages about 30 degrees; this would make a thickness of 650 feet, which is probably the maximum thickness of these beds in the vicinity of Akeley lake.

The iron ore of these rocks is a magnetite, making on the average a rather low grade bessemer ore, with no titanium. During 1892 and 1893 considerable work was done by the Gunflint Lake Iron Company in sections 28 and 29, 65–4, and a railroad was completed from Port Arthur to their headquarters in sec. 28. A number of test pits have been dug and two shafts have been sunk, the deeper of these is in the S. E. ¼ N. W. ¼ sec. 28; in September, 1893, it had reached a depth of 112 feet. As yet no ore has been shipped and no bed of any considerable thickness of clean ore has been encountered, although by sorting by hand a fair quality of ore can be obtained.

Prof. N. H. Winchell considers these rocks to belong to the

† Cf. Bull. 10, p. 2, and the explanations to plates 10-12.

lower part of the Animikie,* while Dr. W. S. Bayley has included them in the gabbro.† In this preliminary report the origin of these ore-bearing rocks and their relations to the Animikie and to the gabbro will not be discussed, (See remarks concerning the absence of a basal quartzyte at Gunflint lake on pages 74-75 of this report).

III. ANIMIKIE.

During the season of 1893 considerable new data were obtained concerning the Animikie rocks in the vicinity of Gunflint lake, and it is now possible to construct a much better geological map of this region than has hitherto been published.‡

The Animikie rocks about Gunflint lake have been little disturbed; they dip, with local exceptions, at an angle of 8 to 10 degrees a little east of south. In the immediate vicinity of the gabbro the dip increases and as the slates disappear under this rock it occasionally reaches 20 to 30 degrees. On the north side of the lake, where the lower beds lie upon the older vertical crystallines, there has been some gentle bending of the later rocks, and in the S. ½ sec. 21, 65-4, is a sharp synclinal, on whose southern side the Animikie slates stand almost vertical.

Faults.

The country is made up of parallel ridges trending east and west. On the south side of each ridge gentle slopes occur, but on the north steep, mural descents are seen. The tops of the ridges are composed of diabase sills, which usually cap a considerable thickness of slates. This structure has given rise to the idea that there has been a series of monoclinal uplifts along east and west fault lines, the downthrow occurring on the north side of each fault. While this idea is very plausible as long as topography alone is concerned, still it seems to find little or no confirmation in the sequence of the strata. The Animikie rocks, as stated beyond, can be readily divided into three divisions, and each division is well characterized lithologically. Such being the case it would be a comparatively easy matter to recognize any member if brought out of its normal position by faulting, but in no instance has the writer been able to do this. There seems to be good evidence that no great faults have occurred, although minor ones of comparatively small throw may exist.

*16th Ann. Rept., pp. 82-89, 1888. See especially Bulletin No. 6, 1891.

†19th Ann. Rept., pp. 194-210, 1892. Journ. of Geol., vol. i, p. 694, 1893.

‡The best map yet issued is that by Irving and Van Hise in their work on the Penokee range, 10th Ann. Rept. U. S. Geol. Sur., pl. xlii, 1890; and Mon. XIX, pl. xxxvii, 1892.

Thickness and divisions.

It is easy to separate the Animikie rocks at Gunflint lake into three well marked lithological divisions, and perhaps each of these can be subdivided. Below is given this three fold division, with the estimated miximum thickness of each.*

The upper, or graywacke-slate, member.—Composed of black to gray slates and fine graywackes, with some flinty slates; the upper part shows coarser detrital matter, and the highest beds seen are fine grained quartzytes and quartz slates. Thickness 1,900 feet.

The middle, or black slate, member.—Composed largely of black slates, often very fissile, and apparently carbonaceous. At the bottom of this member is a distinct division of black to gray slates which are fine grained, siliceous and often flinty; they reach a thickness of some 60 feet. They are as distinctly marked off from the black, carbonaceous slates above as from the iron-bearing rocks below, and perhaps might be put in a separate member by themselves, but they seem to be distinctly differentiated only at the western end of Gunflint lake. Thickness of middle member 1,050 feet.

The lower, or iron-bearing, member.—Composed largely of jaspery, actinolitic, siliceous and magnetitic slates, usually quite thinly laminated, and some beds of cherty carbonate and of lean iron ore. The presence of thin bands rich in magnetite is a very characteristic feature of this member. It is also characterized by greenish to reddish siliceous rocks, often spotted and forming jaspers; to similar rocks on the western Mesabi range Mr. H. V. Winchell† has applied the name "taconyte," and Mr. J. E. Spurr‡ has shown that they were originally composed largely of glauconitic greensands, and that in some cases the glauconite still remains. Thickness of the lower member 900 feet.

The quartzyte (Pewabic) and conglomerate found at the base of the Animikie farther west seem to be entirely lacking in the vicinity of Gunflint lake. This statement may need a few words of explanation. The name "Pewabic quartzyte" was proposed for, and applied to, the iron-bearing rocks of Akeley

*The lowest of these divisions corresponds to the "iron-bearing member," and the middle and upper divisions to the "upper slate member," of the geological map of Gunflint lake published by Irving and Van Hise; loc. cit.

†The Mesabi iron range: 20th Ann. Rept., p. 124, 1893.

‡The iron-bearing rocks of the western Mesabi range in Minnesota; Bull. No. 10, 1894.

lake.* Subsequently this term has been applied quite extensively to the quartzyte member at the base of the Animikie on the western Mesabi range, so that now the term Pewabic usually refers to this quartzyte, which, however, in the Minnesota reports has been considered as the equivalent of the iron-bearing rocks of Akeley lake. If the iron-bearing rocks of Akeley lake are thus put at the base of the Animikie, there seem to the writer to be serious objections to regarding them as the basal quartzyte and the equivalent of the quartzyte of the western Mesabi range. In the absence of anything like a conglomeratic base, in the intimate and rapid alternation of bands of siliceous and ferruginous material, and in other respects these rocks are closely analogous to certain parts of the iron-bearing member, and it is to this member that the writer would refer these rocks, if they belong to the Animikie. Moreover, in the Gunflint lake region no quartzyte has been found near the base of the Animikie and in several places the iron-bearing member has been seen lying directly upon the older crystalline rocks. Consequently it is stated that, so far as known, the basal quartzyte member is lacking in the vicinity of Gunflint lake.

As is stated above, the uppermost strata of the Animkie near Gunflint lake are fine grained quartzyte and quartz slates. This increase of coarser siliceous material in the higher beds of the Animikie is quite noticeable, and is also especially well shown in the vicinity of Pigeon point, north coast of lake Superior. At the latter place these quartzose beds (Wauswaugoning quartzyte) have been placed at the base of the Animikie in the recent Minnesota reports.† There seems, however, more reason for placing the Wauswaugoning quartzyte near the summit of this series than at its base, and for considering it as the probable equivalent of the quartzose beds at the top of the Animikie as exposed near Gunflint lake.

In the above estimates of the thickness of each member the diabase sills have been included. Their exact thickness is not known, but it is roughly estimated at not more than 75 feet for the lower, 100 feet for the middle, and 250 feet for the upper member. The following figures then will show the maximum thickness, in feet, of the Animikie at Gunflint lake, the estimate being based on an average dip of not more than 10 de-

*N. H. Winchell; 16th Ann. Rept., p. 86, 1888.

†See especially the "Table of Pre-Silurian Rocks," facing p. 4 of the 21st Ann. Rept.

grees, and on the assumption that there are no faults which would make the apparent thickness greater than the real:

	Sediments.	Diabase	Total.
The upper, or graywacke-slate, member...	1,650	250	1,900
The middle, or black slate, member.......	950	100	1,050
The lower, or iron-bearing, member.......	825	75	900
Total...............................	3,425	425	3,850

Igneous Rocks.

The igneous rocks of the Animikie, so far as seen by the writer, are all in the nature of intrusive sills or dikes; no surface eruptions have been recognized, nor has any evidence of contemporaneous volcanic activity been noted in the vicinity of Gunflint lake.* These sills are composed of diabase that varies much in grain, sometimes being very coarse in the center of the sills. They make up the characteristic ridges of the region and, as far as surface extent is concerned, cover perhaps a third of the area of the Animikie, although their aggregate thickness is much less than one third that of the whole series. The largest and most prominent sill is that forming the highest land between Loon and Gunflint lakes and along the south shore of South lake; it has a thickness of at least 100 feet.

The sills are not found to extend into the gabbro, nor have the two rocks been seen in contact. However, the gabbro is cut by a few dikes of diabase that might be referred to the same date as the sills. At the time of the gabbro intrusion the surrounding rocks were probably heated considerably, as the gabbro is not particularly finer grained at its contact with the country rocks; but in the case of the sills, even of the largest ones and those in closest proximity to the gabbro, both the upper and lower surfaces where seen are exceedingly fine grained. The relative ages of the two rocks are not definitely determined from the data thus far obtained about Gunflint lake.

IV. THE KEWEENAWAN.

Gabbro proper.

The great gabbro mass of this region was examined over a considerable extent of territory, This rock is found to vary somewhat in mineralogical composition, at times becoming, as at Little Saganaga lake, almost entirely composed of feldspar,

*This agrees well with the statement of Dr. A. C. Lawson concerning the absence of volcanic activity in the Animikie; Bulletin No. 8, p. 29, 1893. He proposes for these sills the term "Logan sills," Ibid., p. 48.

thus forming an anorthosyte petrographically similar to those described by Dr. A. C. Lawson from the north shore of lake Superior;* again it becomes exceedingly rich in olivine, this mineral sometimes making up half the rock mass.† The gabbro was found to include fragments of the Animikie slates, and it also was found directly overlying and in contact with beds of the upper member of the Animikie. This gives additional proof of the post-Animikie age of the gabbro.

Fine grained gabbro.

Associated with the coarse grained gabbro, or gabbro proper, and more frequently seen near its northern limit, are finer grained rocks which vary from gabbros and olivine gabbros to norytes and olivine norytes. To these rocks the term "muscovado"‡ has been applied. They are basic igneous rocks and are, as a rule, at least slightly older than the main mass of the gabbro, which is seen cutting and including fragments of them.

Acid eruptives.

In Ts. 62-6, 63-5, 63-4, 63-3 and in the southern edge of T. 64-2 are extensive exposures of reddish, hornblendic, granitic rocks. These make the highest hills of this region and these hills often form the water divide between the St. Lawrence and Hudson bay drainage. These rocks are undoubtedly part of what Prof. R. D. Irving termed the augite syenites of the Keweenawan,§ but as yet the writer has found no augite in them; however, in most specimens examined the original nature of the ferro-magnesian constituent cannot be determined. They probably represent deep-seated parts of the magmas that produced the extensive flows of rhyolytes, now largely aporhyolytes,‖ and other acid lavas seen about the Minnesota coast of lake Superior, especially at the Great Palisades and also at other points along this shore.

On approaching one of these areas of granitic rocks from the north a few small acid dikes are seen in the gabbro. These increase in frequency and size on coming nearer to the central

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*Bulletin No. 8, 1893.

†For a description of the gabbro of Minnesota see article by Dr. W. S. Bayley, Jour. of Geol. vol i, pp. 688-716, 1893.

‡See "Remarks on the so-called muscovadyte or muscovado rock," 21st Ann. Rept., pp. 143-153, 1893. Also Ibid., p. 30. 17th Ann. Rept., pp. 130-131.

§Copper-Bearing Rocks of Lake Superior, Mon. V, U. S. Geol. Survey, 1883.

‖For use of this term see article by Dr. Florence Bascom, Jour. of Geol., vol. 1, pp. 813-832, 1893.

mass of granite, and at the edge of this mass apophyses can be traced directly from the granite into the gabbro. This statement holds true for the relations of the gabbro and these granitic rocks as far as seen in the region here reported on. The dikes are not particularly finer grained, either as a whole or at their edges, than the granite of the main mass, thus indicating the heated condition of the gabbro when the dikes were intruded. From this and from the relation of these two rocks in other places it seems likely that the granite, while of a later date than the gabbro, still is not much younger and perhaps was intruded before the complete solidification of the basic rock.

V.

LIST OF ROCK SAMPLES COLLECTED IN 1893

BY U. S. GRANT.

CONTENTS.

An opportunity has not been offered for the study of these rocks since they were collected; consequently the names are to be regarded only as approximately correct. This list is a continuation of that ending on page 67 of the twenty-first annual report. The specimens in this series are numbered in green and can thus be distinguished from those of any other series of the survey or museum.

NORTH SHORE OF LAKE SUPERIOR.

894. Dark reddish, blotched amygdaloid. Point in S. W. ¼ S. W. ¼ sec. 33, 63-3 E.

895. Dark olivine diabase ("black trap"). Center of W. ½ W. ½ sec. 20, 62-4 E., Chicago (or Sickle) bay. Same as 1811 N. H. W.

TOWNSHIP 65 NORTH, RANGE 4 WEST.

896. Fine grained, gray gabbro. S. W. ¼ S. E. ¼ sec. 27, at the Y of the railroad.

897. White pegmatyte, from veins or dikes in the last.

898. Fine grained, gray gabbro, 2 inches from contact with slate. N. W. ¼ S. E. ¼ sec. 27, in railroad cut.

899. Coarse, gray gabbro, 2 feet from contact with slate.

900. Fine grained, micaceous schist (altered slate), 6 inches from contact with gabbro.

901. More micaceous facies of the last, 6 inches from contact with gabbro.

902. Fine grained diabase from dike in gabbro; the specimen shows one edge and about half the width of the dike. S. E. ¼ N. W. ¼ sec. 27, in railroad cut.

903. Small dikes of diabase, ¼ to 1½ inches wide, in greenstone. N. W. ¼ S. E. ¼ N. W. ¼ sec. 28, in railroad cut.

904. Impure, magnetitic quartzyte with films of hisingerite. S. W. ¼ N. E. ¼ sec. 29, 65–4, shaft 2, Akeley lake.

905. Graphitic rock. Same place.

906. Actinolitic rock holding pieces of quartz and a gray cherty rock. S. W. corner of N. W. ¼ N. W. ¼ sec. 27; from the "nickel" pit just S. of the wagon road.

907. Some of this gray cherty rock. Same place.

908. Fine grained, black, carbonaceous rock. Hill in the S. E. ¼ N. E. ¼ N. E. ¼ sec. 26, just south of the railroad.

909. Fine grained diabase. N. E. ¼ S. E. ¼ sec. 24, just north of the wagon road.

IRON REGIONS OF MICHIGAN.

910. Recomposed jasper of Upper Huronian. Millie mine, Iron Mountain.

911. Potsdam quartzyte showing quartz enlargements. Iron Mountain.

912. Lower Huronian magnetite-actinolite schist. Republic.

913. Lower Huronian quartzyte near base of this formation. Republic.

914. Quartzose pebble from basal conglomerate of the Lower Huronian. Republic.

915. Jaspery conglomerate at base of Upper Huronian. Goodrich mine, near Ispheming.

916. Impure quartzyte at base of Lower Huronian. Near Ishpheming.

917. Greenstone of the Basement Complex. Near Ispheming.

918. Carbonate rock of Lower Huronian. Near Ispheming.

919. Volcanic ash of Upper Huronian. Near Ironwood.

920. Cherty carbonate of the Upper Huronian. Palm mine, near Bessemer.

921. Carbonate changing to ore, Upper Huronian. Black river. east of Bessemer.

922. Granite of Basement complex. Near Bessemer.

923. Recomposed portion of the same forming a conglomerate that rests on the granite.

924. Chert with "bands and shots of ore." Colby mine, Bessemer.

DULUTH.

925 Very fine grained, black rock. Crossing of Piedmont and Lake avenues.

926. The same showing irregularly outlined, foreign pieces.

927. Same as the last.

928. The same with yellowish, vein-like forms.

TOWNSHIPS 64 AND 65 NORTH, RANGES 2, 3, 4, AND 5 WEST.

929. Coarse, vitreous quartzyte. N. E. ¼ N. E. ¼ sec. 34, 65-5.

930. Finely laminated magnetite and impure quartzyte. N. W. ¼ N. W. ¼ sec. 35, 65–5.

931. Coarse diabase (or gabbro) from center of sill. Portage in N. ½ N. W. ¼ sec. 35, 65-5.

931A. Finer diabase, 4 inches from top of same sill.

932. Diabase from center of dike in gabbro. Just north of the small island in N. E. ¼ S. E. ¼ sec. 34, 65-5, Kakigo (or Black Trout) lake.

933. Fine grained; gray gabbro. N. E. ¼ N. E. ¼ sec. 12, 64-5, Big Round lake.

933A. The same in contact with coarse gabbro.

934. Biotite granite from dike in gabbro. Near W. quarter post of sec. 7, 64-4, point in Big Round lake.

935. Fine grained, olivine gabbro. S. E. ¼ S. W. ¼ sec. 6, 64 4, Big Round lake.

936. Diabase from center of dike, 8 feet wide, in gabbro. S. E. ¼ S. W. ¼ sec. 8, 64–4, Big Round lake.

936A. Diabase and gabbro in contact. Same place.

936B. Film of diabase, ¼ inch wide, in gabbro. Same place.

937. Gabbro with a green stain. N. W. ¼ S. E. ¼ sec. 9, 64–4, north shore of Little Copper lake.

938. Fine grained, gray granite. Near west edge of S. W. ¼ S. W. ¼ sec. 16, 64–4.

939. Fine grained, olivine gabbro. N. W. corner of S. W. ¼ N. W. ¼ sec. 5, 64–4, south shore of small lake.

940. Slaty greenstone. A few rods south of the west quarter post of sec. 22, 65-4.

941. Gray syenite. West quarter post of sec. 22, 65-4.

941A. The same. Same place.

942. Grain syenite and greenstone in contact. N. ½ S. W. ¼ sec. 22, 65-4.

943. Magnetite iron ore from a bed 3 feet thick and about 110 feet below the surface. Shaft 1, S. E. ¼ N. E. ¼ sec. 28, 65-4.

944. Quartzyte, below gabbro sill. S. W. ¼ S. E. ¼ N. E. ¼ sec. 29, 65-4, within a few rods of Akeley lake.

945. Fine grained gabbro within six inches of bottom of sill. Same place.

946. Coarse gabbro from center of sill. Same place.

947. Quartzyte above gabbro sill. Same place.

948. Gabbro. S. W. ¼ N. E. ¼ sec. 29, 65-4, the most eastern island in Akeley lake.

949. Gabbro from sill in quartzyte. S. E. ½ N. E. ¼ sec. 28, 65-4, railroad cut.

950. Cherty carbonate. S. ½ N. W. ¼ N. E. ¼ sec. 24, 65-4.

950A. A rusted phase of the same.

951. Coarsely porphyritic diabase. S. E. ¼ N. W. ¼ sec. 19, 65-3, railroad cut just west of the narrows of Gunflint lake.

952. Diabase. Near south side of S. W. ¼ N. W. ¼ sec. 19, 65-3, railroad cut, north side of Animikie bay, Gunflint lake.

953. Contact of lower edge of diabase sill and slate. Near north side of N. E. ¼ S. E. ¼ sec. 24, 65-4, railroad cut at head of Animikie bay, Gunflint lake.

954. Flinty band in slate. Near same place.

955. Diabase. Near same place.

956. Calcareous deposit on face of cliff. S. W. ¼ N. E. ¼ sec. 24, 65-4, east end of large hill.

957. Conglomeratic portion of the slate. Same place, at foot of hill.

958. Breccia cemented by green amphibole. Same place, top of hill.

959. Peculiar markings on surface of slate. Same place, about half way up the hill.

960. Black, flinty slate. S. W. ¼ S. E. ¼ sec. 24, 65-4, cliff on south shore of Cross river.

960A. Another phase of these slates. Same place.

961. Black carbonaceous rock, scratched side is on line of contact between slate and this rock.

961A. Slate, scratched side is on line of same contact.

961B. Black carbonaceous rock, 30 inches above contact.

961C. Same, 15 feet above contact.

962. Black carbonaceous slate. Near center of N. ½ sec. 30, 65-3, south shore of Gunflint lake.

963. Black carbonaceous rock showing peculiar markings. Top of hill in N. W. ¼ N. E. ¼ sec. 25, 65-4.

964. Diabase from dike. N. W. ¼ N. E. ¼ sec. 25, 65-4.

965. Biotite gabbro. Near center of west side of S. W. ¼ sec. 25, 65-4.

965A. A phase of the same. Same place.

966. Gabbro. Near center of S. ½ sec. 25, 65-4.

967. Coarse grained diabase, 18 feet above contact with slate, top of cliff. S. E. ¼ N. E. ¼ sec. 29, 65-3.

967A. Fine grained diabase, 10 inches above contact.

967B. Fine grained diabase, 5 inches above contact.

967C. Fine grained diabase at contact; the side on the contact is scratched.

967D. Slate at contact.

967E. Slate.

967F. Slate. The upper surface of these specimens of slate are scratched; these pieces were in contact with each other.

968. Hard siliceous slate. Near east edge of N. E. ¼ S. E ¼ sec. 25, 65-4, 100 yards S. W. of the road.

969. Slate, 15 feet below contact with gabbro. Near center of S. E. ¼ sec. 25, 65-4.

969A. Slate, 4 feet below contact.

969B. Slate, 3 feet below contact.

969C. Contact of slate and gabbro.

969D. Gabbro, 1 foot above contact.

969E. Gabbro, 25 feet above contact.

970. Spotted, black, carbonaceous slate. S. E. ¼ S. W. ¼ sec. 29, 65-3, north or lower cliff of Prospect mount.

971. Gray, cherty rock from bed 9 inches in thickness. Same place.

972. Slate spotted with small white crystals. S. E. ¼ S. W. ¼ sec. 29, 65-3, main cliff of Prospect mount.

973. Fine grained black rock with small blotches. Same place.

974. Black slate, one-half inch from lower surface of diabase sill. Same place.

974A. More fissile slate, 10 inches below sill.

975. Coarse grained diabase. N. E. ¼ N. W. ¼ sec. 32, 65–3, top of Prospect mount.

976. Gabbro? N. E. ¼ N. E. ¼ sec. 31, 65–3.

977. Coarse grained porphyritic diabase. Sec. 27, 65–3, north shore of Loon lake.

977A. Coarse grained diabase, not porphyritic. Same place.

978. Fine grained siliceous slate. S. W. ¼ N. E. ¼ sec. 32, 65–3, southwest corner of Loon lake.

979. Gabbro. Top of ridge at same place.

980. Fine grained, gray quartzyte. Near center of N. ½ sec. 35, 65–3, north shore of point in Loon lake.

980A. Same, banded with black slate. Same place.

981. Spotted black slate. West line of sec. 27, 65–3, a short distance north of the quarter post.

982. Dark siliceous slate, one inch below diabase sill. S. E. ¼ N. W. ¼ sec. 35, 65–3, hill on point in Loon lake.

983. Gabbro. Near center of E. ½ sec. 32, 65–3, near southwest corner of Loon lake.

983A. Fine grained, biotitic rock. Near same place.

983B. Siliceous slate. Near same place.

984. Fine grained, reddish weathering, gray quartzyte. N. ½ N. E. ¼ S. E. ¼ sec. 32, 65-3, near southwest end of Loon lake.

985. Gabbro? A few rods south of the last.

986. Gabbro? West line of sec. 34, 65–3, one-fourth mile south of Loon lake.

987. Mottled dioryte. N. W. ¼ S. E. ¼ sec. 34, 65–3, on road.

988. Gabbro. N. W. ¼ S. E. ¼ sec. 35, 65–3. Between road and Loon lake.

989. Olivine gabbro interbanded with coarser gabbro. S. W. ¼ N. W. ¼ sec. 11, 64–3.

989A. Coarser gabbro. Same place.

990. Gabbro. S. W. ¼ sec. 11, 64–3, south shore of lake.

991. Gabbro. S. E. ¼ N. E. ¼ sec. 11, 64–2, Poplar lake.

992. Diabase. N. E. ¼ N. W. ¼ sec. 34, 65–2, top of hill at east end of lake Emma.

992A. Fine grained, porphyritic diabase. North side of same hill.

993. Micaceous schist. N. W. ¼ N. E. ¼ sec. 34, 65-2, portage between No-Name lake and lake Emma.

994. Diabase. West line of sec. 36, 65-2, 500 feet south of No-Name lake.

995. Coarse grained, gray diabase. N. E. ¼ S. E. ¼ sec. 35, 65-2, north shore of No-Name lake.

996. Fine grained, gray quartzyte, scratched side was one-quarter inch below diabase sill. Near center of sec. 27, 65-2.

996A. The same, 13 inches below diabase sill.

997. Diabase. N. E. ¼ S. W. ¼ sec. 22, 65-2, north shore of South lake, just west of the International Boundary portage.

997A. A phase of the same. Same place.

998. Fissile, black, carbonaceous slate. S. W. ¼ S. E. ¼ sec. 21, 65-2, west end of South lake.

999. Fine grained diabase showing effects of weathering. N. W. ¼ N. W. ¼ sec. 25, 65-2, portage leading south from South lake.

1000. Breccia of black slate. A short distance north of the S. E. corner of sec. 24, 65-2, south of South lake.

1001. Diabase. W. ½ sec. 22, 65-2, portage between North and South lakes.

1002. Cherty carbonate with rusty-weathering areas; not in place. Sec. 21, 65-2, North lake.

1003. Jasper. Near center of N. E. ¼ sec. 16, 65-2 south shore of narrow arm of North lake.

1003A. Jasper with green and red granules. Same place.

1003B. Gray rock with granules, associated with the jasper. Same place.

1004. Fragments of red jasper, with granules, from the beach; not in place. South shore of North lake just east of the portage to South lake.

1005. Green rock with granules. Pits in N. W. ¼ S. W. ¼ sec. 16, 65-2.

1005A. A more flinty phase of the same.

1005B. A rusted phase of the same.

1005C. Black flinty rock.

1005D. Finely banded jasper and magnetite.

1005E. Magnetite iron ore.

Railroad on north side of Gunflint lake.

1006. Flint. A short distance west of the rapids between North and Gunflint lakes. Nos. 1006 to 1007C belong to the Animikie.

1007. Contact of diabase and flint.

1007A. Gray branded flint.

1007B. Finely banded jasper.

1007C. Cherty carbonate, changing to limonite.

1008. Sheared quartz porphyry. Nos. 1008 to 1008C belong to the Keewatin.

1008A. The same showing weathered surface.

1008B. The same showing contact with a non-porphyritic rock.

1008C. Argillyte.

ELY AND TOWER.

1009. Altered diabase. Ely.

1010. Coarse quartzose rock. South of Stuntz bay, Vermilion lake.

1011. Matrix of conglomerate. Just south of western side of Stuntz bay, Vermilion lake.

1011A. Pebbles from the same.

1012. Sericitic schist with quartz grains. Ely island, Vermilion lake.

1013. More massive form of the same. Same place.

1014. Augite porphyryte ?, showing one-half the width of a dike. Same place.

1014. The same, from a point where the dike was 3 feet wide; center of dike.

1015. Greenstone. Just south of Tower.

1016. Jasper with fine white veins. Tower.

VI.

LIST OF ROCK SAMPLES COLLECTED IN 1893*

BY A. D. MEEDS.

These samples were collected in ranges 12 to 15 (inclusive) west of the Fourth principal meridian, and between lake Superior and the Vermilion iron range. No examination in the laboratory has been made of these rocks, so the designations are only approximately correct. Rocks of this series are numbered in white, each number followed by the letter M, to distinguish them from the other series of the survey and museum.

1. Medium grained gabbro. E. line of sec. 36, 61–12.

2. Very fine grained gabbro, with black lines. E. line of sec. 3, 60-12.

2a. Crystallized quartzyte. Same place.

2b. Same as No. 2. Same place.

3. Red, hornblende granite. Center of N. ½ sec. 10, 61–13; north shore of Stuntz lake.

4. Gray, hornblende granite. Near S. E. corner sec. 15, 61-13; south shore of Stuntz lake.

4a. Phase of the same. Same place.

4b. Granite. Same place.

4c. Pinkish granite. Same place.

4d. Very fine grained, gray granite. Same place.

5. Rather fine grained, olivine gabbro. W. line of sec. 25, 61–12, near quarter post.

6. Fine grained, olivine gabbro. N. E. ¼ S. W. ¼ sec. 10, 60-12; end of portage on Dunka river.

*This list was prepared from Mr. Meeds' specimens and note books by Dr. U. S. Grant.

7. Fine grained, magnetic quartzyte. W. line of sec. 17, 60–12.

7a. The same showing pitted, weathered surface. Same place.

8. Mica schist. S. E. ¼ S. E. ¼ sec. 35, 60–13.

9. Coarse grained gabbro. N. W. ¼ N. W. ¼ sec. 6, 59-12.

10. Magnetic iron ore. W. side of N. W. ¼ N. W. ¼ sec. 14, 59–14.

11. Phase of the same. Same place.

12. Hard hematite. N. E. ¼ sec. 11, 59–14; Mallmann mine.

13. Hard hematite. Sec. 18, 59–14; Stone shaft.

14. Impure hematite. Near same place.

15. Quartzyte. Aurora pit; probably in S. E. ¼ N. E. ¼ sec. 24, 59–15. (Missing).

16. Fine grained quartzyte. Near N. line of sec 24, 59-15.

17. Pinkish gabbro from boulder. Sec. 24, 58-12; island in Seven Beaver lake.

18. Gabbro. S. W. ¼ S. E. ¼ sec. 31, 54–13.

18a. The same with magnetite. Same place.

19. Olivine gabbro. N. W. ¼ N. W. ¼ sec. 15, 54-13; end of portage on Cloquet river.

19a. Phase of the same with much olivine. Same place.

19b. Phase of the same. Same place.

19c. Rough-weathering phase of the same. Same place.

20. Olivine gabbro. Near north edge of N. W. ¼ sec. 15, 54–13; middle of portage along Cloquet river.

21. Fine grained, micaceous quartzyte. Sec. 18, 59–14; Stone mine.

22. Jaspery conglomerate. Same place.

23. Micaceous slate. Same place.

24. Limonitic shale. Same place, top of shaft.

25. Magnetic taconyte. Below last.

26. Dark, slaty taconyte. Same place.

27. Jasper. Bottom of shaft.

27a. Purplish taconyte. Bottom of shaft.

28. Siliceous shale. N. E. of shaft.

29. Hornblende granite. Near Hinsdale.

30. Fine grained diabase from dike. N. edge of N. E. ¼ N. E. ¼ sec. 24, 55-12.

30a. Quartzless porphyry. Same place.

31. Gabbro near dike. Same place.

32. Reddish, mottled dioryte. Same place.

33. Contact of diabase and gabbro. Same place.

34. Mottled dioryte from another dike. E. edge of N. E. ¼ S. E. ¼ sec. 24, 55-12.

35. Olivine gabbro from boulder. N. W. ¼ sec. 24, 55-12.

36. Fine grained, red syenite. W. line of sec. 23, 53-12; in creek bed.

37. Fine grained, red syenite. S. line of sec. 36, 53-12.

37a. Phase of the same. Same place.

38. Fine grained, red syenite, not in place. Near Highland.

39. Dioryte. N. W. ¼ N. W. ¼ sec. 34, 53-12.

40. Coarse grained, olivine gabbro. N. line of sec. 5, 54-13.

41. Coarse grained gabbro from boulder. A little west of the last.

42. Coarse grained gabbro. N. E. ¼ N. E. ¼ sec. 30, 53-14; southeast shore of Boulder lake.

43. Coarse grained gabbro with long, slender feldspar crystals. N. E. ¼ sec. 18, 53-13; falls in Cloquet river.

44. Anorthosyte from boulder. S. E. ¼ S. E. ¼ sec. 19, 53-13; dam in Cloquet river.

44a. Phase of the same with darker areas. Same place.

45. Coarse grained gabbro. N. E. ¼ sec. 36, 53-14; rapids in Cloquet river.

46. Olivine gabbro. S. E. ¼ sec. 35, 53-14; falls in Cloquet river.

VII.

PRELIMINARY REPORT OF A RECONNOISSANCE IN NORTHWESTERN MINNESOTA DURING 1893.

BY J. E. TODD.

ITINERARY.

Having been met by my assistant, Mr. H. B. Hovland, at Minneapolis, we left that city June 22d for Thief River Falls. At that place I engaged Mr. J. C. O'Brien, an experienced "cruiser," to accompany us on a trip on foot through the northern parts of the Red Lake Indian Reservation, completed my outfit, and engaged an experienced hunter to take us with his team to an old hunting camp about thirty miles northeast of Thief River Falls. My purpose was to keep a northeast course, if possible, till we struck the survey of the Duluth and Winnipeg railroad, and then to explore the so-called "Beltrami island of lake Agassiz."*

We left Thief River Falls June 26th, and Cook's shanties in N. W. ¼ of sec. 19, T. 156, R. 39 (the before mentioned hunter's camp) on the morning of the 28th. We kept a northeast course as nearly as was practicable in trackless swamps and for many miles through wind-falls where we did well if we advanced five miles a day. Besides, we lost some time on account of rain. Failing to find the railroad survey, probably because its trace was obliterated by fire, we kept our course till we struck the Rainy river about five miles above its mouth, July 12th. Having there built a raft, we descended the stream till we found settlers. At Hungry Hall we bought a new birch canoe and proceeded to the Lake of the Woods and along its southern shore to Long point. Thence we retraced our course, going

*Warren Upham, in American Geologist, vol. xi, pp. 423-425, June, 1893.

up the Rainy river to Pinewoods P. O., where we took the steamer "Shamrock" to the mouth of the Big fork, proposing to ascend it and the Sturgeon river,* its main western branch, to a portage into the Tamarack river, which we should descend and then cross Red lake to the Red Lake Agency. Owing to misinformation, we ascended the wrong one of the numerous branches of the Sturgeon river, and somewhat rashly abandoned our canoe not far from the northwest corner of T. 154, R. 27. Taking our packs, we traveled southwest and west to the south branch of Tamarack river, made a raft but found the stream closed by the work of beavers, and then, striking a recent land survey near the southwest corner of sec. 24, T. 154, R. 29, we followed it due west from there to Red lake a little south of the mouth of the Tamarack river. We arrived at the Indian village at "the Narrows" the morning of August 3d, hired a canoe, and reached Red Lake Agency late August 4th. Here Mr. O'Brien left us, we bought another canoe, and hired an Indian to take us and our outfit in a wagon to the head of Turtle lake, the spot which Beltrami considered the hydrographical center of the continent. We were landed at this point about noon, August 8th.

We proceeded down Turtle river (making two long portages above Turtle River lake) to Cass lake, and thence went up the Mississippi to lake Bemidji, arriving the 16th. Thence we went south up the Schoolcraft river to sec. 3, T. 144, R. 34, where I obtained a fine view of a wide region from the top of a high spruce, and then returned to Bemidji. There we left our canoe and engaged passage with a settler going by Bagley's dam and How's to Fosston, where we took the cars on the 22d, Mr. Hovland for Minneapolis, and I for Park Rapids, via Sauk Center.

From Park Rapids I took a trip along the new railroad grade to Akeley and on northeast and north into the moraine north of Eleventh lake (the head of the Crow Wing river), to sec. 10, T. 142, R. 32. From Park Rapids I returned to Sauk Center, then took a flying trip up to Northcote, availing myself of the courtesy of the Great Northern railway company to see the country in western Marshall and Kittson counties. I arrived at Minneapolis August 29th.

I met many intelligent woodsmen and Indians at various times who gave me numerous valuable facts regarding the re-

*Called Opimabonowin river by Horace V. Winchell, Sixteenth Annual Report, p. 431.

gion I have been studying, thus supplementing to no inconsiderable degree our personal observations.

SUMMARY OF PRINCIPAL RESULTS.

The more important results of our summer's work may be enumerated as follows:

1. The whole area traversed till we reached Red lake was shaped by lacustrine action. Though I had confidently expected to find areas untouched by it, and having the common glacial topography, I visited none which did not show, wherever above the marsh, sandy ridges which were evidently beaches. The highest point found was an abrupt ridge rising about 40 feet above the swamp surrounding it. I have little doubt that it was crossed by the Duluth and Winnipeg railroad survey before spoken of. It was about in line with it and almost the only area which was completely burned off, and that quite recently. The ridge was quite bouldery, about a mile long, trending northeastward, and seemed to have been a bar detached from land. We saw higher land a few miles west, but there was a wet swamp between and we at that time hoped to find the railroad survey farther on and follow it. I judge that much of the region traversed between Cook's shanties and the Rainy river was considerably higher than those points, because old beaver dams abounded at both ends of that trip. Much of the country between those points was tamarack, spruce, and cedar swamps; but toward Rainy river, especially, low sand ridges 1 to 5 feet high abounded. Among these ridges it was noticed that the swamps were wetter adjoining the south side of each ridge, which was accounted for by supposing a gentle descent toward the north. The only stream crossed, which was at a distance of about fifteen miles southwest of the Rainy river, had a width of about twelve feet and a depth of two feet, with a strong current southeastward. It is probably a branch of the Rapid river.

In our course to Rainy river, we found the marsh, though almost continuous, yet not very deep, except about Mud lake, which is in Ts. 156, Rs. 41 and 42, where there are extensive grassy quagmires, and south of a small lake said to be the head of the east branch of Roseau river in or near the southwest corner of T. 159, R. 33, where a "muskeg" covers several square miles. Elsewhere there seemed to be firm sand 2 to 4 feet below the surface of the moss. We tested it at several points. Large boulders not infrequently rose above the moss, even in open swamps. On our return from Rainy river, we did not have the opportunity, while in the canoe, of noting the country; but from examination at several points, and by the trees and the frequent rills trickling into the streams, we judged that the same shallow sphagnum swamp prevailed. Along the lower course of the Tamarack river, east of the north part of Red lake, we found alder swamps which presented more serious hindrance, with deep muddy bog holes. These were probably connected with the work of beavers.

We found prairie covering most of the region from Thief River Falls to Cook's shanties, and in patches to the northeast corner of T. 156, R. 38, also a considerable area 10 or 12 miles from Rainy river, where a swamp had been burned out and prairie grass had become the main covering, with here and there willow patches around the nearly consumed remains of cedars. The soil was rich, the ground mostly firm, the subsoil a bouldery clay. This suggests that most of this region may be similarly reclaimed. No very large patches of white or red pine were observed.

2. Of the higher region, named by Mr. Upham "Beltrami island," we learned some facts from different hunters. We attempted to sift their stories. The higher portion of it is said to lie between the head of the War Road river and the East Roseau, I judge not far east of the southeast corner of Kittson county. The ridges are higher toward the south and rise "20 feet or more above the swamps between." They trend N. E.-S. W. and are covered with pines. One ridge is five miles wide. No lakes were noticed except in a big swamp eight or nine miles long and two miles broad, north of the higher ridges. The railroad survey runs across this swamp on a strip which bears tamarack.

3. From Red lake southeast, the country rises quite rapidly to the level of a plateau which lies on the divide between the Red lake region and the Mississippi. It is estimated to be, in its highest portions, about 300 feet above Red lake. It is largely covered with clayey poplar flats, with groves of pine and hard maples interspersed. It abounds in lakes and has few elevations except in connection with the moraines hereafter to be enumerated. The watershed is not clearly defined. Former glacial stream channels cross it in several places.

4. Several moraines were crossed in our course.

(*a*). That which divides the two portions of Red lake. We have no important notes to add to those already published. We hoped to find trace of its extension to the west, but failed to discover anything decisive. Probably the higher portion of "Beltrami island" and the ridge between Jadis and the War Road river are to be correlated with it, the intermediate portions of this moraine having been levelled by the waters of lake Agassiz as they were dropped from the ice-sheet or at a later stage. We were unable also to establish the extension of this ridge much to the east of Red lake.

(*b*). Between Red Lake Agency and Cass lake we crossed four well defined moraines, with a less prominent one between the two pairs in which the four might easily be grouped. The first, counting from the north, we crossed two to four miles from Red Lake. It lay along the upper part of a rather abrupt rise from the level of the Agency. Its higher portion rose about 150 feet above the lake. It presented in fine form the usual basins and knobs, but the latter were of more even hight than common and corresponded approximately with the level of the plain just south. This corresponds, without much doubt, to the moraine noted last year north of Clearwater lake, running east across Sandy river, and perhaps to one east of Fosston, trending south.*

(*c*). After crossing a quite level clayey strip, we came to the second moraine, marking another slope and presenting similar features to the last, about eight miles from the lake and reaching up to 225 or 250 feet above it. This corresponds to the moraine crossed last year south of Clearwater lake, and this year east of Popple, or about "15 miles east of Fosston." There it is trending south.

(*d*). About two miles north of the northwest corner of T. 148, R. 33, we crossed low ridges rising 10 to 20 feet above the surrounding clayey plain, as though nearly submerged in it. They trended north of east. Scattering ones a little farther north were also noticed. These seem to correlate with a strip near the Buzzle lakes, crossed east of Bagley dam, which is on sec. 31, T. 148, R. 35, perhaps also corresponding to hills west of Spain's and to some east of Upper Rice lake, which is on the west side of T. 145, R. 36.

(*e*). Another well developed moraine was found running east and west along the north line of Ts. 147, Rs, 32 and 33, south of Turtle River lake and Turtle lakes. Some hills rose

*Twenty-first Annual Report, pp. 72, 73.

60 feet or so above the lakes. This corresponds to the morainic belt crossed last year, and again this year, in the north part of T. 147, R 35. It curves southwest and south, crossing Grant creek near the southwest corner of the same township, and running southwest of the Schoolcraft river into Hubbard county. Some of its inner knobs lie along the west side of lake Marquette and rise 75 feet above it. It has a still higher ridge southwest of lake Plantagenet. It seems, according to reports of woodmen, to correlate with a strip passing Elbow lake, east of Park Rapids, and said to continue on southeast to Pillager.

(*f*). Another well developed moraine was crossed north of the lake next north of Cass lake; i. e. on the southeast corner of T. 147, R. 31; also, where the Mississippi flows southward east of lake Bemidji. Thence it curves more south, passing east of Schoolcraft river, and between lakes Sheridan and Kabekona, thence southeast, south of the latter, and on eastward south of Leech lake, where, as I reported last year, I believe that it forms a re-entrant angle and then runs southward west of Pine lake and on to the western one of the morainic strips south of Gull lake.

These correlations are of course provisional. The conception which was suggested last year seems to be corroborated by the observations of this. Its main features are that two lobes of the ice-sheet, one occupying the Red lake region, the other the basin of lake Superior, were at first confluent, but afterward becoming reduced first deposited the moraine (*d*); that, later, the former of these ice lobes accumulated the moraine (*c*) on its south margin, and the other (*e*) on its northwestern margin. Still later they similarly formed, respectively, (*b*) and (*f*), each contemporaneous pair of moraines being farther apart toward the southwest and probably forming a sharp re-entrant angle or interlobate moraine toward the northeast.

5. Exposures of bed-rock are comparatively rare. Those observed may be enumerated as follows:

(*a*). On the south shore of the Lake of the Woods three granite points run out into the lake. The first on the west, named Rocky point, was visited last year. The second and longest is called Long point, the west side of which trends N. 20° W. (mag.) and consists mostly of gneiss which dips sharply to the northeast. The rock rises about 20 feet above the lake. Stony point, a short point about a mile east of the last, is faced with gneiss for several rods, and is said to have, about a quarter of a mile from the shore, a rocky knob rising some 50 feet above the surrounding country. We did not explore it on account of rain. Several rocky islets appear off these points.

(*b*). At Zipple's fishery, near the mouth of Sand creek, is a low knob of dark magnetic "gabbro", and about half a mile west is an extensive mound of a similar rock rising 40 feet above the lake. These rocks were all evidently shaped by land ice, though glacial striæ were not common. The few noted were east of south.

(*c*). No other outcrops were found till we reached Rapid river. A few rods above its junction with Rainy river, it falls over a high ledge of black siliceous schist or slate. The rock rises about 30 feet above the Rainy river, and the falls are perhaps 20 feet high. A ledge of magnetic "gabbro" with granite juts out on the American side at water level about a half mile east of Rapid river.

Having glanced over Dr. Lawson's report on the Rainy river region to the Canadian government, and Mr. H. V. Winchell's account in the Sixteenth Annual Report of the Minn. Geol. Survey, I forbear saying anything further about other rock exposures on the Rainy river and the Big fork.

No ledges of Paleozoic rocks were found. In the bed of a rapid near the center of sec. 28, T. 148. R. 32, on Turtle river just above Turtle River lake, I found the bottom of the stream covered over several square yards with limestone pebbles and calcareous mud, but found no rock in position. Mr. Joseph Sombs of Park Rapids, who has spent some time "cruising" and also on a claim in T. 150, R. 31, says that on the south side of Black Duck lake there is much limestone along the stream for six or seven miles, that the masses of stone are not worn, and that the south bank is "50 to 60 feet high."

Black Duck river is represented by several from that region as the main stream running into Red lake. Mr. O'Brien states that, when Red lake first freezes in the fall, there is left a narrow strip of open water reaching from the mouth of Black Duck river across the south part of the lake to the outlet, Red Lake river. which remains open considerably longer than the rest. I regret that time did not allow me to ascend the east branch of Turtle river and go over to the head of Black Duck river and examine what is spoken of as one of the most promising tracts for agriculture in that part of the state.

VIII.

NOTES ON THE GEOLOGY OF ITASCA COUNTY, MINNESOTA.

BY G. E. CULVER.

CONTENTS.

INTRODUCTION.

The field season of 1893 was spent by the writer in an examination of portions of Itasca county. Mr. H. C. Carel of the University of Minnesota acted as topographer.

The plan of the work included a somewhat careful survey of two special areas which had been selected by the State Geologist for more detailed study, together with as thorough a reconnoissance of the remainder of the county as circumstances would permit. Particular attention was to be given to the region between the Big fork and the Little fork of Rainy river.

The special areas covered the part of the Mesabi range lying in Itasca county, and included about three hundred square miles. The topography was indicated by fifty foot contour lines drawn on the township plats.

When the work on these areas was completed, the region lying immediately north was examined. The line of travel was through Wabano, Trout, Spider and Ruby lakes to the watershed between the Mississippi river and Hudson bay, which was crossed in T. 59–25. The region about the headwaters of Prairie river was inaccessible on account of the obstruction of Prairie river by logs. Accordingly the trip down the Big fork or Bowstring river was next undertaken. It was expected that the return trip would be made by the Little fork, but the water was found to be so low that this route had to be abandoned and the home trip made by way of Rainy lake, Black bay, Kabetogama and Namekan lakes, and the Vermilion river.

The weather was exceedingly favorable for field work during the summer. The low stage of water in the rivers was a hindrance to travel, compensated for somewhat by the better exposure of some rock outcrops.

The whole county is so deeply drift-covered, in all but the northeast portion, that rock exposures are few and far between. Days and weeks of tramping through the dense brush in search of outcrops were rewarded only rarely by finding them.

The Big fork and Little fork had been traversed in 1887 by Mr. H. V. Winchell, and although he made a very rapid journey, he gathered a great amount of information and made many valuable observations, besides collecting a number of rock specimens. His notes* were of much advantage to me.

TOPOGRAPHY.

In all the southern and central parts of the county, so far as I saw it, the topographic features are very largely due to the action of the great ice-sheet.

Before the advent of the ice the region was probably a level one, comparatively speaking. There were here and there ridges, which still remain; there were also valleys, which may have been deeper than the present ones, as the hills were, no doubt, higher, so that a somewhat stronger relief prevailed then than now.

*Geol. and Nat. Hist. Survey of Minn., 16th Ann. Rept., for 1887, pp. 395-478, with map.

That the ice covered the region for a very long time is a necessary result of its great southward extension. Neverthe-less it seems to have changed the topography rather more by filling than by local erosion. Of this the thick mantle of drift is evidence. The character of the rocks may account for this fact, but the ridges of soft Cretaceous rocks seem also to have withstood the action of the ice.

On its retreat the ice seems to have given up its occupancy with considerable reluctance. The disposition of morainic accumulations indicates many halts in the final retreat.

In the immediate valley of the Mississippi a considerable belt of stratified drift occurs. It forms irregular terraces, which are rarely true river terraces, being sand plains formed by the wash from adjacent moraines. The belt of this material varies from one to five or more miles in width. In the wide places the plains often slope steadily down to swamps.

Plains of a similar character are found in the valley of Prairie river and its tributaries. A good example is found in the region of Wabano and Trout lakes. The east half of T. 57-25 and the east two-thirds of T. 58-25 are occupied by a practically continuous plain, separated by the lakes named from a moraine running roughly parallel with the plain. In both these townships, but particularly in T. 58-25, numerous lakes are sunk deep below the level of the plain. These lie nearly at the same level, so that while the surface of the plain rises to the north the water level in the lakes is maintained and their surfaces are found to be steadily farther below the surface of the plain as we go north. In the southern part of the plain they are from forty to fifty feet below the plain, and in the northern part eighty to ninety feet below. Many of them have no outlets.

The large lakes, Trout and Wabano, as well as half a dozen smaller ones, form a chain extending from the water shed in T. 59-25 to Prairie river. This chain of lakes marks the position of an old drainage line or valley in the expansions of which the lakes now lie. The plain just noted lies immediately to the east and rises from fifty to ninety feet above the water. A moraine lies close along the west side of the valley.

It will be seen that the water in the chain of lakes lies very nearly at the same level as that of the lakes which are sunk in the plain.

The valley is narrow and somewhat gorge like between Trout and Ruby lakes in T. 58-25, a distance of a mile and a half. Its width in this portion is a quarter of a mile and it is ninety fee deep. The eastern side is steep.

In all the rest of the upper part of the valley it appears t be mature. Clearwater creek, which connects Wabano lak with Prairie river, is a postglacial stream. The old valley was filled by the stratified drift below Wabano lake.

I.—LAKES AND SWAMPS.

Knobs and kettles are abundant in this part of the county The depressions are sometimes dry "kettles," but more ofte by far they are either swamps or lakes, both of which ar almost innumerable and of sizes varying from a few rod across up to lakes several miles in diameter and swamps whic cover a township.

II.—PREGLACIAL RIDGES (CRETACEOUS).

Rising above the morainic accumulations in some places ar various hills and ridges, some flat-topped, more oval, an others narrow and elongated. The morainic hills are almost al ways sandy. These hills are always clayey. Very few boulder are seen and the coat of blue clay till is very thin. The timbe on these ridges is nearly always maple, while that on th other hills consists of birch and other soft wood.

The largest of these ridges is found in the southern part o T. 54–26, southwest of Pokegama. lake. It is a long an rather narrow ridge with northeast by east trend and rise three hundred feet above Pokegama lake. Its north flank i covered by heavy morainic accumulations, which do not how ever reach its summit. They abound in kettles and irregula depressions often seventy-five feet and sometimes more tha one hundred feet in depth.

Another hill oval in shape rises one hundred and fifty fee above Pokegama lake in sections 22 and 23, T. 55-26. It i like the ridge just noted in all but shape and elevation an like it is flanked on its north side by a moraine.

From the fact that these hills, of which these two are type are apparently of blue clay at the surface, and from the furthe fact that in shallow cuts, made in grading logging roads, found what I think was Cretaceous shale in small fragment only, I am of opinion that they will prove to be Cretaceou outliers which have withstood the gnawing of the streams an the grinding of the ice and yet endure to mark the forme eastward extension of the great Cretaceous sea.

Viewing the topography of the district as a whole, it is seen to be almost entirely recent in origin. Drainage is not yet fully established. There has been very little postglacial erosion. The precipitated moisture collects in the numberless swamps and lakes and there remains. The supply is only a little more than the demands of evaporation and the needs of the abundant vegetation. The large lakes have outlets, but they constitute the exception.

The northern part of the county is apparently quite level, especially towards the west. However, less was seen of this portion and it may be that there are topographic features here not now known, which will appear when the timber is cleared away.

It is not improbable that the suggestion made by Mr. H. V. Winchell, that this region lies in that covered by lake Agassiz, will prove to be correct. Still no important evidence pro or con, was collected by the writer. Careful watch was kept for indications of old shore lines and beaches, but none were seen. Sections along the river did not show beds which could be attributed to any but river or ice action. Through T. 61-25 and T. 62-25 moraines were noted crossing the river. Beds of sand washed down from these moraines are common, but elsewhere only clay was seen along this stream (Big fork). The banks of the Little fork are of the same nature, so far as they were seen by me.

III.—ROCK BASIN DISTRICT.

The topography of the northeastern part of the county is, in many respects, quite different and constitutes a distinct district. Going up Rainy river, we pass, at the Koochiching falls, somewhat abruptly from a region so deeply drift-covered that rock is seen only in the beds of the streams, to one in which drift is seen only in depressions in the uneven rock surface or along the beaches of the lakes. Rock bosses, ridges and knobs are everywhere, but they seldom rise more than twenty or thirty feet above the lakes, until the region about the mouth of the Vermilion is reached. There the rock masses rise to perhaps one hundred and fifty feet in some cases. Till is scarce until after the mouth of the Pelican is passed, going up Vermilion river; at that point the drift begins to thicken again.

The county is thus seen to be separated into three well marked topographical districts. Roughly speaking, the south two-thirds of the county constitute the first district. Its topography is mainly morainic. The west two-thirds of the remainder of the county is an alluvial or lacustrine plain, while the north-east corner belongs in the district of bare rocky basins and rocky prominences.

ROCK SYSTEMS OBSERVED.

I. POKEGAMA QUARTZYTE (PEWABIC).

The first rock examined was the quartzyte at Pokegama falls, on the Mississippi.

This rock appears at intervals along an irregular line extending from the north end of Pokegama lake, in the S. W. ¼ of the N. E. ¼ of sec. 23, northeasterly to the rapids of Prairie river. Test pits show the continuation of this rock as far east as the east line of T. 56–24, where it passes out of my district. It is not known to outcrop east of Prairie river, and is only seen in a few places between the rapids of that stream and Pokegama falls.

It is a flat lying rock with a low southerly and southeasterly dip, and seems to have been bowed up into a series of low flat arches. This feature is more noticeable in the large exposures near Prairie river.

At all exposures the rock appears pinkish, is rather fine grained and very hard. At Pokegama falls, where it has been quarried to some extent, the rock is seen to have been originally greenish in color. The reddish coloration is due to causes external to the rock itself. The coloration has penetrated from the surface and from all fissures and joints toward the center of the cubical blocks into which the joint-planes divide it. In some cases the blocks are small enough so that the change from green to red is complete; in others a greenish core is surrounded by a pinkish shell, which varies from one to four inches in thickness. Cross sections of these blocks (figure 1) show that the change proceeded from all sides.

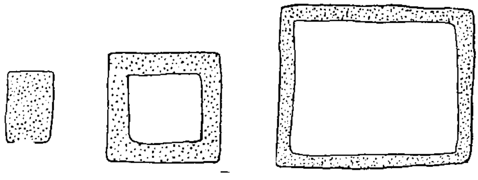

FIG. 1—Sections of quartzyte blocks, showing mode of change in color; outside pinkish, greenish within. Pokegama falls.

Some of the more massive beds toward the base of the section are very little changed in color. This is well seen in the bed of the Prairie river, a little above the bridge in the S. E. $\frac{1}{4}$ of sec. 34, T. 56-25, and also at the quarry above Pokegama falls.

Besides the red coloration, considerable iron ore is found in the quartzyte at many places, apparently always in the upper portion of the series. The character of these upper, ore-bearing strata is decidedly different from that of the lower beds. The ore-bearing rock, when seen in cross section, presents an irregularly banded appearance; the layers are alternately sheets of ore and sheets of quartz. As seen under the hand lens, the quartz layers show no grains; the structure is porous, and the quartz is usually stained red. The ore sheets vary from ferruginous quartz to a very good ore. Both ore sheets and quartz layers are exceedingly irregular and are often interrupted or cut by each other.

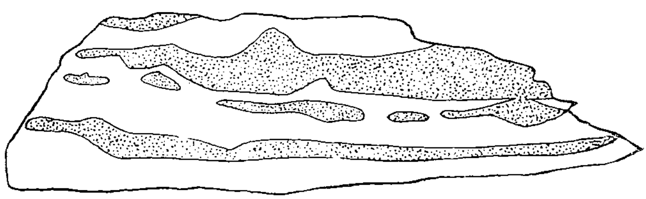

Fig. 2.—Hand specimen of ore-bearing rock, T. 56-24; showing the irregular banding seen in cross sections. The dotted areas are quartz, the others lean ore.

This irregularity is far greater than any that could have been produced by the slight movements which have affected the containing beds, and evidently it dates from the formation of the ore, whether that was contemporaneous with the formation of the containing beds or not.

The study of a large number of thin sections of this rock is necessary to determine the genesis, both of the ore and of the quartz layers.

Whether the ore was deposited at the time of the coloration of the lower beds, or not, my observations do not determine. That the latter process was long subsequent to the formation of the quartzyte is clearly shown by the fact that the coloration proceeded inward from all joint-planes toward the centers of the blocks, as already explained. This could not have been the case if the rock had not already become indurated and jointed before it was bathed in the iron-bearing solution (which seems to have come from the surface and not from below).*

It is of course possible that this ferruginous liquid was derived from the ore-bearing portion of the beds at a time long subsequent to the deposition of the ore. Opportunities for a thorough examination on this point are not yet to be had. The test pits are only sunk to the surface of the rock, or a few feet into it, as the ore, if found at all, is found near or at the surface of the rock.

In places the quartzyte is somewhat conglomeratic. The pebbles are small, not larger than coarse shot. The conglomeratic layers are near the base of the series.

With the exception of the iron ore, this rock very closely resembles the Sioux quartzyte of southeastern South Dakota.

The quartzyte was nowhere seen in contact with any other rock.

Near the dam at the foot of Prairie lake, just north of the quartzyte exposure, is a narrow belt on which are thickly strewn many small boulders of greenish-gray sandstone. No rock like it is exposed anywhere in this region, at least I was unable to find any. As represented by the boulders it is a quartz sandstone, somewhat micaceous, of only moderately firm texture and inclined to split into flags.

It gives no indication whatever of the presence of iron oxide. The belt on which the boulders lie is some four or five rods wide. Passing across this belt toward the quartzyte area, the sandstone boulders are quite abruptly replaced by boulders of quartzyte, which occupy a belt perhaps ten or fifteen rods wide, beyond which the quartzyte in place appears in oval topped masses here and there; often hidden by the drift but showing fairly well all the way to the river, a half mile southeast, where the iron-bearing beds are seen.

It was my impression, while on the ground, that beneath the belt of quartzyte-boulders the quartzyte lies, and that under the strip covered with boulders of gray sandstone, beds of that rock must be (making due allowance for the southward movement, due to ice action).

* With reference to the coloration of the quartzyte it is obvious that there are two ways in which this might occur. If the greenish quartzyte contains iron in any form other than the ferric oxide, then simple weathering would produce the change noted. Nor is there any fact observable in the field that militates against this as the way in which the change in color occurred. As a rule the red coat is as firm as the green core Microscopic study would determine this point.

The other way of accounting for the color change is indicated in the body of this paper.

Just across the river (north) lies a body of granite. Boulders of this rock are strewn for a short distance to the south of the granite. Then comes a stretch of swampy ground in which no boulders can be seen, and after that, the succession before noted. The relations of these rocks are shown by the section (figure 3).

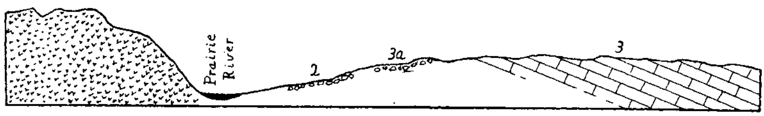

FIG. 3.—Showing stratigraphic relations at the falls of Prairie river. 1, granite; 2, sandstone boulders; 3a, quartzyte boulders; 3, quartzyte in place.

The depression which separates the granite from the near-lying quartzyte indicates the removal of some easily destroyed rock,—possibly the gray sandstone, possibly some other rock, no traces of which were seen,—lying between the tough granite on the one hand and the hard quartzyte on the other. No positive evidence, other than that just stated, supports this view of the stratigraphic relations here announced. On the other hand, nothing was found which opposes such a view.

II. PRAIRIE RIVER GRANITE.

This rock is exposed in the S. E. ¼ of the S. E. ¼ of sec. 32 and also in sec. 33, and very abundantly in sec. 34, T. 56, R. 25. It is seen to lie in a belt parallel to the quartzyte just described. It is a fine grained gray rock with some gneissic phases, and it contains some bodies of schist which were taken to indicate that the granite is eruptive. Its surface is quite uneven and is marked by roughly parallel ridges or corrugations, which mark lines of yielding to lateral pressure. These run in the direction of the outcrop, i. e., northeast and southwest. They are not high but are noticeable by reason of the incipient folding or bulging up of the rock.

Thrust planes are numerous and generally have either vertical or very steep dip.

Nothing like bedding was observed in this rock. Its relation to the quartzyte has already been noticed. The dip of the latter away from the granite shows that the region has been slightly uplifted, either by a general movement or by the intrusion of the granite. In T. 56-24, in the N. W. ¼ of sec. 9 and also in the eastern part of sec. 8, outcrops of a rock very similar to the granite rock at Prairie river, occur in the form of low mounds, two in number, a half mile apart. The one in sec. 8 is low-lying and is exposed by the action of a small creek, for perhaps a quarter of a mile. The other outcrop, in sec. 9, is larger, rising perhaps fifteen feet above the little valley to the north. No other rock outcrops in this township. Test pits one mile south of the granite encounter the conglomeratic phase of the quartzyte, with very little ore. A half mile farther south the ore is found more abundant, and in the central and eastern parts of the township numerous pits have been sunk and in each the ore bearing rock was found.

The Diamond mine in the center of the township has been developed enough to show the presence of a considerable body of good ore. It was noticed in the sinking of these pits that the ore and rock were found at very different levels, e. g., one was sunk in a depression in the top of the highest hill in the township and another at the foot of the same hill. In the first case the ore was found at a level about that of the surface of the ground at the second pit. In the latter the ore was quite as far below the surface, which shows a difference of level in the rock surface of 150 feet in an eighth of a mile.

It is noteworthy that among the score of pits in this township not one seems to have touched the granite.*

Granite was reported in the next township north but it could not be examined.

III. DIORYTES OF THE BIG FORK OR BOWSTRING RIVER.

On the Big fork a few miles above the mouth of Rice river a ridge of dioryte about fifty yards wide crosses the river running north and south. The river runs at the south end of the ridge and then makes a bend and cuts squarely across it. The greater part of the ridge, which rises some twenty feet above the river, is on the left bank. Its length is less than a quarter of a mile.

The rock is a rather fine-grained dioryte with possibly some granitic phases. Quartz and colorless feldspar are the chief minerals. At the upper end of the exposure some reddish feldspar was seen.

A small dike of greenstone cuts the dioryte and runs N. W. by W. Up the river some two hundred yards from the south end of the dioryte, a low exposure of a dark basic rock, which looks a little like a gabbro, rises about three feet above the

*The rock here called granite has not been studied by me under the microscope hence I do not know that the rock is a granite. It may be a dioryte.

water at its very low stage. This may prove to be dioryte also but is decidedly basic. No contact of it with the dioryte could be found; nor could any extension of the latter be discovered in the woods on either bank. Five miles down the river another small body of dioryte, macroscopically indistinguishable from the exposure just noted, is found crossing the stream and disappearing in the banks. One hundred and fifty yards farther down is another mass of the same rock. This rock is black on the surface, but it may be that this is the result of its being covered by the stream at high water.

Perhaps five miles farther down the river is another body of the same rock. It shows in the bed and on the right bank of the stream. A number of large boulders four to six feet in diameter, apparently broken from this ledge, lie in the edge of the river and on the bank close to the solid rock. Their upper surfaces are striated and the striæ are parallel on the separate boulders and with those on the moutonnéed surfaces of the ledge.

IV. DIORYTE AT KOOCHICHING FALLS.

The Koochiching falls of the Rainy river are due to a ridge of quartz mica dioryte which is crossed by the stream about three miles below the outlet of Rainy lake. This rock forms the American shore for a mile below the falls, below which are two good sized islands of the same rock. It may appear farther down on the Canadian bank, but does not show itself on the U. S. side. This ridge of dioryte lies in the midst of a great body of mica schist* [Coutchiching of Lawson] through which it has been intruded. As evidence of this, many fragments of the schist of varying size are to be seen embedded in the dioryte.

Its character is better seen on the two islands than elsewhere. On fresh surfaces it appears as a light gray, rather coarse-grained rock made up of quartz, plagioclose, microcline and biotite. On weathered surfaces the color is faintly reddish, and large crystals of feldspar stand up prominently from the surface, giving a porphyritic appearance to the rock not seen in the fresh sections. At the upper end of the lower island a true porphyritic phase of the rock is seen. It changes notably in color and becomes finer in grain. At the upper end of the upper island a gneissic phase appears.

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*Classed by Dr. A. C. Lawson as a mica syenite gneiss, Report on the Geology of the Rainy Lake Region, p. 126 F. (Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, vol. III, for 1887-88, Part F.)

A greenstone dike cuts the dioryte, passing through the upper island and then to the American shore, along which it was traced for a mile, or to the falls, where it crosses the river and disappears on the Canadian side. Like the dioryte, its trend is nearly east and west. It varies in width from three to ten feet. It is probably a diabase.

The dioryte is clearly younger than the schists, and the diabase dike is still more recent. Later still slight movements of these rocks have occurred, which have opened small fissures on the American shore and produced slight dislocations which are shown in the schists and also in the diabase dike.

V. THE GREENSTONES.

These appear in two distinct types, which, however, shade or merge into each other in such a way as to make it often doubtful whether one is dealing with one or the other of the types. When they appear as dikes, as they often do, they are of course plainly and purely eruptive. Also they may be and are found in such condition as to make it certain that we have to do with beds of consolidated tuffs. But again they are found in such condition that it is not possible to say to which class they shall be assigned. Along the Big fork these rocks constitute the chief exposures between Rice river and Big falls. These exposures are mainly low oval mounds or moutonnéed surfaces from which the river has removed the drift. No other rock is found associated with them. In T. 61-25 the greenstone forms considerable hills, fifty or sixty feet high, and extending for several miles. From the foot of Rice River rapids on the Big fork to Little falls no rock but greenstone is exposed, but the intervals between exposures are so great there is plenty of room for other rocks. At the Little falls the river pours over a large mass of greenstone which here shows nearly all gradations of that rock. Some of it seems from a microscopic examination to be eruptive. Other portions appear more like tuffs. No other rock occurs here. A fracture was noted running across the exposure.

Two miles down the river a small mound of greenstone is seen. This is the last noted except in the form of dikes. These will be noticed in describing the beds cut by them. At two exposures, one near the mouth of Deer river and the other a mile up that stream, pebbles or amygdules of quartz up to two inches in diameter were noticed in the greenstone. They have a little elongation which was thought to be due to squeezing.

VI. MICA SCHISTS.

These rocks with the intruded granites, etc., constitute an immense series, extending, on the Big fork, from a point about twelve miles by river below the Little falls to within fifteen miles of Rainy river. The exposure is by no means a continuous one for the drift is deep all the way down this stream, but erosion has uncovered the rock in places enough to indicate the continuity of the beds. On the Little fork mica schist was found within four miles of the Rainy river, while on Rainy lake the rocks are exposed in almost continuous section. Dr. Lawson* estimates their thickness on Rainy lake at four and a half miles.

The first exposure of these schists is about twelve miles below Little falls. The river runs in the schists for about an eighth of a mile. The rock stands up ten or twelve feet above the water. Two or three moutonnéed surfaces appear in the stream rising from one to three feet above very low water.

The rock seems to be composed almost wholly of biotite and quartz. The dip and strike were somewhat doubtfully made out by means partly of quartz lenses which were thought to indicate the bedding planes, and partly by means of a thin bed of green rock which was taken to be tuff.

As thus determined, the dip is some 30° or 40° west of north at an angle of perhaps 85°, and the strike east 30° or 40° north.

The schists are cut by a dike of greenstone, probably diabase, near the middle of the outcrop. It is twelve feet wide and strikes south 40° east.

Near the lower end of the exposure, in close proximity to the supposed tuff bed, an intrusion of granite is seen on the right bank. It is here twenty feet wide. On the opposite bank twenty rods away a narrow one foot vein of the same rock is seen. It is fine grained, light colored, slightly greenish, and extremely brittle.

At Big falls is a still larger exposure of mica schist veined with granite over which the river tumbles in a series of cascades falling about thirty feet in a quarter of a mile. Here the schists strike 8° or 10° south of east, but with local variations caused by the intrusion of the granite in the form of veins, sheets, bosses and dikes.

Two of these granite masses have flexed and contorted the schists in a very complex fashion. The dip is nearly vertical except where locally modified by the granite.

*Report on the Geology of the Rainy Lake Region, p. 102 F.

A dike of greenstone eighty feet wide cuts the schist parallel with the strike, near the head of the rapids. The schists are not notably changed at the contact with the dike. The granite sheets are very numerous. They run parallel with the strike of the schist and vary in thickness from less than one quarter of an inch to ten feet. The larger sheets do not follow the bedding of the schist very closely. They often show gneissic phases. This exposure extends for two miles along the river, but could not be found in the woods above the immediate valley.

A half mile below the mouth of the Sturgeon river—six miles from Big falls by river—mica schists veined with granite again appear. Apparently the same rock is seen at intervals in the river for twenty-five miles, always with a very steep dip to the north and with strike varying from east and west to southeast-northwest.

In the bed of Rainy river three miles below the falls a bed of fine-grained very hard mica schist is seen. It has a dip of 85° to the north and strikes east and west. Exposures of similar rock are found to within a mile and a half of the falls. Here it has been invaded by a large ridge of dioryte which has apparently carried it up so far that weathering and erosion have removed it, exposing the dioryte.

Four miles up the Little fork an exposure of mica schist of the same hard fine-grained type is seen crossing the river from northeast to southwest. This is also the direction of the strike. Dip vertical.

Above Ft. Francis at the Koochiching rapids, along the route through Rainy lake, Black bay, Kabetogama, Namekan and Sand Points lakes, and far up the Vermillion river, the schists were seen, sometimes free for long stretches from any intruded rock, and again seamed in every direction with granite.

There was usually a gradual increase in the abundance of the granite until it became the predominant rock, then in passing along the reverse conditions obtained until the simple schist was all that was to be seen.

No detailed work was done in this most interesting region, the time having been consumed in literally "beating the bush" in search of outcrops farther southwest in the region so thickly drift-covered that only rarely was the search rewarded with anything but negative results.

GLACIAL PHENOMENA.

I. THE TILL.

With some local exceptions, the till of the district is sandy, often gravelly. There is a notable scarcity of large boulders, in fact of boulders of any size except in cases to be hereafter specified.

The drift thins steadily to the northeast, so that by the time the southeast end of Rainy lake is reached only the depressions in the rocks are covered by drift.

T. 54–26 is one of the exceptions in that it is nearly all covered by a blue clayey till. This is doubtless due to the presence of the hills referred to on a previous page as possibly Cretaceous. There is evidence, in the shape of fragments of shale and pieces of lignite, that considerable areas of Cretaceous clays were to be found in this region at the time of the ice invasion. Blue clay lies under the till in many places in the southern part of the county. It was also noted along the Mississippi as underlying the sand and silt on the river bank from Grand Rapids to the swamp below Blackberry station.

No clayey till was noticed except in the immediate neighborhood of high non-morainic hills and ridges.

II. MORAINES.

A tolerably well-marked and continuous moraine enters this district in the southwest corner of T. 54–26 and runs northeast by north through three townships, leaving my territory in the northeast corner of T. 56–24.

The Mississippi river cuts this moraine two miles west of Blackberry station in the northwest corner of T. 54–24. At this point the morainic hills rise one hundred feet above the river. [A sand plain (overwash plain) lies along the east side of the moraine in T. 54–24 and the southern part of T. 55–24.]

Four miles north of the river the highest point of the moraine rises three hundred feet above Trout lake, in sec. 18, T. 55–24.

Somewhat disconnected morainic accumulations extend from the southern boundary of T. 54-26 north through at least six townships where they pass into a region not visited.

The frequent interruptions almost invariably transfer the moraine to the west, so that, while the segments trend about northeast by north, the moraine as a whole extends nearly due north.

This moraine has its strongest development in the southern half of T. 54-26, on the northwest flank of the high ridge of supposed Cretaceous beds. It is also well developed in the north-eastern part of T. 56-24.

Along both these moraines knobs and kettles are often well shown. The latter are in some cases one hundred feet deep.

One peculiar kettle is worth noting. It is in the top of the highest hill in T. 56-24, in sec. 21. The hill is about one hundred and fifty feet above the little stream near its base, and is quite separated from the adjacent hills. The kettle simulates a crater very closely. It occupies nearly the whole top of the hill, is about sixty feet deep and fifteen rods across the top of its narrow rim. The till is gravelly and quite bouldery. The boulders are well rounded and some of them well travelled. This is the only case that has come under my observation, of a large kettle in the top of an isolated hill.

III. BOULDER BEDS.

The scarcity of boulders in the till has already been noted. In one little area near the granite outcrop in T. 56-24 boulders were quite plentiful and some were of good size; but in all the rest of the district the till was found to contain but few boulders.

Whoever makes a canoe journey along either the Big fork or the Little fork in low water is not likely to complain of the infrequency of boulders in the bed of the stream. Scattered boulders here and there, more abundant than in the till, were to be expected. But that by no means tells the story. At all too frequent intervals the streams cross thick beds of boulders which extend in trains for unknown distances. In one case on the Big fork the same train was crossed three times in successive bends of the stream. They often occupy the bed of the stream for two miles at a stretch, but in such cases it is probable that the stream crosses the boulder train obliquely. On the Big fork these beds of boulders were first encountered about ten miles above the mouth of Rice river, and they were found at intervals all the way to within fifteen miles of Rainy river. The number of the boulders is astonishingly great. In some instances the river nearly disappears in the mass of boulders. More frequently it forms rapids, quite unfavorable to canoe navigation in low water. At the places where these boulder beds were found the country was almost invariably level. Exceptions to this are found in the vicinity of Deer river. There are no indications of the presence or proximity of a moraine. There are no signs of a rock outcrop. There are no boulders on the banks of the stream. They seem to be confined to levels not far above that of the water. Whether these boulder trains mark the position of earlier moraines from which the other material has been removed, or whether they are combings from the bottom of the ice-sheet, I am unable to say. But from the extension of the belts, and from the fact that where outcrops occur no such boulder beds are found, and from the further fact that just above Deer river where a moraine crosses the stream boulder beds do occur, I incline to the former view.

IV. GLACIAL STRIÆ.

The following table gives the results of observations on the direction of striæ, as noted by me, referred to the magnetic meridian:

At Pokegama falls	S. 60° E.
At Prairie River rapids	S. 4° to 10° E.
On Big fork above Rice river, T. 61-26	E. 15° S.
On Big fork above Rice river, 40 rods down stream	E.
On Big fork below Rice river, T. 61-26	E. 11° S.
On Big fork below Rice river, T. 61-25	E. 15° to 45° S.
On Big fork above Deer river, T. 62-25	E. to E. 10° S.
On Big fork above Deer river, T. 62-25	E. 10° S.
On Big fork at Little falls	S. 12° to 18° E.
On Big fork 12 miles below Little falls	E. 10° to 22° S.
On Big fork at Big falls	E.
On Big fork below Sturgeon river	S. 34° E.
On Big fork 12 miles below Big falls	E 18° to 22° S.
On Big fork 25 miles below Big falls	S. 34° W.
On Little fork 4 miles above Rainy river	S. 40° W.
On Rainy river 2¾ miles below Ft. Francis	S. 30° W.
On Rainy river 1½ miles below Ft. Francis	S. 30° W.
On Kabetogama lake near Black bay	S. 42° W.
On Namekan lake, west end	S. 30° W.
On Sand Points lake, 10 miles from Vermilion river	S. 12° W.
At Tower, south of Vermilion lake	S. 8° W.

Some interesting facts, relative to the direction of the ice-movement, are brought out by a study of this table. It is seen that there is a broad belt in which the movement, as indicated by the striæ, was to the east of south instead of west of south, as would be expected from previously observed striæ along the north coast of lake Superior and along the lakes on the International boundary. The abrupt change from southeast to southwest, as shown on the Big fork, is certainly suggestive, in view of the fact that the region is a very level one so that local topography can hardly be appealed to for an explanation. Hardly less looked for is the lessening of the westerly movement noted in passing from Namekan lake to Vermilion lake, since the course is directly toward lake Superior. So far as I am aware, no suggestion of a cause for an easterly movement of the ice in this region has been made by any one. In fact, I think it has been generally supposed that the movement to the southwest along lake Superior and along the lakes of the International boundary, as far at least as to the Lake of the Woods, necessitated a parallel movement in the district lying between these two. That such was not always the case is shown by the evidence here recorded.

IX.

PRELIMINARY REPORT ON FIELD WORK DONE IN 1893.

BY J. E. SPURR.

CONTENTS.

ITINERARY.

The writer began his field work at the town of Virginia, in St. Louis county, where he arrived June 9, 1893. June 23d, he was joined by a competent assistant, Mr. R. P. Johnston of St. Paul, who remained with him throughout the rest of the season. Later in the summer, the change in the methods of work made it necessary to secure another assistant, and Mr. N. J. Cavanaugh was engaged at Mountain Iron, and continued in the employ of the survey from August 14 to November 7.

During the first part of the season it was convenient to make headquarters at towns and mining camps, along the Mesabi range, and from there to explore and map the surrounding country. Soon after my arrival the town of Virginia was destroyed by a forest fire, and during the rest of my stay in the vicinity, I, with many others, was indebted to the generous hospitality of Mr. R. B. Green. On June 27 we went to the mining town of Eveleth, in sec. 31, T. 58–17, where we made our headquarters; from Eveleth the next move was to McKinley; from McKinley to Biwabik; and from Biwabik to Mountain Iron. Having at length completed the survey of the Mesabi in ranges 16–19 west, a reconnoissance of the country to the north was undertaken. The services of Mr. Cavanaugh were secured, and on August 15 our party of three left Mountain Iron on foot, with a tent, camping outfit, and two weeks' provisions in our packsacks. Our route lay along the trail on the line between ranges 18 and 19, which we followed without difficulty, save in one case where a detour into T. 60–19 is made, and where nearly two days were spent in finding it. This brought us, in the northern part of T. 61–18, to the Sturgeon river road, which runs west from Tower to Sturgeon river. This we followed into Tower.

After some slight examination of the vicinity of Tower, two canoes were bought, and we left the town August 30 and made our way up the Pike river. The portages upon the upper part of this stream have been disused for some time, so that progress was somewhat difficult, and the old portage to the Embarras lakes was passed by unnoticed. We therefore kept on till we reached the county road, a few miles west of Merritt. From this point a portage was made to the Embarras lake at Merritt.

In order to gain some idea of the country lying south of the Mesabi range and north of the immediate vicinity of Carlton county, our party set out again from Merritt September 6th, and canoed down through the Embarras lakes and Esquagama lake, through the Embarras river to the St. Louis river and down this latter stream as far as the crossing of the Duluth, Missabe and Northern railroad, at Albert. Some attempt was made to follow this river further down, but passage became progressively more difficult, on account of log jams, and the country was so unpromising for discoveries of geological importance that it seemed wise to turn back. At Albert, therefore, canoes and camp furniture were loaded into a train and carried to the crossing of the White Face river, at Kelsey. From here an expedition was made up the White Face river for some twenty-five miles, and back to the same point. After this trip the canoes were disposed of, and the rest of the season's work was done on foot, with the aid of railroads when these were convenient. For the reconnoissance of much of the southeastern part of St. Louis county, the Duluth, Missabe and Northern railroad between the stations Kelsey and Pine (on White Pine creek) was made a center and base of supplies. On September 28th we packed from Columbia Junction to Stony Brook Junction, on the Duluth and Winnipeg railroad at the St. Louis river.

From Stony Brook Junction we worked both east and west, using the railroad, as before, for our base of supplies. On the west, we worked past Floodwood; and on the east, down into Carlton county. On October 24th we crossed the St. Louis river at Nagonab on a log jam, and made our way north along White Pine creek to the Duluth, Missabe and Northern railroad. Crossing this, we kept on northward to the Cloquet river road, which runs westward from Duluth. Having from this route completed the reconnoissance of the southeastern corner of St. Louis county, the same road was followed westward, across the Cloquet and St. Louis rivers, to Floodwood; and thence north to Floodwood lake. From Floodwood lake north the trail could not be followed, but by pressing onward through the woods we reached the unfinished Duluth, Mississippi River and Northern railroad, and in a few days arrived at Hibbing, on the Mesabi range.

At Hibbing, Mr. Cavanaugh left us. From this point and from the various mining camps in the vicinity that part of the Mesabi range which lies in ranges 20 and 21 was carefully examined, so far as circumstances would allow, as far west as the Mesabi Chief mine in sec. 22, T. 57-22. When this task was completed, the weather had become unfavorable for further work. We therefore left the field, and on November 18th Mr. Johnston and myself reached Minneapolis.

AREA MAPPED.

During the season sixty-two towns were roughly mapped, both geologically and to some extent topographically. When it is considered that these represent 2,232 square miles, and that all the information which we have in regard to them was obtained by one person in five months, and was secured in often unfavorable circumstances, it will be seen that there can be no possibility of having done careful and detailed work on most of the area, and the errors which will doubtless be detected may be fully accounted for.

GEOLOGICAL METHODS.

Somewhat careful and detailed work was done along the Mesabi range, in ranges 16 to 21. This is the most varied and interesting district in the territory examined, both geologically and topographically. Here the limits and relations of the different formations were carefully traced, most of the test-pits were visited, and a collection which was especially rich in the various phases of the iron-bearing rock was made. The opening up of the country by the exploration for iron, and the cutting of roads and trails, made this detailed study possible.

Outside of this district, however, the country was passed over at wide intervals, so that only a general knowledge of its features was obtained, which may be a guide to future work. There are some interesting special results, but, as a whole, it should be considered in the light of a reconnaissance.

TOPOGRAPHICAL METHODS.

Contour lines have been drawn for the whole area mapped, for each fifty feet above the level of the sea. In determining elevations the aneroid barometer was used, and sketching was often resorted to. Valuable checks were obtained at numerous places by hights determined by levelling, especially along the lines of railroad.

The most varied topography was along the Giant's range of hills, and here, where necessary, every section line was gone over and readings taken at short intervals. In the less varied country north of the Giant's range fewer determinations by barometric readings were possible, and sketching and to some extent the use of the hand-level took their place. Much of the territory lying south of the range is exceedingly monotonous, so that the placing of the contour lines here was very simple.

SALIENT POINTS IN THE GEOLOGY.

Of the many varied and interesting observations which were made during the summer, it is the purpose of this report to give not more than a brief outline. The fuller discussion of the various problems involved will appear, or has already appeared, in various other publications of the survey, and elsewhere.

1. THE GIANT'S RANGE GRANITE.

It will be necessary first to speak of the granite of the Giant's range, although properly, in the order of its age, this should come after the Keewatin rocks. The granite, which is nominally of the hornblende-biotite variety, constitutes a continuous belt, several miles in width and upwards of a hundred miles in length, which runs about N. 70° E. across the area examined. The divide between the great drainage basins of the Red river on the north and the St. Lawrence system on the south follows for many miles this granite ridge.

Formerly, this granite had been generally assumed to represent sedimentary beds altered in situ, to be of Laurentian age, and to repose stratigraphically beneath the schists (of Keewatin age) with which it is associated. But the developments of this season's work show conclusively that this rock, whatever its earlier history and derivation, is in its present position intrusive, and is younger than the Keewatin rocks. The study of other granitic and gneissic areas in northeastern Minnesota has in other cases led to a similar conclusion,* and so the limits of the old Laurentian area have been considerably reduced.

The reasons for assigning to this rock an intrusive origin are those of the ordinary nature, and may be thus in part enumerated:

1. Contacts have been found, which show the granite sending stringers into the schists along the line of junction.

2. The granite contains numerous inclusions of the schists, and of all sizes. These fragments show various stages of

*Dr. U. S. Grant, Twentieth Ann. Rep. of this Survey, pp. 35-95; Twenty-First Ann. Rep., pp. 50-54. The probability of a large portion of the Giants' range being of the nature of eruptive rock was shown by Prof. N. H. Winchell in the Fifteenth Annual Report, pp. 349, 355; Seventeenth Report, pp. 21, 30, 31, 67.

metamorphism and recrystallization, which in general seem to vary with the size.

3. At the contact, the schists are more or less metamorphosed.

4. In two instances at least, the granite nearly surrounds areas of schist, which are, however, still connected with the main body. These peninsular areas show much greater metamorphism than the main body. (See Plate III).

5. In T. 58-17 are two lenticular masses of granite, separated from the main body, and surrounded by the schists. The longest axes of these bodies are parallel with the general trend of the main body; in mineral composition they are identical, and in texture they correspond to the phase in the main body which is commonest near the contact with the schists. They are undoubtedly the surface exposures of apophyses from the main mass.

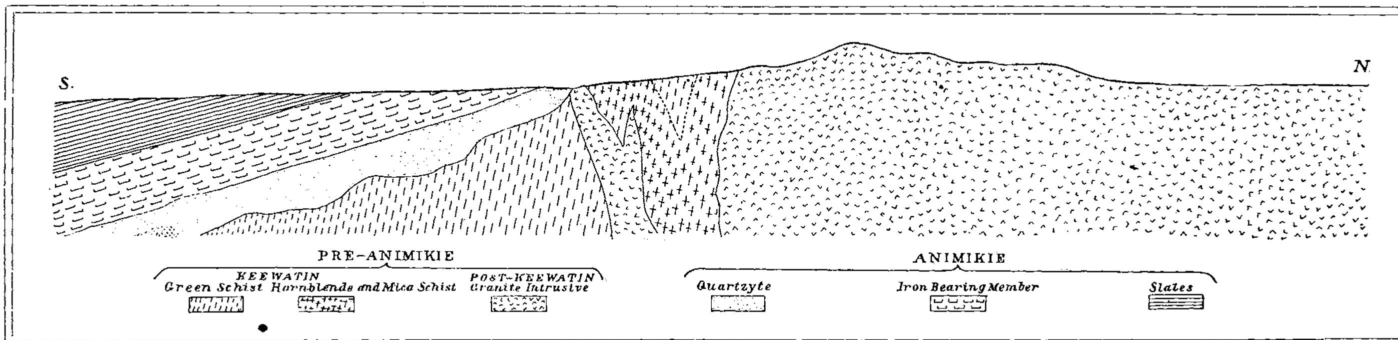
6. Near the contact, the granite is fine-grained; but as the distance increases, it becomes coarser and often porphyritic.

It is not possible to consider the question whether or not this granite consists of buried and fused acid sediments of the Laurentian, which by the movements of the inner crust were intruded among the later strata, and there recrystallized. The northern contact of the granite with the schists, though still distinct, is much more complicated than at the south, and this might suggest the idea that this is nearer the ancient granitic reservoir.

2. THE KEEWATIN SERIES.

Among the formations mapped was a hitherto unexplored area of Keewatin rocks, lying south of the granite belt above described. Frequent specimens were collected here, but no special microscopic study has been attempted. It is evident that the rocks vary in origin, some being undoubtedly igneous, while others have had a simple detrital origin. They are traversed by a regional cleavage which has a nearly uniform trend of about N. 70° E., and a hade which is nearly vertical. Most of the rocks are marked by the development of sericite and kindred minerals, resulting in the familiar "green schist" which has been considered the lithological peculiarity of the Keewatin.

Near the contact, however, as has been noted, and especially in those positions where they are partly surrounded by the granite, these schists have been altered into more perfectly crystalline hornblende and mica schists. The distribution and



SECTION ACROSS THE MESABI RANGE.

Drawn North and South through the Central Parts of Townships 58-18 and 59-18, thus passing through the Town of Mountain Iron.

Horizontal Scale ⅔ mile=1 inch. Vertical Scale three or four times exaggerated.

This section shows the typical stratigraphy of the Western Mesabi range.

relation of these crystalline schists make it clear that they represent no distinct stratigraphical division, but are simply among the contact phenomena of the granite. (See Plate III.)

The chief interest in this lies in the fact that the hornblende and mica schists have in general been considered as peculiar to a lower horizon than the Keewatin—the Vermilion or Coutchiching,—and their existence has been held as sufficient evidence of the age of the rocks in any given case. In the district examined, however, it appears that this rule will not hold.

On the other hand, in those parts of the Keewatin further from the granite, especially in the southern part of T. 58-17, there were found rocks which were undoubtedly clastics, cleaved but not greatly metamorphosed, slates and quartzytes.

To sum up, there are in the Archean of the Mesabi range rocks which according to their lithological features might be held to represent three great horizons: The granites (sometimes gneissic), the Laurentian; the hornblende and mica schists, the Vermilion or Coutchiching; and finally the sericitic schists, the Keewatin. Actually, however, we are as yet unable to make any stratigraphical subdivision of the Archean in this place. In classifying the sericitic schists as Keewatin, we must assign to the same period all except the granite, and include the crystalline schists and the simple detritals.

*The Thomson Slates.**

The detrital series, which is well exposed in Carlton county, especially along the St. Louis river from Thomson to Cloquet, was traced for some distance further north than before known, into St. Louis county. The northernmost outcrop was in sec. 27, T. 51–19; and further north still the drift suggests that this continues to be the underlying rock.

These slates and graywackes have been sharply folded, and subsequently were subjected to strains which induced two sets of regional cleavage. Of these the most prominent, and apparently the first developed, varies from N. 60° E. to nearly east-and-west. Near Cloquet, where a later dike cuts the slates, a third cleavage is locally induced.

These rocks were correlated by Irving† with the Animikie of the Mesabi range, and subsequent writers have accepted this correlation. There seems to be a preponderance of evidence, however, in favor of considering them the equivalent of the

* Cf. "The stratigraphic position of the Thomson slates," by J. E. Spurr; Amer. Jour. Sci., III, vol. xlviii, pp. 159–166, Aug., 1894.

† Seventh Ann. Rep. U. S. Geol. Survey, p. 422.

Keewatin of the Mesabi range rather than the Animikie, and thus placing them below the great unconformity which is there displayed.

3. THE ANIMIKIE SERIES.

Upon the Mesabi range the rocks of the Animikie series rest unconformably upon the Keewatin schists. To the north they abut against the schists or the granite; while on the south they are covered by a great thickness of drift. The exposed belt thus follows the general strike of the strata, which in turn corresponds closely with the trend of the Giant's range of hills.

The observations upon the geology of the Animikie, and especially of the iron-bearing member, have been incorporated in Bulletin 10 of the survey. Excepting the belt above described, no other areas were encountered whose rocks were distinctly referable to this period.

4. THE CRETACEOUS BEDS.

The existence of certain small areas of conglomerates and shales which from their fossils proved to be Cretaceous has already been noted by Mr. H. V. Winchell.* These Cretaceous strata are found only in small, isolated areas, so far as is yet known; and these seem to be but the remains of a greater sheet which has been stripped away by erosion. They lie unconformably upon the Animikie strata; and in the places identified have apparently derived most of their material from the rocks of the iron-bearing member.

That they were laid down close to the shore is indicated not only by their conglomeratic and shaly characters, but also by the presence of numerous fragments of fossil wood, which are found imbedded among other materials. In one of the localities, moreover, a conglomerate of this sort is closely associated with a lignitic swamp deposit, showing that by a slight subsidence a coastal swamp had become transformed into a sea-beach. From the presence of these scattered fragments of purely littoral deposits, and the absence of any rocks indicative of deeper water conditions, it is possible that this region may actually have been the extreme limit of the Cretaceous ocean.

5. THE DRIFT.

Two moraines cross the area examined—the Mesabi moraine on the north, which in general follows the Giant's range of hills; and on the south, very near the junction of St. Louis and

*American Geologist, October, 1893, p. 220.

Carlton county, another, which has been identified by Mr. Upham with the Leaf Hills moraine, further northeast. In the nature of their composition, these two moraines are characteristic, and yet strikingly different. That of the Mesabi range contains boulders which, when of large size, are generally of granite, evidently derived from the Giant' range and the more extensive areas further north. The more southern moraine is characterized by the constant presence of large boulders of the coarse anorthosyte and other rocks which are found chiefly in the Keweenawan province, and so must have come in a southwesterly direction.

North of the Giant's range, as far as the Vermilion range, the drift consists mainly of till and little-washed gravels, but so scant in quantity that they determine the topography only to a minor extent.

Between the Mesabi moraine and that on the south lies an area which is nearly flat, but slopes gently toward the south. A large part of this is occupied by a swamp, of the common and well-defined variety which is called by the Indian name "muskeg."*

Where cuts have shown the nature of the soil which underlies the peat, it is usually of sand or stratified gravels. A large area lying chiefly between the St. Louis and the Floodwood river, is composed of a uniform siliceous clay, or extremely fine sand. This is not encumbered with muskeg.

Unmodified drift, however, encroaches upon the area in many cases. Noteworthy and interesting are the occurrences in the southeastern part, especially noted between Grand lake and the Cloquet river. Here in numerous cases cuts show a veneer of till, with many boulders (chiefly of anorthosyte and other rocks characteristic of the Keweenawan province), which covers an apparently deep deposit of fine, perfectly stratified sand. This must indicate a late advance of the ice after the deposition of most of the drift of this muskeg area; and the similarity of the boulders in this till to those of the southern moraine suggests that they both may be referred to the same episode.

*This name is distinctive, and should be retained. The muskeg supports a thick growth of mosses and water-loving plants, and is always sprinkled with stunted spruce and tamarack trees. In distinction from the "cedar swamp" the muskeg or "tamarack swamp" is in the geological sense a true swamp, i.e., its soil consists of peaty material which represents the accumulation of vegetation in shallow bodies of standing water.

The Duchess slough.

The St. Louis river skirts the northern border of the southern of the two moraines described, and is thus deflected easterly from its previous course. In T. 50–17 it cuts across the morainic tract and resumes its southerly course. At the bend, near the junction of the river with White Pine creek, there is an interesting abandoned postglacial valley. This is now comparatively dry, or at most swampy, and is strongly marked for a large part of its course by distinct escarpments. The point of its leaving the present river channel and that of rejoining are within two miles of one another. This old river-bed represents an *ox-bow cut-off*, and differs from the ordinary occurrence in that the area enclosed by the cutoff is hilly and morainic. It goes by the name of the *Duchess slough*, and is the proposed northern terminus for the projected canal to furnish water-power for Duluth.

X.

LIST OF ROCK SAMPLES COLLECTED IN 1893

BY J. E. SPURR.

Most of the specimens were collected from the iron-bearing rocks of the Mesabi range; and from the study of these specimens have been derived many of the results which have been incorporated in Bulletin No. X of this survey. For the nomenclature of these iron-bearing rocks, and an explanation of the terms used, this bulletin should be consulted, especially the final discussion on page 248. All the specimens from the Mesabi range were taken from the general region included between ranges 16 and 21.

Many of the samples of other rocks were collected with a view to their bearing upon the problem of the iron ores; while others had no connection with this subject. The collection is intended to represent as completely as possible the known formations between Carlton county on the south and the region of Vermilion lake on the north, in ranges 16 to 21.

In general, this catalogue is to be considered as compiled simply for convenience of reference; the rocks are indicated by field names, which may often prove upon close study to be incorrect, and are perhaps manifestly indefinite. No study sufficient to permit of an accurate description of some of the rocks has as yet been made, except in the case of the rocks of the Mesabi iron-bearing formation.

Rocks of this series are numbered in white, each number followed by the letter S, to distinguish them from the other series of the survey and museum.

10. Gray taconyte (magnetitic). N. W. ¼ N. W. ¼ sec. 3, 58–17.

11. Light gray porous taconyte, banded with magnetite. Same locality.

12. Pale pink friable decomposed taconyte, stained brown in places by iron oxide. N. W. ¼ N. E. ¼ sec. 9, 58–17. Near the town of Virginia.

13. Hard lean iron ore (hematite). From the Rouchleau (Norman) mine, near Virginia.

14. Hard green taconyte, banded with magnetite. S. E. ¼ N. E. ¼ sec. 30, 58–17.

15. Granular quartzyte. S. E. ¼ S. E. ¼ sec. 29, 58–17.

16. Pebbly quartzyte, decomposed and stained red by iron. Same locality.

17. Dark green spotted-granular taconyte. S. E. ¼ S. E. ¼ sec. 30, 58–17.

18. Jointed taconyte slate. S. E. ¼ S. W. ¼ sec. 20, 58–17. From the face of a steep cliff.

19. Gray siliceous taconyte, changed in part to brown pulverulent rock. S. W. ¼ N. W. ¼ sec. 31, 58–17.

20. Siliceous and magnetitic taconyte, a pseudo-conglomerate. S. W. ¼ sec. 34, 58–17.

21. Taconyte breccia. S. E. ¼ sec. 30, 58–17.

22. Taconyte, pseudo-conglomeratic. Same locality as 20.

23. Fine-grained quartzyte. N. W. ¼ N. E. ¼ sec. 33, 58–17.

24. Gray slate. N. E. ¼ N. W. ¼ sec. 33, 58–17.

25. Taconyte, heavily magnetitic. Pseudo-conglomeritic. S. W. ¼ S. W. ¼ sec. 34, 58–17.

26. Hard hematite, coated with limonite or göthite. N. W. ¼ S. W. ¼ sec. 34, 58–17.

27. Sideritic chert banded with siliceous and chloritic slates. N. E. ¼ S. E. ¼ sec. 33, 58–17.

28. Taconyte slate (magnetitic) with residual fragment of red siliceous spotted-granular taconyte. Same locality.

29. Taconyte slate (magnetitic). Same locality.

30. Taconyte slate (magnetitic), jointed. Same locality.

31. Gray jasperoid taconyte, changing to light yellow pulverulent rock. From the Rouchleau (Norman) mine, near Virginia.

32. Gray jasperoid taconyte, altered in part to hard brown jasperoid taconyte. Same locality.

33. Green chert, with a finely brecciated band. From S. E. ¼ S. W. ¼ sec. 8, 58-17.

34. Gray siliceous spotted granular taconyte. Probably from sec. 17, 58-17, near Virginia.

35. Reddish taconyte jasper, banded with magnetite, and showing pitted decomposition. From Chicago property, in S. E. ¼ sec. 4. 58-16.

36. Light gray siliceous taconyte, showing pitted decomposition. Same locality.

37. Gray taconyte, impregnated with calcite or magnesite, and containing a fine-grained green residual fragment. Same locality.

38. Light green siliceous taconyte. Same locality.

39. Light green spotted-granular taconyte (green-sandstone?). Same locality.

40. Banded taconyte jasper, with bands of hard hematite. From Iron Cliff, S. E. ¼ N. W. ¼ sec. 36, 59-17.

41. Dark red siliceous taconyte, with sand grains. Same locality.

42. Gray jasperoid taconyte, changing to hard hematite, and stalactitic limonite. S. E. ¼ S. E. ¼ sec. 5, 58-16.

43. Altered conglomeritic quartzyte. S. E. ¼ S. W. ¼ sec. 4, 58-16.

44. Contact facies of mica schist. S. W. ¼ N. W. ¼ sec. 35, 59-17.

45. Mica schist. 45 paces north of 44, and nearer contact. Same locality.

46 Actinolite (?) schist. Same locality as 45, within five feet of contact with granite.

47. Contact of granite (hornblende biotite) with Keewatin schist. Same locality.

48. Biotite schist, in contact with granite, as above. From the main contact of the two formations. Same locality.

49. Contact of small stringer of granite with the schist as above. Same locality.

50. Granite (hornblende biotite) from within a few feet of the contact. Same locality.

51. Granite (hornblende biotite), like 50. From N. E. ¼ N. E. ¼ sec. 7, 58-16.

52. Granite, gneissic. About S. W. ¼ S. W. ¼ sec. 21, 59-17.

53. Dark green spotted-granular taconyte (green-sandstone?), in contact with black, carbonaceous shale. From the Chicago property, in the S. E. ¼ of sec. 4, 58-16.

54. Green schist, part stained brown by contact with the

iron of the iron-bearing rocks. From the Hale mine, S. E. ¼ N. W. ¼ sec. 1, 58-16.

55. Mottled greenstone. N. W. ¼ S. W. ¼ sec. 34, 59-16.

56. Dark, spotted greenstone. S. E. ¼ S. E. ¼ sec. 36, 59-16.

57. Mica schist. N. W. ¼ S. W. ¼ sec. 27, 59-18.

58. Hornblende schist. About 200 paces north of 57.

59. Mottled actinolite (?) schist. Same locality.

60. Muscovite (?) schist. Occurs interbanded with 59.

61. Conglomerate, probably Cretaceous. S. E. ¼ N. E. ¼ sec. 6, 58-17.

62. Conglomerate (probably Cretaceous), thoroughly iron-stained. N. E. ¼ N. E. ¼ sec. 10, 58-18.

63. Chip from boulder of hard iron in conglomerate. Partly magnetic, much pyritized. Same locality.

64. Red siliceous jointed taconyte, somewhat decomposed. S. W. ¼ S. W. ¼ sec. 2, 58-18.

65. Same as 64. Same locality.

66. Decomposed taconyte (pseudo-conglomerate). Same locality.

67. Conglomerate, thoroughly ferrated and changed to lean ore. Probably Cretaceous. Same locality as 62 and 63.

68. Brecciated taconyte, cherty and jasperoid fragments in a spotted-granular matrix. N. W. ¼ S. W. ¼ sec. 2, 58-18.

69. Postglacial taconyte conglomerate. From the drift, a mile south of Mountain Iron, in 58-18.

70. Banded silica-kaolin. S. E. ¼ N. E. ¼ sec. 6, 58-17.

71. Compact taconyte gritrock. S. W. ¼ N. E. ¼ sec. 3, 58-18.

72. Taconyte breccia. N. W. ¼ S. W. ¼ sec. 2, 58-18.

73. Same as 72.

74. Taconyte breccia, showing pitted decomposition. Same locality.

76. Dark gray impure limestone. N. W. ¼ N. E. ¼ sec. 7, 58-17.

77. Same as 76.

78. Dark red taconyte. N. W. ¼ S. W. ¼ sec. 2, 58-18.

79. Taconyte breccia. Same locality as 72.

80. Same as 79.

81. Taconyte hematite slate, jointed. S. W. ¼ N. W. ¼ sec. 3, 58-18.

82. Drill core of taconyte. S. E. ¼ N. E. ¼ sec. 6, 58-17.

83. Same locality. Slightly different phase.

84. Fragment (taconyte?). S. W. ¼ S. W. ¼ sec. 35, 59-18.

85. Taconyte pseudo-conglomerate. A decomposition phase. Same locality as 66.

86. Conglomerate (probably Cretaceous). Same locality as 82.

87. Same as 86, with incrustation of siderite (?). Same locality.

88. Consolidated carbonaceous clay (probably Cretaceous). Same locality.

89. Taconyte (?) shale. S. E. ¼ sec. 9, 58–18.

90. Same, banded. Silica-kaolin? Same locality.

91. Taconyte (?) shale. Same locality.

92. Same. Same locality.

93. Taconyte jasper. From the Snively property, S. W. ¼ N. W. ¼ sec. 3, 58–18.

94. Massive hornblende rock. S. W. ¼ N. E. ¼ sec. 17, 59–17.

95. Sericitic (?) schist. N. W. ¼ N. W. ¼ sec. 32, 59–17.

96. Taconyte jasper, with disseminated crystals of magnetite. N. E. ¼ N. E. ¼ sec. 23, 59–18. Probably from drift.

97. Taconyte jasper, with coating of limonite. From the rock-bluff to the north of Mountain Iron mine, 58–18.

98. Jointed magnetite slate (taconyte?), N. W. ¼ N. W. ¼ sec. 8, 58-18.

99. Taconyte chert, changing to taconyte slate, magnetitic. Same locality.

100. Reddish taconyte, changing to taconyte slate. S. E. ¼ N. E. ¼ sec. 7, 58–18.

101. Taconyte(?) shale. S. E. ¼ N. W. ¼ sec. 18, 58–18.

103. Same as 101. Same locality.

104. Preglacial wood. From drift. Same locality as 101, etc., and imbedded in the soft shale in part.

105. Conglomerate (probably Cretaceous). From drift at same locality.

106. Same as 105. Same locality.

107. Gray siliceous taconyte. S. W. ¼ S. E. ¼ sec. 2, 58–19.

108. Porous taconyte. S. E. ¼ S. W. ¼ sec. 8, 58–19.

109. Siliceous taconyte. Same locality.

110. Porous and siliceous taconyte. Same locality.

111. Siliceous taconyte, changing to taconyte slate, and coated with dendrites of maganese (wad?).

112. Sideritic and cherty slate. N. W. ¼ N. E. ¼ sec. 17, 58–19.

113. Same. Same locality.

114. Same, more definitely banded. Same locality.

115. Same. Same locality.

116. Same. Same locality.

117. Same. Same locality.

118. Cherty slate. S. W. ¼ S. W. ¼ sec. 17, 58–19.

119. Yellow taconyte gritrock, changing to brown taconyte jasperoid. N. E. ¼ S. W. ¼ sec. 17, 58–19.

120. Gray chert, changing to porous pulverulent rock (gritrock). Same locality.

121. Same. Same locality.

122. Cherty slate. Same locality as 112, etc.

123. Gray siliceous taconyte, changing to taconyte slate. S. E. ¼ N. E. ¼ sec. 17, 58–19.

124. Siliceous and decomposed taconyte, with coating of limonite. N. E. ¼ S. W. ¼ sec. 17, 58–19.

125. Glauconitic taconyte. From near 124.

126. Honeycombed limonite. From near 124 and 125.

127. Banded taconyte slate. Same locality as 123.

128. Siliceous taconyte. S. E. ¼ S. E. ¼ sec. 18, 58–19.

129. Taconyte chert. Same locality.

130. Same. Same locality.

131. Siderite-actinolite slate. Same locality.

132. Same. Same locality.

133. Taconyte gritrock, with seams of iron. 200 paces north of 128, etc.

134. Same. Same locality.

135. Siliceous taconyte, much altered to hematite. N. E. ¼ N. E. ¼ sec. 19, 58–19.

136. Porous taconyte, banded with hematite. Same locality.

137. Gray siliceous taconyte, impregnated with calcite or magnesite. N. W. ¼ N. W. ¼ sec. 17, 58–19.

138. Red taconyte shale. N. E. ¼ N. E. ¼ sec. 34, 58–20.

139. Cretaceous conglomerate (chiefly taconitic, much ferrated) containing fossil wood. N. W. ¼ S. W. ¼ sec. 20, 58–19.

140. Cretaceous conglomerate, containing fossil casts. Same locality.

141. Same. Same locality.

142. Cretaceous conglomerate. Contains pebbles of taconyte. Same locality.

143. Porous taconyte. Same locality as 135.

144. Cretaceous conglomerate, with fossil casts. Same locality as 139.

145. Green Cretaceous shale, with fossils. Same locality.

146. Sandstone conglomerate. From large drift boulder. N. W. ¼ S. W. ¼ section 10, 58–19.

147. Same. Same locality.

148. Taconyte gritrock, stained with iron in bands. S. E. ¼ N. E. ¼ sec. 17, 58–19.

149. Yellow taconyte jasperoid. N. E. ¼ S. W. ¼ sec. 10, 58–19.

150. Porous taconyte, changing to taconyte jasperoid. Same locality.

151. Gray porous taconyte, stained with iron on the periphery. Same locality.

152. Red taconyte shale. From near 148, etc.

153. Same. Same locality.

154. (Taconyte?) slate. From near 149, etc.

155. (Taconyte?) cherty slate. Same locality.

156. Taconyte gritrock, with seams of hematite. N. W. ¼ S. W. ¼ sec. 10, 58–19.

157. Gray taconyte, changing to red taconyte and taconyte slate. N. E. ¼ S. E. ¼ sec. 33, 58–17.

158. Banded taconyte slate. Same locality.

159. Gray taconyte chert. Same locality.

160. Same. Same locality.

161. Red siliceous taconyte, changing to taconyte gritrock. Same locality.

162. Hard hematite, with limonite. N. W. ¼ S. W. ¼ sec. 34, 58–17.

163. Same. Same locality.

164. Taconyte jasper, with quartz vein. N. W. ¼ S. E. ¼ sec. 33, 58–17.

165. Same, showing prismatic jointing. Same locality.

166. Gray and red taconyte. Same locality.

167. Incrustation of chalcedonic silica, in stalactitic forms, upon gray taconyte. S. E. ¼ S. W. ¼ sec. 8, 58–17.

170. Pitted taconyte slate, N. W. ¼ N. E. ¼ sec. 2, 58–18.

171. Taconyte breccia. N. E. ¼ S. W. ¼ sec. 1, 58–18.

174. Conglomerate (probably Cretaceous) stained red with iron. From N. W. ¼ N. W. ¼ sec. 11, 58–18.

175. Granite from contact with crystalline schists. N. E. ¼ sec. 12, 60-19.

176. Schist from same contact.

177. Granite from a dike in the schists. N. E. ¼ N. E. ¼ sec. 36, 61-19.

178. Schist from contact with granite. Same locality.

179. Actinolite (?) schist. From within a foot of the contact of the schists with the main body of granite, in N. E. ¼ sec. 12, 60-19.

180. Biotite schist. N. E. ¼ N. E. ¼ sec. 1, 60-19.

181. "Red jasper," with quartz vein. From the Minnesota mine at Tower.

182. "Black jasper." Same locality.

183. Siliceous jasperoid rock. Same locality.

184. Drill cores from near Lee mine, at Tower. "Jasper."

185. Banded jasperoid taconyte. From the Mountain Iron mine, at Mountain Iron.

186. Schist. S. E. ¼ S. W. ¼ sec 32, 61-16.

187. Fragment of gray calcareous nodule in slates, at Cloquet, near the Duluth & Winnipeg bridge across the St. Louis river.

188. Coarse gabbro. Duluth Hights.

189. Diabase (?) from center of large dike. Duluth Hights.

190. Diabase (?) from near margin of same dike.

191. Red rock. Duluth Hights.

192. More coarsely crystalline phase of same. Same locality.

193. Same. Same locality.

194. Red rock from narrow dike in coarse anorthosyte. Same locality.

195. Same. Same locality.

196. Diabase (?). Same locality.

197. Same. Same locality.

198. Red rock. Same locality.

199. Gabbro pebble, showing peripheral decomposition. From cut in drift, at Stony Brook station, on the Duluth and Winnipeg railroad.

200. Slate (Keewatin?). N. W. ¼ S. W. ¼ sec. 27, 51-19.

201. Quartzose slate. Same locality.

202. Schistose slate. Same locality.

203. Chips of fossil tree, found under a peat-bog, in the glacial gravels. From cut on D. M. & N. railroad one-half mile east of Pine station. (T. 50-16)

204. Hard hematite. Mountain Iron mine.

205. Quartzyte (Pewabic). N. W. ¼ N. W. ¼ sec. 36, 58-21.

206. Dark green quartzyte. Same locality.

207. Actinolite schist. S. W. ¼ S. W. ¼ sec. 25, 58–21.

208. Taconyte. N. W. ¼ N. W. ¼ sec. 36, 58–21.

209. Glacial boulder of taconyte jasperoid. N. W. ¼ N. E. ¼ sec. 1, 57–21.

210. Gray taconyte chert, changing to brown banded taconyte gritrock. S. E. ¼ N. E. ¼ sec. 29, 58–20.

211. Gray siliceous porous taconyte, changing to hematite. Same locality.

212. Gray siliceous taconyte, stained in part brown with iron oxide. N. W. ¼ N. W. ¼ sec. 22, 58–20.

213. Dark red jasperoidal taconyte. Same locality.

214. Gray siliceous taconyte, changing to brown taconyte jasperoid. Same locality.

215. Same as 213. Same locality.

216. Same. Same locality.

217. Glauconitic taconyte, with magnetite. Same locality.

218. Taconyte jasperoid, changing to hematite. Same locality.

219. Same as 217. Same locality.

220. Same as 213. Same locality.

221. Taconyte slate. N. E. ¼ S. W. ¼ sec. 29, 58–20.

222. Red taconyte shale. Same locality.

223. Green taconyte shale. Same locality.

224. Taconyte jasper. Same locality.

225. Gray taconyte gritrock. Same locality.

226. Quartzyte. S. W. ¼ N. W. ¼ sec. 35, 58–21.

227. Actinolite (?) schist. N. W. ¼ N. W. ¼ sec. 35, 58–21.

228. Muscovite schist. Same locality.

229. Silica powder. S. E. ¼ N. W. ¼ sec. 23, 57–22. Near Mesabi Chief mine.

230 Same. Same locality.

XI.

PRELIMINARY REPORT OF LEVELLING PARTY.

BY CHAS. P. BERKEY.

The party that entered upon work for the Geological and Natural History Survey on the 26th of June at Grand Marais consisted of L. A. Ogaard, Alex. N. Winchell and myself under the direct supervision of Dr. Grant. It was proposed to level across this portion of the state to the International boundary, to pay as much attention as practicable to the topography of the country as the levelling advanced, and to determine accurately by level such knobs or ridges as seemed of unusual elevation. The bench marks of the level were used as primary stations in the use of the aneroid barometer, by the aid of which the contour lines were established. The territory that occupied most of our attention comprises the central and northern portions of Cook county. This was known to be the most elevated district in the state and therefore considerable care was taken in an endeavor to locate more accurately the prominent points and ridges.

On account of the method of travelling in this district and the extreme difficulty of running a level through such a country of hills, swamps and poor trails, the work had to be planned by trips of two or three weeks duration. The first one of these was planned to extend from Grand Marais by the old "Iron trail" through Devil's Track lake, Little Pine lake, over Brulé mountain to the Misquah hills and then west to Winchell lake and south again to Brulé lake, where supplies had to be obtained again.

On a part of this first trip, which occupied the first three weeks of our work, we were obliged to engage two Indians, Jo Caribou and Alex Morrison, to help in packing and cutting through the woods. This first trip was by a great deal the most difficult and tedious of the whole summer's work. The trail followed was old and abandoned, and in many places could not be found at all, even by the Indians. The character of the underbrush was such, furthermore, that it became utterly impossible to use the level at all without constant cutting. Frequently after the most diligent work, nightfall would find us little more than a mile in advance of the former camp. But this first trip, in spite of the enforced slow travelling and difficult work, gave, in fact, the most satisfactory results of the whole summer's expedition. The Misquah hills proved to be the highest points reached in Minnesota. Several knobs were accurately determined by level and many more by the aneroid, some of which are given in the list accompanying this report

The highest point on which direct observations were taken is between Misquah and Winchell lakes in sec 36, 64-2 W. It was carefully determined by barometric readings and corrected by level bench marks close at hand, as well as by level observations from neighboring hills. Its elevation is 2,230 feet above sea level,—there is no greater recorded in the state. The Misquah hills form a broken ridge extending east and west a distance of many miles just north of Brulé river valley. A few separated knobs also stand outside of this main ridge. But the area in which peaks of an elevation exceeding 2,200 feet occur is very limited, Misquah lake being nearly a central point. For a distance of three or four miles both east and west of this lake, this hight is attained by several knobs. The more exact position is in the southern tier of sections of T. 64, R. 1 and 2 W.

An opportunity is offered for a general view of the central portion of Cook county here, such as can be secured at no other place. Standing upon the bare knob of red rock just east of Misquah lake, a very large portion of the surrounding country can be seen in every direction and especially to the north and south. The minor details are thus of course entirely overlooked, and only important ridges bounding prominent valleys are noticeable.

Toward the north, the general impression is that of a broad quite uniform valley extending east and west an indefinite distance and bounded on the north by the bluffs and ridges along the International boundary ten miles away. In the valley a dozen or more lakes can be seen, while hundreds more are hid behind wooded ridges or lie in narrow deep secluded valleys. Toward the south are three well marked features.

First is Brulé river valley lying immediately at the foot of the hills, extending east and west here also, and bounded abruptly on the south by Brulé mountain and connected ridges. This valley is exceptionally narrow and deep, being nearly 600 feet below the Misquah hills and over 500 feet below Brulé mountain, while the maximum distance between these two points is not over four miles.

Brulé mountain is very prominent from this point of view. It lacks only 60 feet of equalling the Misquah hills in hight, and is even more striking. On its northern slope the descent is 521 feet in less than a mile (three-fourths of a mile). In this regard, however, it is not so remarkable as the first ridge at Grand Marais which ascends 730 feet in a mile, or even some of the bluffs along the International boundary which have an almost perpendicular face from one to two hundred feet in hight. Three miles east of Brulé mountain are three remarkable knobs belonging properly to the Misquah hills, although they are south of the river valley. They are near together and have an elevation of 2050 feet by aneroid reading on the lowest of the three. A hundred feet can safely be added to this for the highest one.

Just beyond the crest of Brulé mountain to the south lies lake Abita, the mountain lake of Minnesota, 2048 feet above the sea, the most elevated lake in the state so far as recorded. But beyond this is the third great valley in our general view of this part of Cook county. It extends almost east and west as the others, but is broader and not so uniform. The southern limit is formed by the Saw Teeth bluffs along lake Superior, several of which appearing quite prominent seem to give a very substantial boundary to the valley. Lakes are not so abundant in this most southerly valley as were afterwards found in the districts farther north and west. Swamps of no very great extent were abundant and often small ones occur near the highest points. Large drift boulders are found in abundance even upon the bare knobs of the highest of the Misquah hills. Very little attention could be paid to details in any other lines of investigation.

After obtaining supplies from Gunflint City, the work of our second trip began with topographical work about Brulé lake. James Marshall took the place of the two Indians who had returned to Grand Marais. Similar work was then carried forward through the country adjacent to the canoe route to Gunflint lake. Georgia, Surveyor, Ida Belle, Kiskadinna, and

Ham lakes are the principal ones on the route and Cross river is the only stream of any size. The surface slopes gradually northward with no very high ridges after leaving Surveyor lake until Gunflint lake and vicinity is reached. Some more careful work was done in T. 65-4 W., especially in the southern half of the town and in section 28 in particular. As all these points will appear just as clearly on the maps when they are published I will not attempt any explanation here.

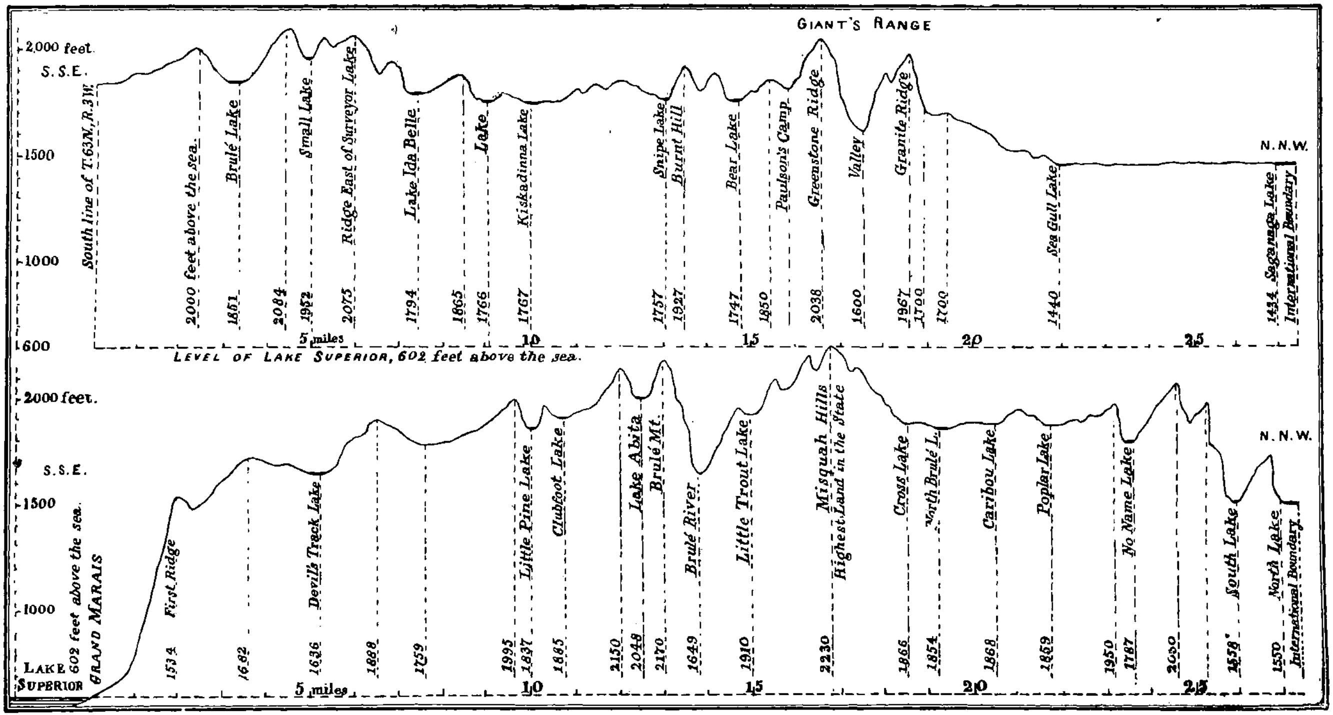
The third trip of our party included towns 64 and 65, 1, 2, and 3 W. and was made by canoe through Loon, Mayhew, Tucker and Banadad lakes and eastward through a continuous chain of small lakes to Poplar lake. From this place a trip was made toward the south through Caribou to north Brulè lake in order to check on our former determination of level. The return was then made from Poplar lake through Hungry Jack, Birch, Duncan's and Rose lakes, from which the International boundary route was followed to Gunflint again. The most noticeable features of this section of country are: first the comparatively low and uniform ridges of the gabbro belt crowded thickly together with usually only sharp narrow ravines between them running in every direction; second, the bold-faced bluffs north of the gabbro belt within three miles of the boundary lakes. All these ridges are comparatively high and have a gradual rather gently inclined southern slope and a very precipitous northern one. The lakes are very abundant and lie in deep narrow valleys. They are connected frequently by falls and rapids, as at Rose lake where the fall from Duncan's lake is 136 feet in a distance of less than a quarter of a mile. One of the most noticeable of these characteristic precipitous bluffs is called Rose Lake mountain. It rises from Rose lake 470 feet by aneroid determination. The highest points are, first a hill on the section line between sections 26 and 35, 65-2 W., which is 2050 feet, and second, the quarter post on the north line of sec. 28, 65-4 W., which is 2038 feet. The former was determined by aneroid and the latter by level. Other features will be shown sufficiently well by the maps.

In the territory thus far covered since leaving Grand Marais a few other points come into prominence by combining the observations of the three trips. The hight of land extends in a southwest direction from between North and South lakes to the ridge between Ida Belle and Surveyor lakes. Lakes to the southeast of this line drain into lake Superior; and lakes northwest of it drain into Rainy lake. Brulé lake has two prominent outlets, one toward the east giving rise to Brulé river, and the other to the west into Georgia lake, from which probably Temperance river rises, flowing toward the south. Ida Belle lake is the head of Cross river which flows north to Gunflint lake. For the greater part of its course it is a chain of narrow small lakes connected by rapids. North lake is the head of drainage westward along the boundary, and South lake is the head of the eastern boundary drainage, which reaches lake Superior through Arrow river in Canada and Pigeon river on the boundary. The Port Arthur, Duluth and Western railroad enters Minnesota at the narrows at the west end of Gunflint lake and the western terminus is now Paulson's camp four miles west. The county road extends from Grand Marais northward to Hungry Jack lake. During the past summer it was cut out from near Poplar lake westward to the railroad near the west end of Gunflint lake, and now forms a good trail from this point to lake Superior.

The fourth trip extended from Gunflint lake westward through Ts. 65–4and 5 W. and return through Ts. 64–5 and 4 W. There are no features of this needing especial attention. There are many very prominent hills, but none so high as those already given, the most elevated ones being usually between 1800 and 1900 feet.

After finishing this trip the entire original make-up of the party was broken by the return of Mr. Winchell and myself to the University. The further work was done by Mr. Ogaard, who then joined Dr. Grant, working on the geology of the district. And on their return to Ely the entire distance was levelled, thus completing a very extended list of bench marks as a basis for contour corrections in northeastern Minnesota.

Below I have added a list of accurately determined points from the field notes of the party, and have also, with the aid and advice of Mr. Warren Upham, drawn a plate showing two profiles across Cook county from Grand Marais and Brulé lake N. N. W. to the International boundary. These are each 27 miles in length and are about 10 miles apart. The one starting at Grand Marais includes only such points as fall within one mile of a direct line to the west end of North lake. The other, starting at Brulé lake, takes a direct line to the north quarter post of sec. 28, T. 65–4 W., and then runs northeast to the granite ridge, from which place it assumes the original direction to the boundary. (See plate IV.)



Two Profiles across Cook County, from Brule Lake and from Grand Marais N. N. W. to the International Boundary.

The following points are of sufficient prominence among those which have been accurately determined by level to warrant giving them a place here for future reference:

	Feet above the sea.		Feet above the sea.
Devil's Track lake	1636	Banadad lake	1944
Little Pine lake	1837	1st lake E. of Banadad lake	1942
Club Foot lake	1885	2d lake E. of Banadad lake	1927
Pound lake	1920	3d lake E. of Banadad lake	1927
Lake Abita	2048	Poplar lake	1859
Brulé mountain	2170	Straight lake	1879
Brulé River lakes	1649	Caribou lake	1868
Little Trout lake	1910	Meeds lake	1879
Ridge S. of Little Trout lake	1994	Hungry Jack lake	1687
Misquah lake	1911	Birch lake	1684
Hill E. of Misquah lake	2223	Daniel's lake	1684
Cross lake	1866	Duncan's lake	1664
North Brulé lake	1854	Rose lake	1528
Gaskanas lake	1878	Rat lake	1531
Winchell lake	1910	South lake	1558
Hill S. of Winchell lake in sec. 34, 64-2 W	2213	North lake	1550
		Little Gunflint lake	1548
Sham lake	1915	Akeley lake	1779
Brulé lake	1851	Paulson's lake	1708
Georgia lake	1841	Black Trout lake (Kakigo lake)	1663
Hill at W. end of Brulé lake, sec. 18, 63-3 W	2084	Bashitanagueb lake	1657
		Peter lake (Clothespin lake)	1608
Surveyor lake	1849	Gabemichigama lake	1587
Lake Ida Belle	1794	Agamok lake	1585
Narrow lake	1782	Little Saganaga lake	1600
Kiskadinna lake	1767	Muscovado lake	1706
Ham lake	1706	Green lake	1730
North ¼ post of sec. 28, 65-4 W.	2038	Gaiter lake	1782
Gunflint lake	1547	Charley lake	1763
Loon lake	1745	Bear lake	1748
Mayhew lake	1853	Flying Cloud lake	1738
Beaver lake	1880	Greenwood Island lake	1641
Tucker lake	1847	East and West lake	1618

The following are on the canoe route from Gabemichigama lake westward to Ely:

	Feet above sea level.		Feet above sea level.
Fox lake	1539	Knife lake	1381
Ogishke Muncie lake	1488	1st lake west of Knife lake	1371
Dike lake	1491	2d " " " "	1367
Zeta lake	1490	3d " " " "	1361
Epsilon lake	1460	Carp lake	1355
Delta lake	1469	Sucker lake	1330
Gamma lake	1470	Basswood or Bassimenen lake	1300
Beta lake	1475	Newton lake	1307
Alpha lake	1495	Fall lake	1313
Kekequabic lake	1497	Long lake	1337

The following are a few points of prominence determined by barometric readings and corrected by level bench marks:

	Feet above the sea.
South Devil's Track lake	1613
Knob S. of Little Pine lake	1995
Knob 3 miles E. of Brulé Mt., sec. 24, 63-1 W	2050
Hill N. E. of Little Trout lake	2023
Hill, sec. 36, 64-2 W., at Winchell lake	2230
Ridge S. of Brulé river, sec. 22, 63-2 W	2027
Granite ridge sec. 14, 65-4 W.	1967
Ridge south in sec. 23, 65-4 W.	1942
Sea Gull lake	1440
Ridge S. of Gunflint lake sec. 25, 65-4 W	1892
No-name lake	1787
Portage lake	1872
Hill S. of Hungry Jack lake, sec. 3, 64-1 W	1902
Moss lake	1729
Knob south of Duncan's lake	1907
Ridge between Duncan's and Rove lake	1947
Rose Lake mountain	1997
Hill, sec. 31, 65-5 W	1827
Hill, sec. 29, 65-5 W	1867
Little Round lake	1677
Little Copper lake	1777
Lake, sec. 15, 64-4 W	1867
Hill ¼ mile west of this lake	1967
Snipe lake	1757
Burnt hill north of Snipe lake	1927
Big Round lake	1702

XII.

PRELIMINARY REPORT OF FIELD WORK DURING 1893 IN NORTHEASTERN MINNESOTA.

BY ARTHUR HUGO ELFTMAN.

CONTENTS.

GENERAL REPORT OF FIELD WORK.

I. REGION TRAVERSED.

The territory assigned for investigation was ranges 8 to 11 (inclusive) west of the Fourth principal meridian between the latitude of Ely and Snowbank lakes and the shores of lake Superior. The writer, accompanied by Mr. H. E. White, as assistant and topographer, and Mr. B. F. Merrill, left Ely May 4th and spent the first week in making observations around White Iron lake. As soon as the ice had sufficiently broken up to permit canoe travelling, a trip was taken up the Kawishiwi river, north through Triangle, Moose, Snowbank and Disappointment lakes. Snowbank lake, excepting a narrow passage along the south shore, was covered with a field of ice. The work assigned on this lake was thus postponed until later in the season. Wilder lake completes the list of lakes examined during May. During June the region around the south Kawishiwi and Isabelle rivers was examined.

Some of the important lakes which were geologically reviewed and investigated, are Isabelle Trail, Bald Eagle, Gull, Gabbro and the eastern end of Birch lake. An overland trip through townships 60–11 and 61–11 was taken during the latter part of the month. The work was considerably hindered by the great forest fires upon the Mesabi range. The northwestern part of T. 60–11 was swept by the fire and the Stony river marks the eastern extent of the great conflagration. Numerous other fires were started by careless campers and large quantities of valuable timber were destroyed. During the hight of the fire the sun was obscured by the smoke for several days.

In July a trip was taken up the Stony river to Sand lake (T. 59–11) and to the center of T. 59–9. This river is so named on account of the large number of boulders in the stream, which greatly hinder and even make canoeing quite dangerous. From the Stony river the work was transferred to the south branch of the Isabelle river in T. 60–9. Heavy rains filled the streams and made travelling comparatively easy on the rivers, but almost impossible through the swamps. Owing to the unexplored condition of this region it was necessary to cut a number of portages. A canoe route was made from Smokehouse lake (sec. 28, T. 60–9) to Clear lake in section 14 of the same township. This makes a complete connection of the three principal canoe routes used in reaching the headwaters of the streams flowing north. From Clear lake we went down the south Isabelle river and returned to Ely. After getting supplies, several days were spent on Snowbank lake to make the observations which were postponed on account of the ice during our first visit to this lake.

We went up the south Isabelle river to Clear lake, from which a two weeks' overland trip was made through townships 61, 60, 59 and 58 of range 8. This was by far the hardest part of the summer's work. The region around Greenwood lake was next examined. The prominent elevation south of the lake was called Greenwood mountain. It is an oblong ridge about a mile long, extending in an east and west direction, a mile wide at the base, one half a mile across the top, one hundred and fifty feet above the lake and the surrounding country, which is nearly level and has an approximate altitude of 1850 feet above sea level and is covered with a heavy growth of green timber. From Greenwood lake it is the only ridge visible, and can be readily recognized by its peculiar form from the high hills at Disappointment lake, fifty miles north, and from the ridges around Beaver bay, seventy-five miles southeast. Greenwood mountain marks the most prominent western outcrop of the group of rocks called "red rock" on the map accompanying this report.

The examination of townships 58-11 and 57-10 and 11 was completed by the first of September. During the months of May, June, July and the fore part of August the supplies were obtained at Ely. In August a trip for supplies was taken down the St. Louis river to the Duluth & Iron Range R. R. and thence by rail to Mesabi.

On September 2d the headquarters were transferred to Two Harbors and Beaver Bay. At Two Harbors Mr. John Bean, an experienced surveyor and one well acquainted with the region to be examined, was employed in place of Mr. White, who left for Minneapolis August 23d. Three weeks were spent in the vicinity of Beaver Bay. Special attention was given to the relations of the anorthorsyte to the other rocks. Three excursions were made north from Beaver Bay to connect with the work carried on from the north during the fore part of the season. The remainder of the season was spent in working north of Two Harbors.

On October 20th the work assigned for the season was completed and the party disbanded.

II. ROUTES OF TRAVEL IN LAKE COUNTY.

The different routes of travel by which points in this region are made accessible will be given in groups under the places from which they start.

Ely Routes. The canoe routes along the International boundary and the Kawishiwi (Cashaway) river are well known and need no description. The Isabelle river route follows the Kawishiwi river to the portage in sec. 30, T. 63-10, passes through Clearwater lake to the south Kawishiwi river in sec. 32, T. 63-10, and then through Gabbro and Bald Eagle lakes and up the Isabelle river, which flows through the southern tier of sections of T. 62-8 and 9, to Isabelle lake in the southeastern part of T. 62-8. The main stream of the Isabella river crosses the northeastern part of T. 61-8, and comes from Bel lissima lake in the southeastern part of T. 61-7.

A short distance east of the portage in the center of sec. 34, T. 62-9, is the mouth of the south branch of the Isabelle river. This river, although of considerable size, spreads out near the mouth into low marshy ground and is almost wholly concealed. It flows in a zigzag manner in a northeasterly direction through T. 61-9, and in T. 60-9 it flows in a southwesterly direction. The river is canoeable to the lake in sec. 15, T. 60-9, from whence a portage is crossed to Clear lake in sec. 14, on another branch of the Isabelle river which flows northeast from there, and is not canoeable. From Clear lake trails connect with the Mesabi and Beaver Bay trail, and trails running through T. 60-8 and T. 59-8.

The Stony river route from Ely is through White Iron and Birch lakes, then up the Stony river which empties into the lake in section 30, T. 61-11, in a concealed bay nearly a mile long. From Birch lake to Slate lake the river is full of rapids and numerous portages must be crossed. The fall in the river through this distance is about 230 feet. On account of the difficulty experienced in going up the river to Slate lake, this part of the route is seldom used. The Harris lake route or the "60-10" winter road is taken instead. This road leaves Birch lake in the narrow bay in sec. 20, T. 61-11 and reaches Harris lake in sec. 27,—a distance of three miles (6,000 paces). Harris lake is 170 feet above Birch lake. From the east end of the lake the road runs southeast to Slate lake a distance of four miles, and follows the Stony river to Pike lake in sec. 36, T. 60-10. A portage from Pike lake goes to Smokehouse lake and the Isabelle river. At "Headquarter camp" in the center of sec. 21, T. 60-10 a short trail runs east through the center of Towns. 60 10 and 9 and crosses the southwest corner of T. 60-8.

For the portages on the Isabelle and Stony rivers, see the list of altitudes given below.

Mesabi route. This trail leaves Mesabi station, follows the Masabi range to the north town line of T. 59, and continues eastward along the same line to the northeast corner of T. 59-8 where it crosses Beaver Bay trail running northward. From here the trail continues southeast and eastward to Pork bay on lake Superior. Minor trails run north and south from the main one at different points. This is not a canoe route.

St. Louis river route. This route leaves the Duluth and Iron Range R. R. at the St. Louis river and follows the river nearly up to its source in T. 59-11 and then by a portage four miles long crosses to Sand and Stony lakes and the Stony river, or from Sand lake to Greenwood lake.

Cloquet route. A trail leaves the railroad at Cloquet river and runs to the north line of town 55 and east on the line to the lake in the northwest corner of T. 55-10. From here a good trail runs north to the two lakes in sections 29 and 31, T. 56-10 and east along the north line of sections 28, 27 and 26; then it takes a southeasterly direction to the northeast corner of sec. 35, and thence eastward across T. 56-9 to the Beaver Bay and Greenwood lake trail.

Highland route. This trail leaves the railroad one mile north of the station and is easily followed. In town 55-10 it has numerous branches and connects with the Cloquet trail.

Two Harbors trails. The county road runs along the lake shore from Duluth to Grand Marais passing through Two Harbors and Beaver Bay. A trail leaves Two Harbors and follows the line between ranges 10 and 11 north to the Highland trail. A number of minor trails leave here, but it is unnecessary to mention them as they are well known. From Two Harbors to Beaver Bay the usual route is by steamer.

Beaver Bay routes. Besides the county road there are several good town roads which run north into T. 56-8 and west to T. 55-9. From the end of the road in sec. 27, T. 56-8, a trail runs to Schaff's lake in sec. 12 and from the east end of the lake follows the range line north to the northeast corner of T. 59-8 where it connects with the Mesabi trail. The trail does not follow the range line very closely, but runs about one-half a mile east of it. The Greenwood lake trail leaves the town road in the center of sec. 9, T. 55-8, and runs nearly northwest to Greenwood lake twenty-four miles from Beaver Bay. An old and indistinct trail follows the line between ranges 9 and 10, between the Mesabi and Greenwood trails. A portage four miles long connects Greenwood lake with Sand lake. In sec. 25, T. 56-9 the Cloquet trail connects with the main trail.

Among other trails which run north from lake Superior those following the Split Rock and Gooseberry rivers and the one on the line between ranges 9 and 10 are the only ones deserving to be mentioned. In T. 55–9 are a number of trails which connect with the more important ones given upon the map.

III. ECONOMIC RESOURCES OF LAKE COUNTY.

Upon this subject not much can be said. In the northwestern part of the county are numerous outcrops of iron ore, but beyond a few diamond drill sections, nothing has been done toward exploring and mining the ore bodies.* Towns 61 and 62 are nearly wholly within the gabbro area. Both of these towns are absolutely worthless, being covered with bare knobs of granite and gabbro, and with swamps in the valleys. Town 60 has a large amount of valuable timber, mostly white and Norway pine. The greater part of this when cut will be taken down the Stony river and thence to Fall lake, where a saw mill is in operation. Towns 59, 58 and 57 have scattering patches of good timber, but on account of the small quantity scattered over so large a region, and the inaccesibility of the same for the present, this has but little value. The greater part of these towns is covered with "muskeg" and almost impassable cedar ("tanglefoot") swamps. In T. 56 there is a large amount of good timber, the greater part of which is not yet large enough to be cut. T. 56–8 has considerable farming land. In Ts. 55–10 and 11 and 54–11 there is considerable timber which is widely scattered. The towns immediately back from the shore of lake Superior have good hay meadows and agricultural land. That farming can be successfully carried on in this region is shown by the flourishing farms around Beaver Bay. The region is not very heavily wooded. Maple trees are quite common.

IV. TOPOGRAPHY.

The topographical work consisted of drawing contour lines for every fifty feet in elevation above the sea level and the determination of the altitude of all prominent places. An aneroid barometer was used to determine the altitudes. Especial care was taken in obtaining the hights of the various lakes and

*H. V. Winchell, 17th Ann. Rep., pp. 120-127.

rivers along the more common routes of travel. Whenever possible the altitudes determined along these separate routes were checked with each other in order to eliminate any errors which might have arisen. The fall over rapids in the rivers when less than five feet was estimated.

The mapping of plates 78 and 79, embracing Ts. 61–10 and 11 62–10 and 11, and Ts. 62–8 and 9 and 63–8 and 9, respectively, was completed.

In Ts. 64-8 and 9 the region around Disappointment, Snowbank, Ensign and Moose lakes was mapped in connection with the geological work.

In the region south of plates 78 and 79 and north of the water divide between the streams flowing into lake Superior and those flowing northward, the principal determinations were along the Stony river to its source in T. 58–10; the Isabelle river and its southern branches; St. Louis river from the Duluth & Iron Range R. R. to its source in section 17, T. 59–11. The altitudes along the main lines were computed from the mouth of the rivers toward their source, and were checked at the following places: Seven Beaver lake on the St. Louis river to Sand lake which is tributary to the Stony river; Pike lake (sec. 36, T. 60–10), a widening of the Stony river, through Smokehouse lake (sec. 28, T. 60–9) to the South Isabelle river in sec. 27, T. 60–9, and then to Clear lake in sec. 14, T. 60–9 on the south east branch of the Isabelle river.

Region around Beaver Bay.—The work is this locality was carried on from lake Superior toward the interior and connections were made with the work on the north of the "divide." Ts. 85, 56, 57 of ranges 8 and 9 are included in this area.

North of Two Harbors.—The measurements taken in towns 52 to 56, inclusive, of ranges 10 and 11 are only approximate and in some cases are merely estimated.

The following altitudes or the more important places determined during the season's work have been corrected by Mr. Warren Upham and the writer. The fall in the rivers at the various rapids depends entirely upon the amount of water in the river. In a number of instances the short and low rapids disappear in high water, while in low water it is often necessary to drag a canoe for several miles through shallow water and continuous rapids.

Altitudes in Feet Above the Sea.

Determined by aneroid barometers; excepting several lakes designated by asterisks (*), whose hights are known by leveling:

	Feet.
Fall lake	*1313
Garden or Eve lake	*1384
Farm lake	1386
White Iron lake	1395
Birch lake	1410
Copeland's lake	1425
Fork of the Kawishiwi river, sec. 26, T. 63–10	1435
Crab lake and northeast elbow of Kawishiwi river in sec. 15, T. 63–9	1471
Ridges about ½ mile north of the Kawishiwi river, in the northwest part of T. 63–9, about	1730
Large lake on the Kawishiwi river, in the southeast part of T. 63–9	1491
Lake of Kawishiwi river, sec. 33, T. 63–8	1520
Wilder lake	1540
Lake Alice	1544
Triangle lake	1490
North Twin lake	1475
Bassimenan (Basswood) lake	*1300
Sucker lake	1330
New Found lake	1331
Wind lake	1359
Moose lake	1339
Jasper lake	*1387
Snowbank lake	*1424
Ensign lake	*1342
Disappointment lake	1499
Disappointment hill, sec. 35, T. 64–8, about 1 mile east of this lake	1850
Gabbro lake	1464
Bald Eagle lake	1468
Lake on the Isabelle river, secs. 29 and 32, T. 62–8	1533
Lake Isabelle	1570
Bellissima lake	1650
Harris lake	1580
Slate lake	1640
Stony lake	1668
Sand lake	1674
Greenwood lake	1705
Greenwood mountain, sec. 30, T. 58–10, about 1½ miles south of this lake	1850
Lakes in the west part of T. 59–11, at the head of the St. Louis river	1685
Seven Beaver lake	1675
Pine lake	1705
Pike lake	1700
Lake in sec. 22, T. 59–9	1745
Muck lake, at the head of Stony river	1755
Smokehouse lake	1740
Clear lake	1704
Adams lake	1800
Schaff's lake	1089
Bear lake	1160
Lake Superior, mean, 1870–1888, above mean tide sea level	*602

Portages on the Stony river.

From Birch lake (1410 feet above the sea) to Slate and Pike lakes and the lake in sec, 22, T. 50–9.

No.	Length.	Location.	Ascent in feet.	To altitude above the sea.
1.	⅓ mile	S. E. ¼ sec. 30, T. 61–11	10	1420
2.	¼ mile	N. E. ¼ of N. E. ¼, sec. 31, T. 61–11	20	1440
3.	1 rod	S. W. ¼ of N. E. ¼, sec. 31, T. 61–11	1	1441
4.	¼ mile	N. part of S. E. ¼, sec. 31, T. 61–11	6	1447
5.	⅓ mile	Crossing south line of sec. 31	24	1471
6.	⅓ mile	N. E. ¼ of S. E. ¼, sec. 6, T. 60–11	15	1486
7.	30 rods	N. W. ¼ of N. W. ¼, sec. 8, T. 60–11	20	1506
8.	½ mile	W. ½ of S. W. ¼, sec. 8, T. 60–11	69	1575
9.	¼ mile	S. W. ¼ of N. E. ¼, sec. 17, T. 60–11	15	1590
10.	¼ mile	North edge of S. W. ¼, sec. 16, T. 60–11	5	1595
11.	⅓ mile	S. W. ¼ of N. E. ¼, sec. 16, T. 60–11	7	1602
12.	8 rods	S. W. ¼ of S. W. ¼, sec. 10, T. 60–11	5	1607
13.	¼ mile	Central part of sec. 10, T. 60–11	5	1612

14.	Short rapids	N.W. ¼ of S. E. ¼, sec. 10, T. 60–11 .... The usual portage instead of the last three is ¾ mile long, from the N. W. corner of sec. 15 to the N.W. ¼ of the S. E. ¼ of sec. 10	2	1614
15.	¾ mile	E. part of sec. 11 and W. part of sec. 12 ...	10	1624
16.	½ mile	S. ½ of sec. 12, T. 60–11	10	1634
17.	1½ mile	Current and rapids to Slate lake..........	6	1640
18.	¾ mile	Across E. part of sec. 17, T. 60–10, to Chub lake......................................	15	1655
19.	⅜ mile	S. E. through N. W. ¼, sec. 21, to Stony river at Headquarters camp, near the center of this section	10	1665
20.	Short rapids	N. W. ¼, sec. 34, T. 60–10, to Stony lake....	3	1668
21.	1 mile	Crossing N. W. ¼, sec. 35, to Pike lake	32	1700
22.	1 mile	S. ½ of sec. 31, T. 60–9....................	28	1728
23.		Current and rapids to lake in sec. 8, T. 59–9	11	1739
24.		Current and rapids to lake in sec. 22, T. 50–9	6	1745

Portages on the south branch of Isabelle river.

In ascending the Isabelle river from Bald Eagle lake (1468 feet above the sea) a portage about a half a mile long is made in sec. 5, T. 61–9, with ascent of 50 feet, to 1518; and two short portages successively ascend 2 and 5 feet in the south part of sec. 34, T. 62–9, to the north of this south branch, near the middle of the east half of this sec. 34, at 1525 feet.

No.	Length.	Location.	Ascent in feet.	To altitude above the sea.
1.	10 rods	S. W. ¼ of sec. 3, T. 61–9....................	1	1526
2.	⅛ mile	S. E. ¼ of N. W. ¼, sec. 9, T. 61–9	3	1529
3.	20 rods	N. ½ of sec. 16, T. 61–9......................	4	1533
4.	½ mile	S. ½ of sec. 16, T. 61–9	20	1553
5.	2 rods.	N. W. ¼ of N. E. ¼, sec. 29, T. 61–9.........	5	1558
6.	⅕ mile	N. E. ¼ of N. W. ¼, sec. 29, T. 61–9	4	1562
7.	25 rods	N. part of S. W. ¼, sec. 29, T. 61-9..........	8	1570
8.	⅛ mile	Near the center of the S. W. ¼, sec. 29.	6	1576
9.	5 rods	S. W. corner of sec. 29, T. 61–9	7	1583
10.	¾ mile	W. ½ of sec. 32, T. 61–9, T. 61-9.............	45	1628
11.	⅓ mile	S. W. ¼ of S. W. ¼, sec. 5, T. 60–9..........	15	1643
12.	2 rods	N. W. corner of sec. 8, T. 60–9.............	3	1646
13.	⅕ mile	E. part of N. W. ¼, sec. 8, to a small lake..	14	1660
14.	⅛ mile	S. E. corner of sec. 8, T. 60–9.............	5	1665
15.	¼ mile	S. W. ¼, sec. 9, T. 60–9......................	15	1680
16.	½ mile	S. E. ¼, sec. 9, and S. W. ¼, sec. 10, T. 60-9 .	20	1700
17.	10 rods	W. edge of S. E. ¼, sec 10, to lake in the N. E. ¼ of sec. 15, T. 60–9....................	4	1704
18.	⅔ mile	From foregoing lake through N. ½ of sec. 14, T. 60–9, to Clear lake................	0	1704
19.	1 mile	From Clear lake southwest to the South branch of Isabelle river in the south edge of the N. E. ¼ of sec. 22. T. 60–9....	20	1724
20.	15 rods	N. edge of S. E. ¼, sec. 22, T. 60–9..........	7	1731
21.	10 rods	Central part of S. E. ¼, sec. 22, T. 60–9, to lake on the south line of this section....	7	1738
22.	½ mile	From foregoing lake southwest through the N. W. ¼ of sec. 27, T. 60, R. 9, to Smokehouse lake	2	1740

V. MAP OF THE WEST-CENTRAL PART OF LAKE COUNTY.

The map of the west-central part of Lake county which accompanies this report comprises townships 55 to 61 inclusive, of ranges 8 to 11 inclusive. Nearly one-half of this area is still unsurveyed. The surveyed townships excepting the southern tier of towns, T. 56-8 and T. 57–11, were surveyed within the last two years, The plats of the unsurveyed parts were compiled from data collected by the writer. The town and range lines have been run through this region and all points were located by pacing and running by compass from known points on these lines. In order to guard against errors, all necessary corrections were made in the field. The following towns are not surveyed: 61–8 to 11, 60–8, 59–9 and 10, 58–8 to 11,* and 57–8 to 10. Trails and portages are indicated by dotted lines and were fully described in a preceding section. The geological boundaries are indicated by the continuous lines drawn between the words *gabbro*, *red rock* and *diabase*. These terms are used as convenient designations for the three large groups of rocks included within this area, and will be explained in the geological part of this report. (See plate V.)

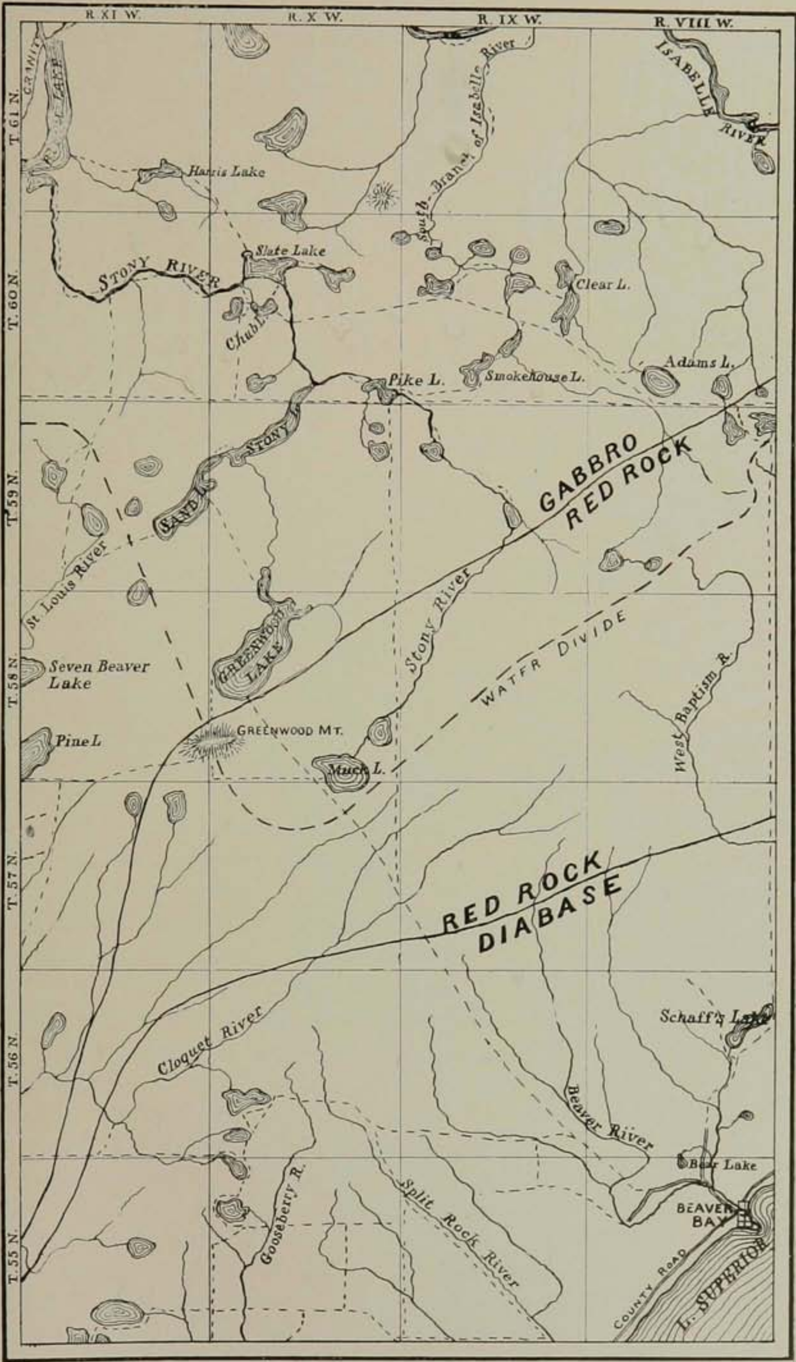
GEOLOGICAL NOTES ON NORTHEASTERN MINNESOTA.

I. INTRODUCTION.

The notes contained in the following pages are based upon observations made for the state geological survey. The laboratory work has been carried on in the laboratories of the department of geology in the University of Minnesota. Over three hundred thin sections have been made from specimens collected for the greater part by the writer. Lack of time, alone, prevents a more extended account of the observations made from being given at this time. The writer hopes in the near future to give in fuller detail the results of further examination of the Keweenawan eruptives of the north shore of lake Superior. In giving the township and range in these notes the township is always north, and the range is always west of the Fourth principal meridian, Minnesota, unless otherwise stated.

The writer desires to express his sincere thanks to Prof. C. W. Hall, of the University, and to Prof. N. H. Winchell and

*Since the above was written plats of towns 60–8 and 58–10 and 11 have been received from the Surveyor General.



MAP OF THE WEST CENTRAL PART OF LAKE COUNTY.

Dr. U. S. Grant, of the geological survey, for kind assistance given throughout the investigation.

II. SNOWBANK LAKE AREA.

Region north of the lake.

Observations on the rock outcrops on the shores of this lake are found in the 15th, 17th and 20th annual reports of the survey. The writer's attention was directed to the hitherto unexplored region extending from the north shore of the lake to Moose, Newfound and Ensign lakes. Between Moose and Snowbank lakes five cross sections were made. On the south shore of the former lake the rocks are sericitic and argillitic schists. The range of hills extending parallel with the lake shore is composed of vertical beds of schists, argillyte and conglomerate. South of these hills, at points from one-fourth to three-fourths of a mile distant from the lake shore and then extending southward through a swamp and valley, are extensive outcrops of quartzless porphyry. This rock extends nearly to Snowbank lake, on the west shore of which is also a ridge of schists and conglomerates.

The accompanying section, Plate VI, Fig. 2, (facing p. 160), from the N. E. ¼ of N. W. ¼ of sec. 35, T. 64-9, on Snowbank lake, N. W. to the ¼ of S. W. ¼ of sec. 22, on Moose lake, fairly represents the rocks north of Snowbank lake. The direction is nearly northwest and southeast, directly across the strike of the vertical formations. Beginning at Moose lake the numbers corresponding to those on the diagram denote the different kinds of rocks occuring along this section.

1. Sericitic schist. At the lake shore this schist is dark in color, fine grained and has a greasy appearance. One hundred and fifty paces from the shore at the base of a perpendicular cliff one hundred feet high is a light colored sericitic schist (165E) with small angular and round feldspars.

2. At the top of the cliff this rock grades into a schist (164E), in which the feldspar nodules have developed to well defined knots one-fourth of an inch in diameter. The schists stand nearly vertical, dipping at different places slightly to the north or south. The strike is about northeast and southwest, although in some places along Moose lake it varies from east and west to nearly north and south. Two hundred paces from the top of the cliff the rock has changed to a dark argillitic, sericitic schist (166E), in which the knotted structure has been dveloped to a greater extent. From the same out-

crop specimen 167E shows feldspars two inches long. The weathered surface here looks somewhat similar to that of the finely concretionary greenstone of Ely.

3. Two hundred and fifty paces farther and on the south side of a small swamp, is an extensive outcrop of argillyte (277E). This rock breaks up into small chips and tablets an inch thick.

4. Two hundred paces from the last outcrop, in a dense balsam thicket, is a knob of conglomerate fifty feet in diameter. In the conglomerate are numerous rounded and angular pebbles of jasper, varying in size from very fine grains to those three inches in diameter. Many of these pebbles show beautiful banding. Besides this jasper are gneiss, granite and slate pebbles not exceeding four inches in diameter. The matrix of the conglomerate is fine grained and green in appearance (276E). In another outcrop of this conglomerate fifty paces northeast of here granite boulders a foot in diameter are common. The conglomerate forms the highest part of the ridge south of Moose lake.

5. In the next one hundred paces there is descent of seventy-five feet into a swamp about a mile wide. Near the northern edge of the swamp is an outcrop of quartzless porphyry, which cuts the conglomerate and forms mica schist as a contact rock. In crossing the swamp there are occasional outcrops of porphyry.

6. In the N. W. ¼ of S. W. ¼ of sec. 26, T. 64–9, about two hundred paces west of Snowbank lake, the porphyry cuts a bed of conglomerate. This differs from number 4 in that no jasper pebbles were found.

7. In the conglomerate are beds of epidote schist, and the whole grades into argillyte. No distinct boundary between this bed and the preceding one can be marked out.

8. About four hundred paces southeast of number 6 and on the broad point in section 26 the argillyte grades into a hornblend mica schist which is considerably contorted and cut by a hornblende granite.

9. The granite continues to the shore of Snowbank lake in the N. W. ¼ sec. 35, T. 64-9.

Of this series of rocks the porphyry is the most important. Quartz porphyry dikes are of common occurrence in the Keewatin rocks of Minnesota, but in no place does it occur in such a large mass as it does west of Snowbank lake. Here it extends in a northeast and southwest direction from the center of section 23, T. 64-9, through sections 27, 33 and 34, then westward to the west range line of T. 64-9, a length of five and one half miles; it varies in width from three fourths to one and one half miles. The rock is exceedingly hard, but owing to the basaltic structure, it readily breaks into angular blocks. The area in which this prophyry occurs is covered with these blocks. The readiness with which the prophyry breaks into angular blocks probably explains why it is found in a valley between ridges of mainly sedimentary rocks. Although these latter rocks are more easily abraded by the ice and at present decompose more rapidly, the porphyry being easily broken off in large blocks would be removed in much larger amounts leaving a depression between the clastics. When freshly broken the porphyry has a purple to grayish color. On a weathered surface the rock is white and occasionally is stained yellow or red by ferric oxide. Porphyritic crystals of feldspar are numerous; those of quartz are rare and in the larger number of specimens are entirely absent. Under the microscope felspar phenocrysts of all sizes, up to one fourth of an inch in length, are embedded in a microcrystalline groundmass of quartz and feldspar. The feldspars are orthoclase and oligoclase and show a more or less altered condition. In 60E the feldspar has been replaced by quartz. Quartz phenocrysts occur only in small quantities and sometimes are pseudomorphs after the feldspar. Chlorite and epidote occur in small flakes throughout the rock. Biotite and apatite are rarely present. Specimen 49*aE* represents the quartzose phase of the porphyry. In thin section, besides the usual constituents, there are numerous quartz phenocrysts. These, with but one or two exceptions, occur as round grains with corroded edges, and have a wavy extinction. The felspars are exceptionally well developed. Epidote is present in small plates and chlorite is scattered throughout the section.

Whenever the relations of the porphyry and the other rocks of this region could be determined it was found that the porphyry cuts the Keewatin rocks, sending dikes far across the strike of this formation. A great deal of the disturbance of the Keewatin rocks in this locality is due to the intrusion of the porphyry and not, as it is generally supposed, to the granite of Snowbank lake, which is the youngest formation in region. Dikes of granite (56E) cut the green schist (58E) and the porphyry (55E) in the S. E. ¼ of the N. W. ¼ of sec. 26, T. 64-9. This is the only place known where the relations between the granite and the porphyry could be determined with certainty. The general strike of Keewatin sedimentaries is parallel to the periphery of the porphyry mass. On the west shore of Snowbank lake this strike is somewhat modified by the granite intrusion.

In going from the bay in Snowbank lake in the N. W. ¼ of S. E. ¼ sec. 24, T. 64-9, north 20° west to Newfound lake, the following outcrops of rocks were seen in the order given:

1. Mica schist and conglomerate in inseparable beds; the former becoming less schistose and micaceous as the distance from the granite area increases.
2. Argillyte.
3. Mica schist.
4. Coarse diabase.
5. Agglomeratic greenstone.
6. Conglomerate.
7. Argillyte.
8. Diabase similar to number 4.
9. Conglomerate and argillyte.
10. Sericite schist at three-fourths of a mile from Snowbank lake. This schist continues to Newfound lake.

The strike of the rocks mentioned above is nearly east and west, and toward the east this remains the same. One-half a mile west of the line of the cross section the strike of the rock, is somewhat changed to a southwest and northeast direction. Farther west, near the north end of Moose lake, the strike, as previously mentioned, is nearly north and south.

In the region north of the central part of Snowbank lake no outcrops of the porphyry, which is so abundant west of here, were found. On the west shore of Boot lake, in the S. W. ¼ of N. W. ¼ sec. 21, T. 64-8, are several large dikes of this rock cutting the graywacke and schist in this vicinity.

In the S. W. ¼ of N. E. ¼ sec. 21, T. 64-8, on the east side of the long point, in the midst of a bed of conglomerate, is a boss of granite partially uncovered. Dikes run out from this mass in all directions, cutting the conglomerate and distorting the strata in a very complicated manner. In the conglomerate are boulders up to four feet in diameter of gneiss, slate, diabase and granite. This last can scarcely be distinguished from the granite which cuts the conglomerate of the region. In several instances a granite dike traced several hundred feet was found to cut some of the large boulders in the conglomerate. The contact between the dike and the granite boulders could not be determined easily. Parts of the boulders adhered to each side of the dike.

The granites.

The granites of Snowbank lake present an interesting problem, as there is some evidence to show that two distinct granites exist here,—an augite and a hornblende granite. The field evidence at hand is not sufficient to warrant an assignment of any definite relations to these granites. The northern shore of the lake is made up of schists and argillytes with several small areas of granite occurring as dikes cutting the other rocks and on the extremities of some of the points projecting into the lake.

On the west side of the narrow bay in the W. ½ of sec. 20, T. 61–8, is a large outcrop of a light gray granite (271E). The rock is medium grained and the ferro-magnesian minerals constitute about one-half of the rock mass. Under the microscope this rock is shown to be an augite granite. Orthoclase, microcline and oligoclase occur in equal proportions. All of the feldspars have a well defined clear zone around a kaolinized center and are in some cases prophyritically developed. Quartz is not very abundant and occurs in small grains. The augite and hornblende are closely associated. The augite is of a light green color, has no pleochroism and extinguishes from 45° to 50°. It forms the cores of the hornblende which has a darker color, is pleochroic in brown and dark green and extinguishes at less than 22°. The cleavage of the hornblende is a continuation of that in the augite core. The line of division between the two minerals is distinct and the extinction angle of both minerals is readily measured along the same cleavage. One pyroxene plate is unaltered, and its extinction and striations bring it near to diallage. Hornblende occurs in several places in bent bundles of slender rods. Sphene occurs in double wedges and rounded grains. Magnetite and biotite are secondary and are not abundant.

Near the section line between sections 19 and 20 this rock (271E) is cut by a granite porphyry (270E). The specimen shows the porphyritic condition of the rock, which, as a whole, has a more even texture. In thin sections are found regular phenocrysts of orthoclase and oligoclase embedded in a microcrystalline groundmass of quartz, feldspar and ferro-magnesian minerals. This rock also cuts and has greatly modified the schists and argillyte. As these hornblende and mica schists grade into the argillaceous slates and graywacke and have their most perfect developement at the contact with the granite, their highly crystalline condition is due to the action of the granite upon the other rocks.

On the east side of the bay mentioned above hornblende granite cuts the older rocks (273E). It has a medium texture and under the microscope shows the feldspars, quartz, hornblende, biotite and a yellow decomposition product, which stains the feldspars and is most likely limonite.

Since the discovery of augite in the granite from Snowbank lake the writer has, so far as time would permit, examined specimens collected by the survey. The following specimens are from this locality.

Specimen 521G*, from the S. E. ¼ of N. E. ¼ sec. 24, T. 64–9, is a fine dark hornblende granite. Under the microscope this shows the feldspars, hornblende, sphene and magnetite. The hornblende has altered to chlorite and shows no traces of augite.

522G, from the island in the N. E ¼ of S. W. ¼ sec. 19, T. 64–8, is an augite granite. The mineral constituents are the same as in 271E. Augite and hornblende are present in separate plates. There is no direct alteration of the former into the latter, but the hornblende possesses the fibrous cleavage of uralite and is a paramorph after the augite. Biotite is secondary from the hornblende. In this section we have a change of augite to hornblende, which in turn is altering to biotite and chlorite.

523G, from the N. W. ¼ of S. W. ¼ sec. 29, T. 64–8, is a medium grained hornblende granite of a light gray color. Examined in thin section, this rock shows the usual composition of the hornblende granite in this locality. The feldspars are considerably altered, quartz occurs only in small grains, and the hornblende is highly pleochroic in green and brown. Sphene is the oldest mineral. Magnetite is largely secondary. Limonite, an alteration product, stains the rock yellow. Combined with the kaolin of the feldspar this produces a yellow powder which is easily removed from the rock and leaves cavities. In the hand specimen this peculiar yellow stain is very noticeable.

*U. S. Grant, 20th Annual Report, pp. 66-67.

524G, from the east shore of the large island (Boot island) on the range line between T. 64-8 and 64-9, is a coarse augite granite. In general the rock is the same as 271E, differing only in the character of the augite, which in this section is fresh, shows no signs of alteration, is not pleochroic, extinguishes at 45° and has a deep green color.

1722 N. H. W., from the island in S. W. ¼ of S. W. ¼ sec. 30, T. 64-8, is a very fine grained granite with orthoclase, microcline and quartz phenocrysts in a microcrystalline base of quartz and feldspar. Hornblende occurs in small scattering plates and is greatly altered. Sphene, magnetite and limonite complete the mineral constituents.

From the above descriptions it is evident that this augite granite occurs at a number of places around Snowbank lake, and an examination of specimens from different outcrops in this locality will probably show a wider distribution of this rock.

Without going into the details of the field observations recorded in the 15th, 17th and 20th annual reports, it will be sufficient to say that all geologist have described two granites hitherto designated in the field as red and gray syenites. The former and of these is a hornblende granite and the latter an augite granite. The exact relations of these granites to each other and of the gray granite to the sedimentaries of this region are still doubtful. The gray granite has not been found in contact with the schists, argillytes and conglomerates of the region, and it is cut by the red granite which also cuts the schists. The most reasonable explanation which can at present be assigned to the occurence of these granites in the same area, is that they are parts of the same magma and that the hornblendic variety was erupted at a later dated and perhaps at a time of greater violence than that of the eruption of the augite granite, which formed the outer portion of the magma. As there is sufficient reason to place all of the eruptive pre-Animikie granites of Minnesota into one period, in comparing this area with the other granite areas the following facts must be considered: on Kekequabic lake the augite granite cuts the Keewatin sedimentaries;* in the White Iron lake area the dark hornblende granite, which corresponds to the augite granite, has the same relations to the Keewatin, as that in the preceding instance; in all localities where the light col-

*U. S. Grant, 21st Ann. Rep., p. 38.

ored granite is found, it is the later granite and has caused a greater disturbance than the augite granite; and wherever granite pebbles and boulders are found in the Keewatin conglomerate, they are almost wholly made up of light colored granite similar to that which cuts these older rocks. The last case is well illustrated by the granite on Boot lake, described on a preceding page.

Augite granite has been found only in two localities in northeastern Minnesota, viz., Snowbank and Kekequabic lake areas. In the granite specimens collected and described by Dr. Alex. Winchell as augite granite from White Iron and Saganaga lakes, a microscopical examination fails to show augite. The mineral taken as such is only hornblende, which occurs in dark masses varying in size from the lenticular patches a few inches in diameter to the irregular areas a fourth of a mile in length. A microscopical examination of a number of thin sections sections from these peculiar areas shows that the rock is composed of hornblende, occasionally some feldspar and rarely quartz. Biotite is due to the alteration of the hornblende. The sagenite structure of rutile is well shown in several slides.

In central Minnesota* the occurrence of the dark inclusions in the granite is the same as that of those just mentioned in the northeastern part of the state. The mineral composition, however, is somewhat different. In thin section these are found to consist of fresh augite or hornblende, with all degrees of alteration of the former to the latter, showing conclusively the secondary origin of the hornblende. Other evidence also shows that most of the hornblende granite of the same locality was originally an augite granite.

From the foregoing notes it is seen that the granite formation of Minnesota, which finds its greatest extent in the mountain masses of the Giant's range, although in the larger part of its area a hornblende granite, yet in other parts there are unmistakable proofs that it was originally an augite granite.

The present altered mineralogical composition of the granite is accounted for by the explanation suggested by Prof. N. H. Winchell to explain the great strength of Minnesota granites:† "We may perhaps account for the greater strength of Minnesota crystalline rocks by supposing them less changed superficially by the process of decay, the lateness of the glaciation

*For information concerning this locality the writer is indebted to Prof. C. W. Hall.

†N. H. Winchell. "The comparative strength of Minnesota and New England granites." 12th Ann. Report, pp. 14-18.

to which they have been subjected having left them comparatively fresh through the recent removal of a considerable thickness." Every one familiar with the occurrence of this granite formation will recognize the fact, that in the localities where augite has been found as one of the original constituents, the glacial action has been more pronounced and has removed a great thickness of the surface rock, up to that time undisturbed, leaving a much fresher rock than elsewhere, and in which one would naturally expect to find a facies of the formation nearer to its original condition.

In connection with the preceding it may be of interest to note that the hornblende and mica schists of Snowbank and White Iron lakes grade into argillaceous slates and conglomerates. The schistose character is most fully developed at the contact with the granite. All evidence tends to show that the schists are due to the intrusion of the granite and suggests that the narrow belts of schist generally found between the granite and the Keewatin rocks and which have hitherto been designated as a separate formation (Coutchiching or Vermilion) are only altered portions of the Keewatin which have been subjected to the heat and action of the intrusive granite.

III. ACTINOLITE MAGNETITE SCHISTS FROM THE EASTERN MESABI RANGE.*

The writer while studying the peculiar rock occurring along the central part of the northern periphery of the great gabbro belt, designated as the Pewabic quartzyte, found in the vicinity of Birch lake an extensive area of actinolite magnetite schists associated with the Animikie. The derivation of these schists from a rock containing a carbonate of iron and their lithological similarity to those found in the Penokee series tend to establish an important analogical link between the two series of which they are a part.

Since this investigation was carried on, actinolite schists from this locality have been described by Dr. W. S. Bayley.† These descriptions and the additional evidence obtained during the summer of 1893 confirm the views previously expressed by the writer.

*Extract of a thesis accepted for the degree of Master of Science in the University of Minnesota. Read before the Minnesota Academy of Natural Sciences, May 1, 1893.

†Amer. Jour. Sci., III. Vol. xlvi, pp. 176-180, Sept., 1893. The writer wishes to acknowledge the kindness of Dr. Bayley for the opportunity given to examine the slides used in his descriptions.

The accompanying map (Plate VI, Fig. 1,) of the west end of Birch lake gives a comprehensive view of the geological structure of this region. The contour lines were taken from the topographical notes of Mr. A. D. Meeds.

Numerous specimens have been collected by the state survey from this locality.* Nearly all these have been examined in thin section. In the following pages the descriptions of the occurrences of the field outcrops are taken from the annual reports of the survey, where more detailed accounts may be found. Beginning with the western extent of this area, where the Animikie approaches nearest to its normal condition found on the western Mesabi, the formation is traced through continuous outcrops to the north shore of Birch lake, where it disappears under the gabbro, and where the crystalline characters have the highest development. In studying the variety and the extremes of the lithological characters, and by noting the gradual change of one extreme into the other, we have undisputable evidence of the origin of the crystalline portions of the formation. The object of the following paper is to show the derivation of the actinolite schists and their relations to their geological associates in the vicinity of Birch lake. The fact that the so-called "Pewabic quartzyte," between Birch lake and Gunflint, is a part of the iron bearing portion of the Animikie will also be shown.

Specimens collected by Prof. N. H. Winchell.

The following specimens, collected by Prof. Winchell,† were examined in thin sections by the writer. Several diamond drill sections have been made under the management of Capt. Wicks. Of these the one (No. 5) on the N. W. ¼ S. W. ¼ sec. 27, T. 60-13, gives the most complete rock section as well as that of the greatest thickness. In ascending order the rock found here is as follows:

1636. Granite, 3 feet.

1635. Bottom of quartzyte, 1 foot.

1634. 10 feet. A hard siliceous greenish rock, which contains many fragmental grains of quartz. In thin section the quartz grains appear angular and show no signs of enlargement. They are derived from the granite, some contain numerous rutile needles and are full of inclusions. The matrix is composed of microcrystalline quartz and aphanitic green material

*H. V. Winchell. 17th Ann. Rept., pp. 81-96.
†21st Ann. Rept., pp. 82-86.

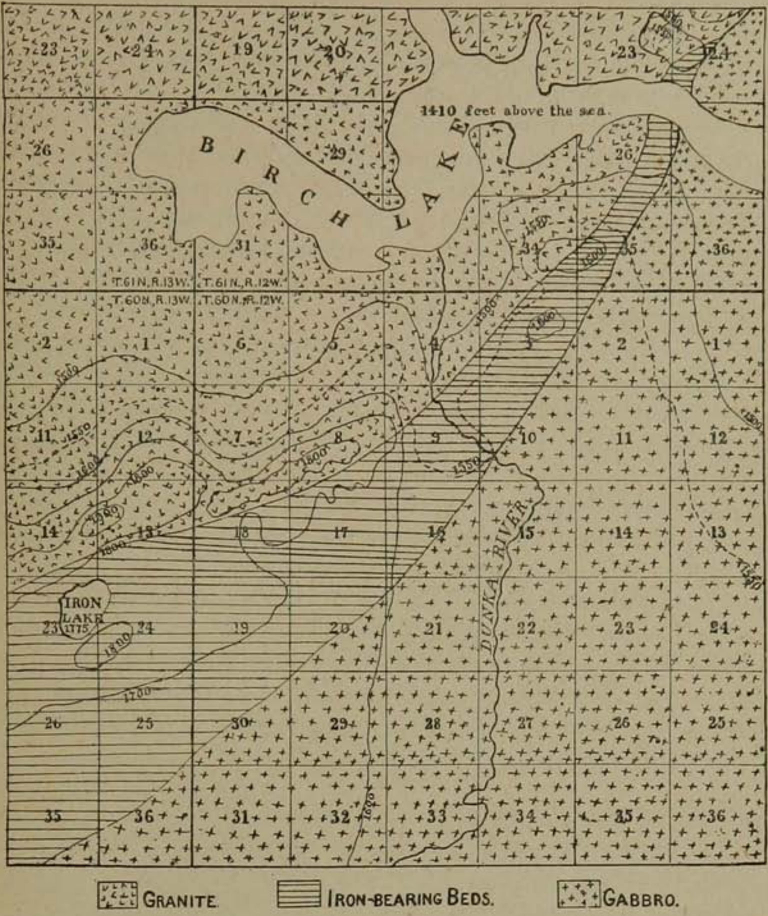


FIG. 1. GEOLOGICAL MAP OF THE WESTERN END OF BIRCH LAKE AND ADJOINING COUNTRY SOUTHWARD.

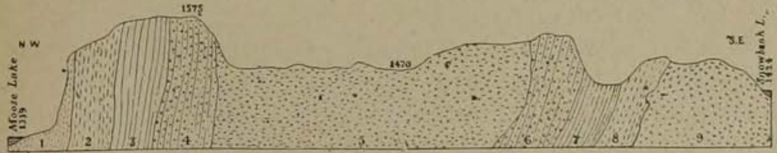


FIG. 2. CROSS-SECTION FROM MOOSE LAKE TO SNOWBANK LAKE. NORTHWEST TO SOUTHEAST. DISTANCE TWO MILES. ALTITUDES EXPRESSED IN FEET ABOVE THE SEA-LEVEL.

which has a tendency to form actinolite needles. These needles occur in bundles and in some cases penetrate the quartz grains. The transition upward to the next is gradual.

1633. 15 feet. Round fragmental quartz grains cemented in a matrix of quartz. In thin section this shows rounded fragmental grains of quartz embedded in a microcrystalline matrix of quartz and some green material. Some of the quartz grains show a slight enlargement, being bordered by a ragged rim of fine grained quartz with similar orientation.

1632. 17 feet. Fine grained pinkish-cream colored quartzyte. The hand specimen is composed of microcrystalline silica similar to the matrix of the preceding section.

1631. 24 feet. Siliceous, fine magnetite. On account of the high percentage of red hematite and magnetite this rock in thin section is nearly opaque. A few small grains of quartz were seen.

1630. 20 feet. Gray quartzyte, nearly all silica with round concretions. This is a magnetitic concretionary chert. Roughly oval and rhombic outlined areas of magnetite and hematite occur in a cherty background. The magnetite occurs in small cubes and the hematite is distinguishable only in reflected light by its red color. These two minerals occur in alternating bands in the same concretions. The iron oxides are often concentrated upon the exterior of the areas, and in some cases they have grown beyond the outer borders and extend into the cherty background.*

Another section from the same specimen shows a concretionary actinolitic chert. The concretionary structure is not so marked as in the preceding section. A considerable amount of a greenish mineral matter is present. Under a high power this shows the development of fine actinolite needles and plates.

1629. 70 feet. "Black slate" heavily charged with magnetite. Magnetite occurs in well developed crystals and composes nearly the whole section. Well developed plates of actinolite lie between the grains of magnetite.

1628. 157 feet. Black and gray, fine banded rock, with fine grained magnetite, the latter being distributed through the whole, and sometimes concentrated along planes of weakness in beds six to ten inches in thickness. The banding is wavy. A thin section of the drill core cuts the light and dark bands of the rock. The light colored bands are composed largely of

*Compare; R. D. Irving and C. R. Van Hise. 10th Ann. Rep. U. S. Geol. Survey, p. 490.

greenish aphanitic material showing numerous minute crystals of actinolite. Other portions of these bands have large plates of actinolite. The magnetite is concentrated along certain lines and extends into the actinolite bands. In places it appears in a roughly concretionary form. The actinolite in this section has been developed to a greater extent than that in the rock lower down in the series.

The above drill section represents a total thickness of three hundred and twenty-one feet. A number of other drills have been made in the same region. The succession of the different rocks is the same as that described above. The different strata vary in thickness as the extreme northern edge of the formation is approached. The only rock of uncertain thickness is number 1632, the fine grained pink quartzyte, which is absent in some places. The whole of the quartzyte is wanting a short distance east of this locality. A drill hole sunk in section 13, T. 60-13, passed through one hundred and ninety feet of hard "jaspery taconyte" banded with ore and resting upon the granite. The bands of ore were five or six inches thick, and the iron ore was hard, black and nearly always magnetic.

Specimens collected by H. V. Winchell.

In describing these specimens, they will be taken up in the order of their occurrence from the west toward Birch lake. Detailed notes of their occurrence may be found in the 17th annual report, and page references refer to this report and the numbers refer to the specimens.

373. (P. 86.) S. W. ¼ of S. W. ¼ sec. 32, T. 60-13. This is a black slate, and is composed of a clouded aphanitic mass of brownish material, which shows some clear pieces of actinolite. Magnetite is not very abundant.

369. (P. 85.) Iron lake, N. E. ¼ sec. 23, T. 60-13. A black magnetic rock lying nearly horizontal. The magnetite and siderite occur in well defined crystals. Part of the latter in thin plates is translucent. The green aphanitic mass of the rock has developed into plates of actinolite.

365. (P. 84.) N. W. ¼ sec. 24, T. 60-13. In a perpendicular wall eight feet high and several rods long of a heavy black rock. This is a concretionary actinolite slate, composed of aphanitic green material considerable developed to actinolite. Actinolite forms small oblong concretions, in which the fibers have a radial structure similar to that of the mineral in the zeolites. Needles and prisims of the amphibole penetrate and

cross these concretions. Magnitite is confined to the concretions.

364. (P. 83.) Is a conglomerate boulder.

363. (P. 83.) "A smoothed, black exposure of ferruginous quartzyte several acres in extent appears on the surface of the ground in the N. W. ¼ of N. E. ¼ sec. 19, 60-12." The rock and magnetite both weather shiny black. The specimen is largely composed of magnetite which occurs in concentrated parallel bands. Actinolite forms the light colored bands of the rock. It is present in small fresh prismatic plates 2 mm. in diameter.

362. (P. 82.) Near the last locality. Banded magnetite. This consists of several alternating light and dark bands. The latter are due to the concentration of magnetite which gradually decreases in quantity as the borders of the light bands are reached, and in the interior of these bands it occurs only in isolated grains. The light bands are composed of almost colorless grains of amphibole, the characters of which cannot be determined. This section represents an intermediate stage of developement between the slates composed of aphanitic and unindividualized green material and the actinolite magnetite schists represented by Dr. Bayley's specimen No. 8783.

361 and 360. (P. 82.) In the N. E. corner of sec. 19, T. 60–12, is a shaft about ten feet deep in a greenish magnetitic slate. Number 361 is a slate composed of unindividualized matter. Number 360 is a concretionary amphibole schist. The amphibole occurs in plates and irregular grains, having extinction angle of 14° to 25°. Actinolite and common hornblende are both present. Augite occurs in irregular plates, intergrown with the amphibole. The concretions of the ferro-magnesian minerals and magnetite lie against a background of medium grained quartz.

359. (P. 82.) In the S. W. ¼ of S. W. ¼ sec. 17, T. 60–12, is a magnetic quartzyte in strata dipping S. S. E. 10° to 12°. Under the microscope this rock shows the same characteristics as those of the preceding specimen. The green substance has not been fully developed to amphibole.

358. (P. 82.) "At one-fourth of a mile south of the S. E. corner of sec. 7, T. 60–12, are numerous angular fragments of olivinitic magnetite projecting through the moss." This rock is largely composed of microcrystalline quartz. The other constituents are magnetite, hematite and a green substance. This substance has partially changed to actinolite, forming

bundles of innumerable fine needles, some of which penetrate the quartz. Several rough rhombohedral pieces of a brownish mineral, probably siderite, are present. An indistinct concretionary structure is also noticeable.

356. (P. 93.) Iron ore, four hundred paces east of the west quarter post of sec. 10, T. 60–10.

396. (P. 93.) A short distance south of Birch lake in the N. E. ¼ of sec. 26, T. 61–12, is a knoll of fine grained crystalline rock. This is a fine grained gabbro. "The gabbro appears in small, detached knobs, lying on the Animikie iron ore beds. These beds are somewhat disturbed and broken and vary in dip from 12° to 30° to the southeast. Near these knolls of gabbro the iron ore rock is semi-crystalline, containing porphyritic crystals of hornblende sometimes two and one half inches long, 397. There are large outcrops of this Animikie rock here. Sometimes the stratification is not very evident, but generally it is distinct and well marked, 398."

397. In thin section this consists of large plates of actinolite, pleochroic in light and pale green and extinguishing nearly parallel. Cross sections of the crystals show the characteristic amphibole cleavage. Numerous small grains of quartz are enclosed by the actinolite, which in several cases forms around a number of the quartz grains a rim of inward penetrating needles. A few small pieces of plagioclase also occur. Magnetite occurs in small crystals in the actinolite.

398. The mineral composition of this is the same as the preceding, having in addition augite and olivine. It is of medium texture. Quartz occupies about one half of the section.

399. "Some of the Animikie is almost all quartz which forms a coarse granular sandstone on decomposing. E. ½ of N. W. ¼ sec. 35, T. 61–12." This is composed of interlocking quartz grains including magnetite and actinolite. The quartz interlocks by irregular sutures. The magnetite, which is the oldest mineral, is often in well marked octahedrons enclosed in the quartz, but more frequently it is in rounded grains, either surrounded by a quartz individual or situated between several of them. The actinolite holds the same relation to the quartz as does the magnetite. Both of these are somewhat altered to limonite and chlorite. In its present condition nothing remains to show a clastic origin. This character of the rock is common in the iron bearing member of the Animikie both on the Mesabi and on the Penokee ranges. It is largely on account of the abundance of this quartz in the so-called "Pewa-

bic quartzyte" between Birch and Akeley lakes that this part of the iron bearing member has been perhaps wrongfully referred to the basal quartzyte of the Animikie.

401. (P. 94). "In the S. E. ¼ N. E. ¼ sec. 35, T. 61–12, are several ridges of magnetic quartzyte having vertical faces 15 feet high on the west. A few feet west of one of these walls of rock there is a knoll of syenite. The quartzyte is in beds which are nearly horizontal and seem to have about the same texture and composition where it lies on top of the syenite as they have ten feet higher up, 401." This is strikingly similar to the preceding rock specimen. It is composed of large irregular interlocking quartz grains, hematite and magnetite, which shows the original concretionary form so common in the Animikie slate. A peculiarity in which it differs slightly from these other slates is, instead of a background of microcrystalline quartz, each of the concretions occurs in a separate grain of quartz. In some of the concretions the hematite and magnetite have a banded structure similar to that seen in jasper. A brown decomposition product, probably limonite, results from the decay of the iron oxides. The magnetite which does not occur as round concretions is arranged in bands through the rock.

402. (P. 95). "In the N. E. ¼ of S. W. ¼ sec. 35, T. 61–12, the magnetitic quartzyte seems to have been affected by some metamorphosing agent which has produced large crystals of hornblende in it." This is an actinolite magnetite schist. The actinolite occurs in plates and needles, which extinguish nearly parallel. The magnetite is irregularly scattered throughout the whole section. Quartz composes about one-third of the rock.

404. (P. 95). "Toward the S. W. ¼ of sec. 35, T. 61–12, the land rises until it is 200 feet above Birch lake. On this high land many large, smooth-topped exposures are produced by windfalls. The strata seem to have been disturbed and slightly elevated by some force from beneath. The usual dip—less than 30° to the southeast—is, however, still maintained. Some of the beds of this Animikie rock are but slightly iron bearing and are almost wholly composed of olivine, 404." A section of this rock is composed of two-thirds of quartz and the remainder of actinolite, olivine and magnetite. The quartz occurs in interlocking grains as described above. The other minerals occur as rounded grains within quartz grains or in masses between the grains. Innumerable fine tufts of actinolite needles pene-

trate the quartz grains in all directions. Numerous crystallites of the same mineral crowd the quartz, forming by their combination beautiful figures. A yellow decomposition product fills up the fractures in the quartz.

405. (P. 95). In the N. ½ of the S. E. ¼ sec. 24, T. 61–12, the general occurrence of the Animikie is the same as that south of Birch lake. Thin strata of rich magnetite are separated from each other by beds of poor ore or quartzyte, 405. Under the microscope this rock is found to be made up of quartz, actinolite and magnetite. The quartz occurs in rounded grains surrounded by the other minerals, and in irregular interlocking grains. The actinolite occurs in long slender plates and in bundles of needles. "There is a heavy covering of drift sand and boulders here. Granite in place and gabbro lying on it were seen a short distance farther east in the S. E. ¼ N. W. ¼ sec. 24, T. 61–12. The Animikie beds seen in the vicinity were in knolls that rise above the granite and gabbro and are estimated to be 150 feet above Birch lake. A thickness of about 25 feet of the iron-bearing strata was seen in the various shafts."

The outcrops just noted mark the eastermost extension of the Mesabi iron-bearing strata, which in the field have been found to be continuous and of the same formation, although varying greatly in lithological characters. Farther east are other isolated outcrops of this formation which will be mentioned below.

Other observations.

Other observations have been made in this vicinity by Prof. Winchell* and the writer.

In the S. E. ¼ of S. E. ¼ sec. 23, T. 61–12, a number of shafts have recently been made by the Spellman Mining Co., under the direction of Mr. W. L. Honnold. The largest shaft was sunk about 200 feet east of the granite. This passes through black slates, gabbro, iron ore and actinolite schist.

The following notes were given to the writer by Mr. Honnold: "The deepest shaft was sunk 37 feet deep,—7 feet surface, 20 feet magnetic ore and 10 feet hornblendic quartzyte (foot wall). Between the ore and foot wall is a seam three or four inches thick of chloritic material, very soft and probably resulting from the decomposition of the foot wall. The foot wall carries considerable ore in irregular distribution, and the ore passed through at first was apparently due to an unusual concentration of this. The 'black slates' were not encountered

*Twenty-first Ann. Rept., p. 156.

in the shaft, but are to be found near the surface about 300 paces east of this shaft. Whether these are a continuous formation or merely a local variation of the quartzyte is undetermined."

The so called black slates of this locality were found by the writer only in large blocks removed from their original position. They are the same as the black slates south of Birch lake, but as they are not found *in situ* north of the lake, they may be dismissed without further mention. All of the specimens obtains from this vicinity were examined in thin sections with the following results: The rock called the hanging wall in the largest shaft is a biotite gabbro of medium texture and considerably altered. This occurs as detached knobs resting upon the iron-bearing rock beneath it, in the same manner as the gabbro south of the lake. The magnetic ore is composed of a high percentage of magnetite, occuring in well defined cubes and rounded grains. The interstices between the grains are filled with plagioclase, augite, biotite and quartz, all of which are very fresh. The rock associated with the ore is composed of actinolite. This mineral occurs in large plates and bundles of numerous beautifully twined crystals. In places biotite and chlorite show the alteration of the actinolite. A few grains of quartz are scattered throughout the section. The "hornblendic quartzyte" is a fresh actinolite schist. The actinolite occurs in crystals several inches in length and encloses numerous quartz grains. This rock is the same in character as specimen 960 and described as an olivinitic quartzyte.* In thin section this rock is an actinolite schist similar to the schist south of Birch lake. The characters of the minerals in this section in every way correspond to those shown in Dr. Bayley's specimen No. 8783, from which it differs only in coarseness of texture. In this locality we have, thus, the actinolite schist and the magnetic ore occurring in alternating bands of great thickness. The original character of the rock has been totally obliterated and in its present condition the rock is wholly crystalline, representing one extreme of the variations in the lithological character of the Animikie schists.

Specimens collected by Mr. A. D. Meeds in 1893 are nearly all from the southern limit of the Animikie rocks.†

Number 2, is a fine grained gabbro, from the N. W. ¼ of N. W. ¼ sec. 2, T. 60–12.

*N. H. Winchell, 15th Ann. Rept., p. 335.

†See list of rocks collected by A. D. Meeds, pp. 87-89 of this report.

Number 2*a*, from an outcrop a short distance north of the N. W. corner of section 2, is the same as specimen 404 described above.

No. 5, is coarse gabbro, near the east quarter post of sec. 28, T. 61-12.

No. 6, from the N. E. ¼ of S. W. ¼ sec. 10, T. 60-12, is a fine grained gabbro.

No. 7, from near the east quarter post of sec. 17, T. 60-12, is the same as the actinolite schists described above.

No. 8, one fourth of a mile south of the N. E. corner of sec. 35, T. 60-13, is a fine grained biotite schist. This is a part of the Animikie slate and is composed of quartz and biotite.

South of this locality the coarse gabbro occurs in numerous knobs and ridges. On account of the level topography in this vicinity the contact of the slate and gabbro was concealed by swamps.

Summary.

In the preceding notes attention is called to the varying lithological characters of the formation under consideration. This formation has been traced by continuous outcrops from the Mesabi iron bearing rock to Birch lake. At the western end the sedimentary character is undisputed. Going eastward the Animikie gradually thins out until it is lost altogether under the gabbro. The lithological characters also change, the nearer the gabbro is approached the more crystalline is the nature of the rock, until on both sides of Birch lake it is wholly crystalline. Near the contact with the gabbro, augite and olivine occur intimately associated with the actinolite and magnetite of the Animikie schists. The black slates have been changed to a quartz biotite schist in the proximity of the gabbro.

The lithological characters of the actinolite schists may be divided into two divisions: 1st. Those which are constant throughout the whole formation: banded structure, due to the concentration of the iron oxides along lines of weakness, leaving bands of lighter material, which finally makes up the ferromagnesian minerals; abundance of secondary quartz; concretionary structure of the iron oxides, and the presence of actinolite, although often in very small amounts. These characteristics agree very closely with those given by Irving and Van Hise* for the corresponding formations in the Penokee series.

*10th Ann. Rep. U. S. Geol. Survey, pp. 389-393.

The second division of the lithological characters is peculiar to the Mesabi formation, as they are largely due to the effect of the gabbro at the time of intrusion. 2d. Those characters which vary: mineralogical composition of the alternating bands. In the western part of the area, the light bands are composed of an unindividualized greenish substance, and the dark bands are composed of magnetite and hematite in about equal proportions, with some iron carbonate. Going eastward the rock passes through consecutive gradations until the light bands are made up of actinolite with local variations, where augite and olivine occur, and in the dark bands the hematite and siderite disappear, leaving only the magnetite. Plagioclase has been noted in several instances. Biotite results from the alteration of the actinolite.

The Pewabic quartzyte at the bottom of the Animikie decreases in thickness as Birch lake is approached from the west, and in the vicinity of Iron lake, section 14, T. 60–13, it disappears entirely. From this locality eastward the iron-bearing rock rests upon the granite, and consequently forms the bottom of the Animikie. The black slates also disappear before the Dunka river is reached. They were removed at the time of the gabbro intrusion.

The outcrops of the Animikie below and inclosed by the gabbro, between Birch lake and Akeley lake, have the same lithological characters and composition as the actinolite schists at Birch lake. These scattered outcrops have heretofore been called a part of the Pewabic quartzyte, but for reasons given above the writer considers them a part of the iron-bearing strata of the Animikie*.

IV. THE GABBRO.

Considerable time was spent in making a close study of the gabbro belt, through its entire width in Lake county. It is intended, on account of lack of time at present, to mention only a few of the localities where interesting observations were made.

In townships 62–10 and 11, and 61–10 and 11, an area about two townships in extent, of a dark, heavy and bedded olivine gabbro was found. Within this area are numerous knobs of feldspar rock as clear, fresh and coarse as the anorthosyte masses found near the lake Superior coast. In many instances

*Note.—W. S. Bayley, in the Nineteenth Ann. Rept., pp. 193-210, in describing rocks from the Akeley lake region, includes much of the so-called Pewabic quartzyte in the gabbro formation.

the feldspar knobs appear like water-worn boulders enclosed in the overlying olivine gabbro. On Greenwood lake (T. 58-10) are extensive outcrops of fresh hypersthene gabbro. This is cut in several places by dikes of the red rock which forms Greenwood mountain south of the lake. A point of importance in studying the gabbro is that the gabbro along the center of the formation has a belt in which are numerous knobs and areas a mile in extent composed of plagioclase rock, similar to that mentioned above. In going from the northern and southern limit of the gabbro toward this belt, it is very noticeable that the ferro-magnesian minerals decrease and the feldspar increases in proportion. The rock has more of a stratified appearance arising from the arrangement of the constituent minerals in bands. This separation of the minerals, when carried to extremes, produces the large aggregations of feldspar. The coarseness in texture is affected in the same manner. In the gabbro we have every evidence that it was a batholitic intrusion rather than a surface flow. The mineral and chemical composition of the various parts of the formation conform to all the known rules which govern the cooling of liquid magmas.

V. THE RED ROCK.

Under this group are included the felsytes, some of the diabases, and the augite syenite, which are closely associated and form a prominent group. The following are descriptions of all the outcrops examined by the writer, within the boundary of this group, as indicated on the map (Plate V, p. 150). In the N. E. ¼ of the S. W. ¼ sec. 8, T. 57-7, is the most northern outcrop of the dark diabases of the lake Superior coast. One half of a mile northwest of this, on the slope of a high ridge, are numerous angular fragments of augite syenite. At the top of the slope, rising four hundred feet in three fourths of a mile, is a perpendicular wall of fiery red augite syenite (225 E), similar to that found on the slope. The land continues at about the same hight north from here, and is covered with swamps. The rock is exposed in scattering outcrops and is the same as number 225E. Microscopical examination shows that this rock is the same as that described from Eagle mountain*. No augite was found in the section. Chlorite is present in small flakes. There are numerous patches of a yellow decomposition product which is easily removed, leaving a kind of porous

*R. D. Irving. Copper Bearing Rocks, Monograph V, U. S. G. S., p. 124, figs. 1 and 2, plate XIV.

structure. Quartz has thoroughly saturated the rock, and some of the cavities just mentioned are partially filled with quartz crystals, showing the progress of the saturation. The only original minerals definitely determined are orthoclase and oligoclase.

Seven miles north of the last outcrop, at the north quarter post of sec. 31, T. 59-7, is a large outcrop of felsyte porphyry, 172E. The weathered surface shows flowage structure on a large scale, 173E. Large black segregations show the peculiar bent and contorted condition noticed in the felsytes near lake Superior. In the N. W. ¼ of N. W. ¼ sec. 31, T. 59-7, are numerous angular fragments of laminated felsyte, 174E. This rock was not seen in place, but occurs in the outcrop one-half a mile east of here.

The next outcrop north of here is in the N. W. ¼ of sec. 36, T. 60-8. In the valley at this place is an exposure of black fine grained diabase nearly one half of a mile wide. The rock has a basaltic structure and in many places it is crossed by fine veins of quartz, 171E. Under the microscope the section shows long lath-shaped plagioclase, augite and magnetite. All of these are considerably altered. In portions of the section are porphyritic crystals of plagioclase. This rock is similar to the diabase cutting the felsytes north of lake Superior. It was not found in connection with the felsyte and augite syenite in this locality, but since in other localities it is always associated with these rocks it is safe to assume that it marks the northern edge of the red rock group in T. 60-8.

On Greenwood lake the gabbro is cut by dikes of augite syenite varying in width from one inch to two feet, 180E. This is the same as the rock which occurs in extensive outcrops south of the lake. Greenwood mountain is a mass of fiery red augite syenite, 185E and 186E. The rock is of medium texture, consisting mainly of feldspar and quartz. In ordinary light a section of this rock shows a red stained field completely riddled by secondary quartz. The quartz is wholly secondary and in many cases assumes a graphic form. The feldspar is mostly orthoclase with some oligoclase. These minerals have been corroded, broken up and replaced by infiltrating quartz. All of the quartz grains in any feldspar crystal are similarly oriented and in no case do those in adjacent feldspars possess the same orientation.

In the S. E. ¼ of S. E. ¼ sec. 1, T. 57-11, on the north side of the low ridge, are several outcrops of felsyte porphyry, 184E.

In microscopical characters it is similar to the following. Near the Beaver Bay trail in the S. E. ¼ sec. 33, T. 58–10, on the south side of the broad ridge, are extensive exposures of felsyte, 181E. "Large surfaces 'ten to twenty-five feet' square show fluidal structure on a large scale. Pale pinkish, light green and black felsytes are twisted together in various forms and assume a banded structure. The contrast between the colors is very strong. Under the microscope it is apparent that this rock is a felsyte with a quartz saturated base."*. The base is microcrystalline and of a red to purple color; the alternation of the lighter and darker portions gives a wavy banding to the rock. Red porphyritic feldspars are numerous.

A mile southwest of this outcrop and on the south side of the swamp which covers the region between the two, is an outcrop of felsyte porphyry, 182E, N. W. ¼ sec. 3, T. 57-10. Microscopical examination shows numerous orthoclase phenocryts embedded in a red to black aphanitic groundmass. The feldspar is somewhat altered to kaolin and shows shattering before the solidification of the base. The felsyte is cut by a fine grained diabase dike fifty feet wide, 183E. This is the same as the rock found in sec. 36, T. 60–8. South of these outcrops no others were observed, until in the S. W. ¼ N. W. ¼ sec. 4, T. 56–9, where the diabase of the lake Superior coast is found.

During the spring of 1892 Mr. C. L. Chase of Hastings, Minn., while surveying townships 56–9, 10 and 11, collected specimens from all of the rock outcrops upon the section lines in these townships. These specimens are registered in the general museum list and are briefly described as follows:

8026. Diabase from the S. E. ¼ S. E. ¼ sec. 4, T. 56-9. This is from the same outcrop from which 215E was taken.

8027. Anorthosyte. 1,500 paces north of S. E. corner sec. 5, T. 56-11. This is north of the red rock belt.

8028. Diabase. 25 chains west of S. E. corner sec. 2, T. 56–11. This belongs to the diabases south of the red rock.

8029. Felsyte porphyry, S. W. ¼ S. W. ¼ sec. 15, T. 56–11.

In the N. E. ¼ of N. E. ¼ sec. 4, T. 56–11, is a ledge of dark diabase, thirty feet high, facing northward and sloping toward the south, No. 8032. A short distance north of here on the north side of a small stream is a low east and west outcrop of gabbro, No. 8031. A dike of felsyte porphyry cuts the gabbro, No. 8033. Farther than this the relations of these

*Irving, op. cit. Description and illustration, p. 318.

rocks were not determined. The dark diabase is the same as that which was found cutting the felsyte in localities described above.

On the range line near the northwest corner of sec. 19, T. 55–11, Mr. A. D. Meeds found gabbro and felsyte porphyry in contact. From this exposure the relations of the rocks could not be determined. The region generally is covered with drift and swamp, which conceal all outcrops. One half a mile south of the last outcrop the felsyte again occurs. This probably represents the southern limit of the red rock belt in this locality. The specimens collected show red porphyritic feldspars embedded in a dark aphanitic groundmass. The gabbro is the coarse black phase of the great gabbro formation.

The bedded red rock surface flows of the lake Superior coast are traced by almost continuous outcrops into the great body of the red rock. The amygdaloidal and compact diabases cover the so-called fine grained gabbros or diabases south of the red rock group.

The varying composition of this group has been noted by other writers. Irving* says: "These three varieties of red rock [same as described above] thus described as occurring at Duluth, are evidently but different phases of the same rock, and without much doubt connected with each other in the mass, though this was not proved in the field." Although recognizing the fact that the different varieties of this group were found cutting all of the subdivisions, Irving places them in the different groups somewhat arbitrarily.

To the writer it seems that the Keweenawan on the north shore of lake Superior can be divided most satisfactorily into three large groups, with a possible smaller group, which in chronological order may be called the *gabbro, diabase, red rock* and the *later dikes* along the shore.

VI. THE DIABASES.

Under this group are included the fine grained dark gabbros so called, and the diabases forming Irving's different groups of the Keweenawan above the basal gabbro. Placing the amygdaloidal diabases and their related rocks in their proper position, i. e., into one large group, it is evident that the grouping of Irving must be readjusted. As a whole, this group is made up of a diabase porphyryte, which surrounds the anorthosytes.

*Copper Bearing Rocks, p. 272.

In the region back of the lake shore it is impossible to subdivide the rocks into the different groups of Irving. The lithological characters vary but little over large areas and would tend to show the unity of these groups rather than numerous subdivisions. The continuity of the rock outcrops in a measure serves to strengthen this view. This is the rock which transported the anorthosyte to its presént position and represents the effusive portion of the magma, out of which the basal gabbro first cooled.

VII. THE ANORTHOSYTES OF THE MINNESOTA SHORE OF LAKE SUPERIOR.*

These rocks are discussed in detail by Dr. A. C. Lawson.† The first part of that paper takes up the petrographical characters. In the second part the distribution and mode of occurrence of the anorthosytes are discussed. These rocks were observed between Carlton peak and Encampment island, a distance of forty-six miles, and extend an unknown distance inland. The occurrence and character is described at the following points on the lake Superior coast: Encampment island, Split Rock point, Beaver Bay, shore below Beaver Bay, Baptism river, slope of Sawteeth mountains, Carlton peak.

In discussing the geological relations of the anorthosyte, it is considered as a pre-Keweenawan terrane for the following reasons: It is traversed by dikes, both acid and basic, of the Keweenawan eruptives; the Keweenawan lavas hold imbedded in them innumerable boulders and blocks of anorthosyte evidently detached from a pre-existing terrane; the anorthosyte forms the surface upon which the Keweenawan lavas now rest and upon which they were originally extravasated; the anorthosyte affords both by its petrographical characters and by the nature of its surface the most satisfactory evidence of profound erosion prior to the extravasation of the Keweenawan eruptives. A great interval must have elapsed during this erosion, and the recognition of a pre-Keweenawan terrane involves certain consequences of geological importance. One of these is the absence of the Animikie in the region of study; another is the correction of Irving's estimate of the thickness of the Keweenawan. Instead of 20,000 feet in thickness, this is placed at barely 2,000 feet. The anorthosytes are plutonic

*Read before the Minn. Acad. of Nat. Sciences, Dec. 26, 1893.
†Bulletin No. 8, pp. 1-25, 1893.

eruptives, invading the Archean and yet long anterior to the Animikie. *Carltonian* is suggested as a local name for the formation.

In view of these conflicting opinions, the writer was instructed to make a detailed examination of the field relations of the anorthosytes and the associated rocks. While engaged in this work all of the localities, except Carlton peak, mentioned in Bulletin No. 8, as well as all the outcrops existing farther inland, were examined. The following notes bear chiefly upon the areas of the anorthosyte existing farther inland, and not described before. These observations confirm the views of N. H. Winchell, Irving, and others, in that they considered the anorthosyte masses as *detached blocks* inclosed in later trap rocks.

The geological relations of the inland anorthosyte areas are much clearer than of those at the lake shore, and, as will be found in the following pages, susceptible of only one interpretation, and the former masses have the same surroundings as those of the latter. Excluding the opinions of previous writers and interpreting the common facts of a part of the formation by the facts common to the whole, an explanation totally different from that of Dr. Lawson must be assigned to the anorthosyte.

In the S. W. ¼ of sec. 10, T. 55–8, at the top of the northward facing bluff, 600 feet above the lake, are large masses of anorthosyte embedded in the black gabbro of the region. The black rock here forms a perpendicular wall one hundred feet high. The anorthosyte occurs only at the top of the ridge; it is surrounded and cut by the diabase. The contact between the two rocks is somewhat irregular and the anorthosyte has the appearance of large irregular masses, rather than that of a water-worn boulder or hilltop. Many of the large blocks have been separated from the enclosing rock and also broken into smaller blocks, mainly through the action of recent ice in the cracks, and finally have fallen over the bluff. One block fifteen feet in diameter has been lifted partly out of its bed of diabase, leaving an irregular basin several feet deep, which was nearly full of water at the time. On the south slope of the same ridge in the S. E. ¼ of sec. 10, are several large masses of anorthosyte. These appeared as though they had been rolled down from the top of the ridge.

Both of the above occurrences are on the western extension of the range which has been mentioned in the following: "Between Beaver Bay and the Great Palisades are numerous feldspar masses, in the coast series, and inland from the shore a very short distance is a range of low hills made up of feldspar, with traprock on the flanks."* The Beaver river breaks through this range and precipitous bluffs of black olivine gabbro along both sides of the stream plainly show that this is the only rock forming the range at this place. Masses of anorthosyte of all sizes occur enclosed in the black rock. The flows of felsyte cover the gabbro and the anorthosyte. In the east ½ of sec. 1, T. 55–8, on the summit and the south slope of the ridge are several large masses of anorthosyte. The southern slope of the ridge is heavily wooded and the rock outcrops are for the greater part concealed. In ascending the ridge from the lake shore nearly to the top the occasional outcrops are black gabbro or diabase. The anorthorsyte at the top is cut and surrounded in numerous places by the black gabbro.

Toward the north, the ridge breaks off abruptly in precipices twenty-five to fifty feet high. The rock is always the black gabbro which continues in extensive outcrops north of here. In the N. E. ¼ of N. W. ¼ of sec. 12, T. 55–8, large irregular masses of anorthosyte are enclosed in the black gabbro, which forms a perpendicular wall fifty to a hundred feet high running at right angles to the trend of the ridge. The black rock was traced northwestward into the valley north of the ridge. This plainly shows that the mass of the ridge is made up of this rock, and that the anorthosyte here simply forms a mass, capping the black gabbro. Going east on the "old county road" the ridge just mentioned is crossed, and for several miles the road runs along the base of a northward facing precipice of black gabbro, which forms the northern side of the ridge.

There are several breaks in the ridge where good cross sections were obtained, viz., along the creeks in section 31, T. 56–7, sections 19 and 20, sections 17 and 16, and along the Baptism river in sections 4, 10 and 15. Along these sections are continuous outcrops of black gabbro having in some places a coarsely bedded appearance, but usually massive. Anorthosyte masses occur frequently at the top and on the south slope of the ridge. A number of these have fallen over the bluff into the valley on the north. In the S. E. ¼ of sec. 8, T. 56–7, the anorthosyte masses are as large as fifty to one one hun-

*N. H. Winchell, 9th Ann. Rept., p. 34, 1880.

dred feet thick and three to five hundred feet wide, in one case covering the surface for an eighth of a mile. The black gabbro cuts these masses, and forms the base of the ridge.

In the N. E. ¼ of S. E. ¼ of sec. 27 and the N. W. ¼ of S. W. ¼ of sec. 26, T. 56-8, is an oblong ridge, one fourth of a mile long and one eighth of a mile wide at the the top and three hundred feet above the surrounding country and six hundred feet above lake Superior. The upper half of this elevation is composed of anorthosyte resting upon a base of the black gabbro of the region, dikes of which cut the anorthosyte, which here is found to vary in mineral composition considerably more than in other localities. It is not a pure feldspar rock. A large part of the rock contains numerous dark areas of the ferro-magnesian minerals. The whole rock has the composition of the normal gabbro. Specimens 188*a* to *g* represent the different phases of the rock.

One half a mile northwest of this locality, in the S. E. ¼ of N. E. ¼ sec. 27, is Schaff's hill. The greater part of this hill is composed of dark diabase, which forms perpendicular walls on all sides of the hill and makes the ascent to the top very difficult. On top of the hill and near the southwestern edge is a mass of anorthoryte about five hundred feet square. This is the same pure feldspar rock which occurs at Beaver Bay. This outcrop, six hundred and twenty feet above and four miles from lake Superior, is the most distant outcrop of this rock from the lake. Other occurrences are in the N. E. ¼ of S. E. ¼ sec. 26, and the S. W. ¼ sec. 25, T. 56-8. At both of these localities there is no doubt that they are enclosed masses. In the latter place an irregular mass of anorthosyte seventy feet in diameter has been broken off from the neighboring diabase wall and lies near its original place in a tilted position.

After these occurrences of the anorthosyte were examined the most important exposures at Beaver Bay on the lake shore were again examined. All of these outcrops hold the same relation to the diabases and gabbros of this region as that held by the outcrops farther inland.

The occurrence at the cove below Split Rock point is of importance, and there exists a difference of opinion concerning it. All geologists agree that the smaller masses of anorthosyte are fragments included in the diabase. Various views have been expressed concerning the large masses.* The limited extent and the relations of the anorthosyte are apparently the same as observed elsewhere. In this locality the relations

*Bulletin No. 8., pp. 11-14.

of the different rocks are somewhat indistinct. Viewed in the light of the other occurrences of even greater extent, whose geological relations are undoubted, it is safe to place the rocks in this locality in the same position. The hypothetical section of the rocks at Split Rock point, given in Bulletin number 8, p. 12, in no way represents the relations of the anorthosyte to the later rock, as understood by the writer.

The mineralogical composition is not as constant as is stated in Bulletin No. 8. Attention has been called to this fact by Prof. Winchell* in the following note: "That some of the masses were not of pure feldspar rock, but contained in the usual proportions, the minerals augite and magnetite. * * * Thin sections have revealed in the feldspar boulders, however pure they may appear to the eye, small quantities of augite, and from these minute quantities there are all gradations to typically constituted gabbro." These statements the writer, after his extended observations, is able to confirm.

In addition to the above, attention may be called to the fact that in the majority of cases the original ferro-magnesian mineral has been altered to chlorite, often forming a pseudo-amygdaloidal structure. 188*f* in thin section shows this character. The most typical outcrop of the anorthosyte is the ridge in the S. E. ¼ sec. 27, T. 56–8. In this large mass all variations and gradations described from different isolated localities are readily seen. Specimens 188*a* to *g* from this ridge represent all the varieties, and may be taken as a typtical set of the anorthosyte of the lake Superior coast.

Sufficient evidence has been presented to show that the anorthosyte occurs *only as included masses* in the diabases and that it does not represent a pre-Keweenawan terrane existing *in situ* beneath the diabase. Conclusions based upon this assumption have therefore no value.

The petrographical characters are the same as those of the central part of the gabbro formation. Considering the gabbro as the intrusive and the diabases as the effusive portions of the same magma, it is easily seen that while the upper portion of the magma was solidified as the gabbro, in the interior of the mass large masses or aggregations of feldspar were separated. These solid masses floating around in the liquid magma were ejected with it and, being considerably lighter than the surrounding molten mass, floated near the surface and are therefore at present only found near the top of the first outburst of

*Bull. VIII, p. xviii.

diabase. Later, when some of this diabase was eroded, the feldspar knobs projected above the surrounding rocks and at the time of the later lava flows were covered up by the felsytes and other rocks of the red rock group. This explains the origin and present position as well as the domed and hummocky characters of the anorthosyte.

VIII. SUMMARY.

In the preceding pages the writer has attempted to show several points of interest to those who are working in the geology of the pre-Cambrian rocks. A brief review of the more important points advanced will not be out of place.

Snowbank lake area. The structure and some of the characters of the rocks north and west of the lake are given. The quartz porphyry, so common in the Keewatin, here has an unusually extensive developement. An augite granite is described, with an explanation of the local occurrence of augite granites in Minnesota. Additional evidence is given showing the derivation of the mica and hornblende schists from the Keewatin.

Actinolite magnetite schists from the eastern Mesabi. Description of the schists and their geological associates is given, showing their derivation from a rock containing an original iron carbonate. These schists were greatly affected by the gabbro. The recognition of the true character of these schists will establish an important analogical link between the Mesabi and the Penokee series. It is also shown that the so-called Pewabic quartzyte between Birch lake and Gunflint lake belongs to the middle member (iron-bearing) of the Animikie.

The gabbro. Several observations in the hitherto unexplored regions are recorded. Attention is called to the varying mineralogical phases of the gabbro showing that it is to be considered as an intrusive rather than an effusive.

The red rock. Augite syenite, quartz porphyry, felsyte, etc., are described from the vicinity of Greenwood lake. These rocks were traced into similar rocks on the shore of lake Superior. It is shown that nearly all of the red rock forms one prominent group. The Keweenawan rocks north of lake Superior are divided into the gabbro, diabase, red rock and the later dike groups.

The diabases. Under this group are included the fine grained gabbros and diabases immediately south of the main body of the red rock group. It is also suggested that the subdivisions of the Keweenawan of Minnesota into the minor groups of Irving is impossible. The diabases are considered as the effusive equivalent of the gabbro.

The anorthosyte. Evidence is produced showing that the anorthosyte occurs only as included masses in the *diabases.* In mineralogical composition it is the same as the gabbro of which it was originally a part. The anorthosyte occurs near the top of the first outflow of the diabase group and afterwards it was also covered by the felsyte and diabase of the red rock group. The conclusions based upon the supposition of Lawson that the anorthosyte formed a pre-Keweenawan terrane are thus rendered valueless.

XIII.

LIST OF ROCK SAMPLES COLLECTED IN 1893

BY A. H. ELFTMAN.

The greater part of these specimens have been examined in thin section. The term "anorthosyte" is used to designate the pure feldspar rocks of the Keweenawan. These specimens are marked with white shellac figures with the letter E after the number.

1. Dioryte inclusion in granite. S. W. ¼ N. W. ¼ sec. 1, T. 62–12.
2. Schistose inclusion in granite. Same locality.
3. Contact of hornblende schist and granite. Same locality.
4. Porous condition of schists. Same locality.
5. Diabase dike. S. W. ¼ S. E. ¼ sec. 24, T. 62–12.
6. Granite near the preceding.
7. Lenticular hornblende mass in granite. N. E. ¼ S. E. ¼ sec. 25, T. 62–12.
8. Quartz dioryte inclusion in granite. 4 specimens. N. W. ¼ N. E. ¼ sec. 7, T. 62–11.
9. Granite. Same locality.

10A. Gneiss. Inclusions in granite. S. E. ¼ N. W. ¼ sec. 7, T. 62–11.

10B. Contact. Same locality.

11. Quartz dioryte inclusion in granite. S. E. ¼ S. E. ¼ sec. 12, T. 62–12.
12. Diabase dike. Same locality.
13. Dioryte. Same locality.
14. Fine grained granite. S. E. ¼ N. E. ¼ sec. 13, T. 62–12.
15. Coarse granite. Same locality.
16. Schistose dioryte. N. E. ¼ N. E. ¼ sec. 13, T. 62–12.
17. Hornblende inclusion in granite. From the point on White Iron lake in S. W. ¼ S. W. ¼ sec. 12, T. 62–12.
18. Hornblende schist. Same locality.
19. Dioryte. Same locality.

20. Quartz. 200 paces north of S. E. corner sec. 11, T. 62-12.
21. Granite. Same locality.
22. Magnetite vein cutting granite. Same locality.
23. Magnetite. Same locality.
24. Light red granite. N. E. ¼ N. E. ¼ sec. 14, T. 62-12.
25. Dark red granite, Same locality.
26. Weathered granite. Same locality.
27. Mica schist. S. W. ¼ N. E. ¼ sec. 35 T. 63-11.
28. Schist. N. E. ¼ N. W. ¼ sec. 2, T. 62-11.
29. Mica schist. Same locality.
30. Concretionary greenstone. N. E. ¼ N. E. ¼ sec. 17, T. 63-9.
31. Diabase. Same locality.
32. Schistose diabase. Same locality.
33. Diabase dikes, *a.* Coarse, *b.* fine grained. N. W. ¼ N. E. ¼ sec. 17, T. 63-9.
34. Talc schist. N. W. ¼ N. E. ¼ sec. 17, T. 63-9.
35. Jasper. S. W. ¼ S. W. ¼ sec. 1, T. 63-10.
36. Schistose diabase. One foot from contact with jasper. Same locality.
37. Diabase. Twenty feet from contact. Same locality.
38. Diabase. Forty feet from contact. Same locality.
39. Dioryte. S. W. ¼ N. W. ¼ sec. 31, T. 64-9.
40. Hornblende porphyry. S. W. ¼ S. W. ¼ sec. 1, T. 63-10.
41. Schistose greenstone. Same locality.
42. Concretions in greenstone. Same locality.
43. Hornblende porphyry. N. E. ¼ S. E. ¼ sec. 31, T. 63-9.
44. Conglomerate. N. W. ¼ S. E. ¼ sec. 31, T. 63-9.
45. Quartzless porphyry pebble in conglomerate. Same locality.
46. Laminated diabase. N. E. ¼ S. W. ¼ sec. 31, T. 64-9.
47. Matrix of conglomerate. Same locality.
48. Dioryte. Same locality.
49. A to E. Quartz porphyry. S. W. ¼ S. E. ¼ sec. 31, T. 64-9.
49. F and G. Weathered surface of the preceding.
50. Diabase. Same locality.
51. Contact of diabase and quartz porphyry. Same locality.
52. Jasper. N. W. ¼ S. W. ¼ sec. 32, T. 64-9.
53. Hornblende porphyry. Same locality.
54. Coarse dioryte. N. E. ¼ S. W. ¼ sec. 32, T. 64-9.
55 Quartzless porphyry. S. E. ¼ N. W. ¼ sec. 26, T. 64-9.
56. Granite cutting porphyry. Same locality.

57. Quartzless porphyry. Same locality.
58. Contact of schist and porphyry.
59. Quartzless porphyry. N. E. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 26, T. 64-9.
60. Quartz porphyry. N. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 23, T. 64-9.
61. Quartzless porphyry. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 23, T. 64-9.
62. Hornblende schist. N. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 23, T. 64-9.
63. Argillyte. S. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 34, T. 64-9.
64. Gabbro. N. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 4, T. 63-8.
65. Gabbro. (Iron ore near bottom of the beds). Same locality.
66. Gabbro. (Iron ore near the top). Same locality.
67. Fine grained gabbro in the ore bed. Same locality.
68. Keewatin schist inclosed in gabbro. Same locality.
69. Coarse weathered gabbro. Same locality.
70. Coarse gabbro. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 4, T. 63-8.
71. Gabbro, largely plagioclase. Same locality.
72A. Olivine gabbro. S. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 4, T. 63-8.
72B. Bedded olivine gabbro. Same locality.
73. Contact of olivine and coarse gabbro. Same locality.
74. Diabase. N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 34, T. 64-8.
75. Iron ore. N. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 4, T. 63-8.
76. Anorthosyte. N. W. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 24, T. 63-9.
77. Feldspar from No. 76. Same locality.
78. Specimens showing weathering of the gabbro.
79. Diabasic anorthosyte. S. E. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 24, T. 63-9.
80. Shows large plagioclase crystal in No. 79.
81. Olivine gabbro. N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 20, T. 63-8.
82. Coarse olivine gabbro. Same locality.
83. Transition of Nos. 81 and 82.
84. Olivine gabbro. Same locality.
85. Olivine gabbro. N. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 1, T. 62-9.
86. Intermediate between Nos. 85 and 87.
87. Olivine gabbro. N. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec, 1, T. 62-9.
88. Granite dike. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 1, T. 62-9.
89. Anorthosyte. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 1, T. 62-9.
90. Plagioclase crystals. N. W. $\frac{1}{4}$ of N. W. $\frac{1}{4}$ sec. 13, T. 63-8.
91. Plagioclase and diallage. Same locality.
92. Diallage. Same locality.
93. Olivine gabbro. S. E. corner sec. 1, T. 62-9.
94. Anorthosyte. N. W. $\frac{1}{2}$ N. E. $\frac{1}{4}$ sec. 12, T. 62-9.
95. Olivine gabbro. N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 8, T. 62-8.
96. Diallage. S. W. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 2, T. 62-9.
97. Gabbro. N. W. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 29, T. 63-9.
98. Fine grained gabbro. Same locality.

99. Gabbro. Same locality.
100. Foliated olivine gabbro. Same locality.
101. Olivine gabbro. Same locality.
102. Contact between Nos. 97 and 100. N. E. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 29, T. 63–9.
103. Contact showing biotite in gabbro. Some locality.
104. Olivine gabbro. N. W. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 21, T. 61–9.
105. Olivine gabbro. S. W. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 31, T. 62–9.
106. Olivine gabbro. N. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 7, T. 61–9.
107. Foliated diabasic gabbro. S. W. $\frac{1}{4}$ sec. 12, T. 61-10.
108. Fine grained olivine gabbro. Same locality.
109. Olivine gabbro. Same locality.
110. Foliated olivine gabbro. S. E. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 27, T. 62–10.
111. Bedded olivine gabbro. Same locality.
112. Olivine gabbro. N. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 27, T. 62–10.
113. Anorthosyte. Same locality.
114. Anorthosyte. 100 paces north of No. 113.
115. Anorthosyte. S. W. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 27, T. 62–10.
116. Plagioclase crystal in No. 115.
117. Olivine gabbro. S. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 15, T. 62–10.
118. Granite. N. E. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 25, T. 62–8.
119. Contact between gabbro and granite. Same locality.
120. Olivine gabbro. S. E. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 20, T. 62–10.
121. Coarse gabbro. 100 feet north of magnetite ore. N. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 30, T. 62–10.
122. Infiltrated quartz. S. E. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 30, T. 62–10.
123. Pyroxenyte. Same locality.
124. Quartz and gabbro. Same locality.
125A. Olivine. Same locality.
125B. Hornblende. Same locality.
126. Olivine gabbro. Muskrat lake. S. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 30, T. 62–10.
127. Olivine gabbro. Muskrat lake. S. E. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 30, T. 62–10.
128. Gabbro. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 29, T. 62–10.
129. Matrix of conglomerate. N. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 26, T. 64–9.
130. Dioryte. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 13, T. 64–9.
131A. Concretionary schistose diabase dike. N. E. corner sec. 28, T. 62–11.
131B. Contact of granite and dike.
132. Granite with part of dike adhering.
133. Granite. S. W. corner sec. 28, T. 62–11.

134. Coarse foliated hornblende granite. N. W. ¼ N. W. ¼ sec. 33, T. 62-11.
135. Gabbro boulder. N. ¼ post sec. 28, T. 62-11.
136. Granite. E. ¼ post sec. 32, T. 62-11.
137. Orthoclase crystals. Same locality.
138. Orthoclase crystals. N. E. ¼ N. E. ¼ sec. 28, T. 62-11.
139. Coarse gabbro. S. W. ¼ S. W. ¼ sec. 19, T. 61-11.
140. Diabase. Same locality.
141. Slate boulder. Sec. 24, T. 61-12.
142. Pyroxenyte. Same locality.
143. Gabbro. Same locality.
144. Gabbro with chalcopyrite. Same locality.
145. Magnetite, sec. 24, T. 61-12.
146. Olivine gabbro. N. W. ¼ sec. 31, T. 61-10.
147. Anorthosyte. N. E. ¼ S. W. ¼ sec. 36, T. 61-11.
148A. Anorthosyte. S. W. ¼ N. W. ¼ sec. 31, T. 61-10.
148B. Olivine and plagioclase segregations in gabbro. Same locality.
149A. Anorthosyte. Harris lake. N. W. ¼ sec. 26, T. 61-11.
149B. Olivine gabbro. Harris lake. N. E. ¼ sec. 27, T. 61-11.
150. Biotite gabbro. N. W. ¼ sec. 29, T. 61-11.
151A. Contact between feldspar and olivine segregations. N. E. ¼ N. E. ¼ sec. 6, T. 60-11.
151B. Laminated weathered surface of No. 151A.
151C. Diallage. Same locality.
152. Anorthosyte. N. W. ¼ S. W. ¼ sec. 8, T. 60-11.
153A. Olivine gabbro. N. ¼ post sec. 2, T. 60-10.
153B. Olivine gabbro. N. W. ¼ sec. 35, T. 61 10.
154. Anorthosyte. S. W. ¼ N. W. ¼ sec. 35, T. 61-10.
155. Olivine gabbro. N. ¼ post sec. 3, T. 60-10.
156. Olivine gabbro. N. E. ¼ N. E. ¼ sec. 4, T. 60-10.
157. Gabbro. S. W. ¼ sec. 4, T. 59-10.
158. Diallage. Harris lake. Sec. 26, T. 61-11.
159. Olivine gabbro. 100 paces west of N. E. corner sec. 1, T. 59-10.
160. Olivine gabbro. S. E. ¼ N. E. ¼ sec. 1, T, 59-10.
161. Gabbro. 500 paces S. of E. ¼ post sec. 1, T. 59-10.
162. Granite. Boot lake. S. W. ¼ N. E. ¼ sec. 21, T. 64-8.
163. Spotted talc schist. N. W. ¼ S. E. ¼ sec. 15, T. 64-8.
164. Spotted talc schist. N. E. ¼ S. W. ¼ sec. 22, T. 64-9.
165. Talc schist. Same locality.
166. Spotted schist. Same locality.

167. Schist with large orthoclase crystals. Same locality. Preceding 4 specimens are transitions from 164 to 167.
168. Quartzless porphyry. S. W. ¼ N. W. ¼ sec. 21, T. 64-8.
169. Ferruginous talc schist. S. E ¼ S. W. ¼ sec. 20, T. 64-9.
170. Gabbro. N. ¼ part sec. 4, T. 60-8. [Lost.]
171A. Diabase. N. W. ¼ N. W. ¼ sec. 36, T. 60-8.
171B. Diabase. S. W. ¼ N. W. ¼ sec. 36, T. 60-8.
172. Black felsyte porphyry. N. ½ post sec. 31, T. 58-7.
173A. Red felsyte porphyry. Same locality.
173B. Weathered surface of No. 173A.
174. Laminated felsyte. Same locality.
175. Olivine gabbro. S. E. ¼ S. E. ¼ sec. 30, T. 59-10:
176. Hypersthene gabbro. S. E. ¼ sec. 32, T. 59-10.
177. Gabbro veins. S. E. ¼ sec. 19, T. 60-8.
178. Hypersthene gabbro. Greenwood lake. N. E. ¼ sec. 9, T. 58-10.
179A. Reddish gabbro. N. E. ¼ sec. 16, T. 58-10.
179B. Olivine gabbro. Same locality.
180. Augite syenite dike. Same locality.
181A to E. Felsyte. N. E. ¼ S. E. ¼ sec. 33, T. 58-10.
182. Felsyte porphyry. N. W. ¼ sec. 3, T. 57-10.
183. Diabase. N. W. ¼ sec. 3, T. 57-10.
184. Felsyte porphyry. S. E. ¼ S. E. ¼ sec. 1, T. 57-11.
185. Augite syenite. N. E. ¼ S. E. ¼ sec. 25, T. 58-10.
186. Augite syenite. 50 paces south of N. W. corner sec. 30, T. 58-10.
187. Gabbro. "Grandmother" hill. S. W. ¼ S. E. ¼ sec. 8, T. 57-13.
188. Anorthosyte. N. E. ¼ S. E. ¼ sec. 27, T. 56-8. *a* Light colored. *b* Shows fracture. *c* Dark colored, *d* Chlorite segregations. *e* Weathering. *f* Fine grained. Chlorite evenly distributed.
189. Gabbro cutting No. 188.
190. Anorthosyte, shows weathering and chlorite. Schaff's hill. S. W. ¼ N. E. ¼ sec. 27, T. 56-8.
191. Gabbro. Schaff's hill.
192. Diabase at top of hill. S. W. ¼ S. E. ¼ sec. 22, T. 56-8.
193. Diabase north base of hill.
194. Diabase. In river bed. N. W. ¼ S. E. ¼ sec. 22, T. 56-8.
195. Amygdaloidal diabase, laumontite, chlorite, calcite and quartz. Same locality.
196. Diabase porphyryte. S. W. ¼ S. E. ¼ sec. 22, T. 56-8.
197. Diabase. Same locality.

198A. Red mottled gabbro. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 34, T. 57-7.
198B. Diabase. S. E. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 34, T. 57-7.
199. Gabbro. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 27, T. 56-8.
200. Gabbro. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 11, T. 56-8.
201. Gabbro. N. E. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 13, T. 56 8.
202. Diabase. N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 7, T. 56-7.
203. Diabase porphyryte. Same locality.
204. Gabbro containing plagioclase crystal 1 inch in diameter. N. E. $\frac{1}{4}$ sec. 6, T. 56-7.
205. Gabbro. N. W. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 6, T. 57-7.
206. Gabbro. S. E. $\frac{1}{4}$ sec. 19, T. 57-7.
207. Gabbro. N. W. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 25, T. 56-8.
208. Diabase. N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 25, T. 56-8.
209. Anorthosyte. N. E. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 26, T. 56-8.
210. Red gabbro. N. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 25, T. 56-8.
211. Diabase. Bear lake, N. W. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 3, T. 55-8.
212. Diabase. N. E. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 3, T. 55-8.
213A. Amygdaloidal diabase porphyryte. On town road, $\frac{1}{4}$ mile south of N. E. corner sec. 3, T. 55-8.
213B. Same, one half mile south of the preceding.
214. Diabase. S. E. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 31, T. 56-8.
215. Gabbro. 50 paces south of N. W. corner sec. 15, T. 56-9.
216. Diabase porphyryte. N. E. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 9, T. 55-8.
217. Diabase. S. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 9, T. 55-8.
218. Diabase. S. E. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 9, T. 55-8.
219. Anorthosyte. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 10, T. 55-8.
220. Olivine gabbro. Second falls of Beaver river. N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 12, T. 55-8.
221. Fine grained diabase. N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 3, T. 55–8.
222. Amygdaloidal diabase. S. E. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 2, T. 55–8.
223. Gabbro. N. W. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 1, T. 55–8.
224. Anorthosyte. S. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 1, T. 55–8.
225. Augite syenite. S. W. $\frac{1}{4}$ sec. 5, T. 57–7.
226. Diabase. S. W. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 22, T. 57–7.
227. Olivine gabbro. W. $\frac{1}{4}$ post sec. 35, T. 55–11.
228. Diabase. S. W. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 33, T. 55–10.
229. Diabase. S. E. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 11, T. 55–10.
230. Anorthosyte boulder. Same locality.
231. Diabase. N. W. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 15, T. 55–10.
232. Diabase. N. W. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec, 23, T. 55–10.
233. Diabase. S. E. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 26, T. 53–11.
234. Ophitic gabbro. 100 paces north of S. E. corner sec. 27, T. 53–11.

235. Ophitic olivine gabbro. Same locality.
236. Contact between 235 and anorthosyte inclusion. Same locality.
237. Fine grained red gabbro. N. E. ¼ N. E. ¼ sec. 34, T. 53–11.
238. Diabase. N. W. ¼ S. W. ¼ sec. 12, T. 53–11.
239. Diabase. N. E. ¼ N. E. ¼ sec. 17, T. 53–11.
240. Diabase. S. W. ¼ N. W. ¼ sec. 8, T. 53–11.
241. Diabase with feldspar crystals. Same locality.
242. Compact felsyte. Railroad cut. N. E. ¼ sec. 21, T. 52–11.
243. Amygdaloidal diabase. Lake shore. sec. 21, T. 52–11.
244. Diabase. S. W. ¼ N. W. ¼ sec. 8, T. 53–11,
245. Amygdaloidal diabase containing laumontite, calcite, etc. Stewart river, S. W. ¼ N, E. ¼ sec. 29, T. 53–10.
246. Amygdaloidal diabase. From "copper mine." S. E. ¼ N. E. ¼ sec. 29, T. 53–11.
247. Fine grained phase of 246.
248. 4 specimens represent the rock below the amygdaloidal diabase, and form bed of the Stewart river. N. E. ¼ N. W. ¼ sec. 29, T. 53–10.
249. Diabase. Upper falls ("the slide") of Stewart river. N. W. ¼ S. W. ¼ sec. 20, T. 53-10.
250. Gabbro. S. W. ¼ S. W. ¼ sec. 15, T. 53-10.
251. Diabase. Mouth of Stewart river.
252. Gabbro. N. W. ¼ S. W. ¼ sec. 4, T. 53-10.
253. Diabase. Same locality.
254. Contact between Nos. 252 and 253.
255. Gabbro. N. W. ¼ sec. 6, T. 54-9.
256. Amygdaloidal diabase. Point below Split Rock river.
257. Diabase. First falls of Gooseberry river.
258A. Diabase. Flood bay. S. E. ¼ N. W. ¼ sec. 32, T. 53-10.
258B. Laminated diabase. Same locality.
259. Diabase. Rock cut two miles north of Highland. D. & I. R. railroad.
260. Diabase. N. W. corner sec. 12, T. 52-11.
261. Fine red mottled diabase. Lighthouse point at Two Harbors.
262. Diabase. Rock cut one mile north of Two Harbors.
263. A different phase of No. 262.
264. Diabase. One mile south of Cloquet.
265. Red rock boulder. Same locality.
266. Diabase. On old county road north of Great Palisades.
267. Quartzless porphyry. S. E. ¼ S. E. ¼ sec. 23, T. 64-9.
268. Granite. Same locality.

269. Schist. S. E. ¼ N. W ¼ sec. 24, T. 64-9.
270. Quartzless porphyry. N. E. ¼ S. E. ¼ sec. 19, T. 64-8.
271. Augite granite. N. W. ¼ S. W. ¼ sec. 20, T. 64-8.
272. Quartzless porphyry. S. W. ¼ N. W. ¼ sec 20, T. 64-8.
273. Granite. S. W. ¼ N. W. ¼ sec. 20, T. 64-8.
274. Siliceous schist. Boot lake. N. W. ¼ S. E. ¼ sec. 21, T. 64-8.
275. Granite. S. W. ¼ N. W. ¼ sec. 20, T. 64-8.
276. Matrix of conglomerate. N. E. ¼ S. E. ¼ sec. 22, T. 64-9.
277. Argillitic schist. Same locality.
278. Dioryte. N. E. ¼ S. W. ¼ sec. 28, T. 64-9.
279. Quartzless porphyry. Flask lake. S. E. ¼ S. E. ¼ sec. 28, T. 64-9.
280. Dioryte. Same locality.
281. Hornblende porphyry. S. W. ¼ N. W. ¼ sec. 31, T. 64-9.
282. Hornblende schist. Jasper lake, sec. 1, T. 63-10.
283. Hematite. S. W. ¼ S. E. ¼ sec, 1, T. 63-10.
284. Hornblende porphyry, Same locality.
285. Dioryte. N. W. ¼ S. W. ¼ sec. 26, T. 64-9.
286. Argillitic schist. N. E. ¼ S. W. ¼ sec. 26, T. 64-9.
287. Spotted talc schist. N. W. ¼ S. E. ¼ sec. 15, T. 64-8.
288. Diabase. Bed of Baptism river at the crossing of the old county road. S. E. ¼ sec. 4, T. 56-7.

MUSEUM ADDITIONS

SPECIMENS REGISTERED IN THE GENERAL

Serial No.	Obtained.		Name.	Number of specimens.
	When.	Whence.		
7947	Aug., 1891	A. E. Foote	Diablo canyon meteoric iron	1
7948	"	"	Siliceous iron	1
7949	Feb.. 1892	H. A. Ward	Fayette county, Texas, meteorite	1 slab
7950	Sept., 1892	Donation	Slag from the first iron furnace in America	3
7951	"	"	Iron " " " " " " "	1
7952	Sept., 1893	Dr. A. Brezina	Carlton meteorite, slab, etched	1
7953	"	"	Bella Roca meteorite, slab, etched	1
7954	"	"	Crab Orchard meteorite, slab	1
7955	"	"	Mercedetas meteorite. slab. etched	1
7956	"	"	Duncan meteorite, slab, etched	1
7957	Feb., 1891	Presented	Magnetitic iron ore from crystalline schists	2
7958	"	"	Granite " " "	1
7959			Stratified volcanic dust (with casts of grasses)	1
7960			Ripple bedded volcanic dust (with pellets)	1
7961	July 3, 1892	Geol. Survey	Beach stone	1
7962		"	Pyrite	2
7963		"	Iron ore	1
7965			Clinton Iron are	1
7966			Glacial clay	
7967	Sep. 20, 1889	Donated	Sperrylite	
7968	Aug. 7, 1892	Geol. Survey	Quartzyte, light gray	11
7969	J'ne 20. 1893	"	Diabase, black	3
7970	"	"	" "	1
7971	Oct. 17, 1893	"	Granite. gray, coarse	3
7972	"	"	" " " (with inclusions of black hornblende schist)	9
7973	Sep. 14, 1893	"	Schist, sericitic, weathered, ferruginous	1
7974	J'ne 19, 1893	"	Magnesian limestone, pyritiferous,—from a boulder	1
7975	Aug. 3, 1293	"	Pebbles, red, of igneous rocks from N. E. Minnesota	10
7976	"	"	Lignite, fragments in modified drift	1
7977	Oct. 17, 1893	"	Taconyte (20th Ann. Rep., p. 124), a fissile, slaty variety—from morainic drift	3
7978	1892	"	Diabase, coarse, magnetic	1
7979	"	"	Gabbro, coarse	1
7980	"	"	Diabase	2
7981	"	"	Granite, reddish	2
7982	"	"	" "	2
7983	"	"	Various rocks	6
7984	1893	"	Slate, black	3

MINERALOGY AND LITHOLOGY.

MUSEUM SINCE THE LAST REPORT.

LOCALITY.	Formation.	COLLECTOR AND REMARKS.
Diablo canyon, Ariz.		A. E. Foote. Weight 12¾ oz.
" " "		Found in connection with 7947. 7¾ oz.
Fayette county, Tex		A large polished slab, 22x11 in.
Lynn, Mass		N. H. Winchell. From the old cinder piles.
" "		" " " " "
		By exchange. 249 gr.
Durango, Mex		" 210 gr.
Cumberland Co, Tenn		" 55 gr.
		" 422 gr.
Maverick Co., Tex		" 118 gr.
N. of Long L., St. Louis Co., Minn	Vermilion	Hillberg and Brandine.
" " " "	"	" "
McPherson Co., Kan		J. A. Udden.
" "		" "
Morrison's bay, Pigeon Pt., Minn		N. H. Winchell.
Neenah, Wis	Galena	Chas. Schuchert.
1½ m. N. of Iron Ridge, Wis	Clinton	" "
" " " "		" "
Menasha, Wis		" "
Sudbury, Ontario		Present by F. L. Sperry.
N.W. side of Dam lake, Aitkin Co., near middle of W. ½ of sec. 35, T. 46, R. 25	Pewabic	Warren Upham. (About 3¼ m. south of Kimberly).
S.W. ¼ of sec 9, T.46, R.25, Aitkin Co., western outcrop		" " (About 3 m. S. W. from the foregoing).
Same locality, eastern outcrop		" " These outcrops are about 20 rods apart, the 2d and smaller being N. E. from the first.
Hinsdale, D. & I. R. railroad, near center of S. ½ of sec. 8, T. 59, R. 14 W.; abandoned quarry		Warran Upham. (Forming the Giant's or "Mesabi" range; quarried here for the auditorium, Chicago.)
Same quarry with preceding		Warren Upham. (Boulders of similar granite, with such inclusions, sre found rarely in southwestern Minnesota; for examples in Big Stone and Otter Tail counties, see vol. i, p. 625; and vol. ii, p. 551).
Near S. E. cor. of sec. 20, T. 46, R. 20, Carlton county		Warren Upham. (Close, W. of Kettle river, on road from Moose Lake station to Beaver, Aitkin county.)
Hickory P. O., sec. 26, T. 46, R. 27, Aitkin county	Gl. drift	Warren Upham. (Limestone boulders are very rare in this country.)
Shore of Sandy lake, Aitkin county, along road ½ m. south of dam	Mod. drift (Kame plateau gravel)	Warren Upham. (Forming the greater part of the gravel.)
Excavation for Sandy lake dam, Aitkin county	Mod. drift	Presented by Archibald Johnson, Superintendent of Construction. (Plentiful in a bed of sand and gravel below the level of the river.)
Mesaba station, D. & I. R. railroad, near S. E. cor. sec. 20, T. 59, R. 14	Gl. drift	Warren Upham. (Abundant in Knolly morainic drift here, and especially in belt crossed by railroad ¾-1¼ ms. S. E. of Mesaba.)
Cormorant island (3 m. N. E. of Rocky point) Lake of the Woods		J. E. Todd. No. 1.
Rocky point (near Gunderson's fishery) Lake of the Woods		J. E. Todd. No. 2.
Same locality		J. E. Todd. No. 3.
"		J. E. Todd. No. 4. (Sample of layer, vertical, 1-2 ft. thick at junction of gabbro and granite.)
"		J. E. Todd. No. 5. (Forming S. W. portion of Rocky point at Gunderson's.
Cormorant island, Lake of the Woods		J. E. Todd. No. 6.
Rapid River falls		J. E. Todd.

MUSEUM ADDITIONS

SPECIMENS REGISTERED IN THE GENERAL

Serial No.	Obtained.		Name.	Number of specimens.
	When.	Whence.		
7985	July 22,1893	Geol. Survey...	Diabase	1
7986	"	" ...	Granite, biotitic	1
7987	1893	" ...	Mica schist, with pegmatite vein	6
7988	1893	" ...	Diabase	1
7989	July15,1893	" ...	Syenite, hornblendic	2
7990	1893	" ...	Mica schist with pegmatite vein	3
7991	"	" ...	Granite and diabase in contact	4
7992	"	" ...	Dioryte with feldspar vein	7
7993	"	" ...	Mica schist	1
7994	"	" ...	Granite, gray	1
7995	"	" ...	Gneiss, coarse	1
7996	"	" ...	Diabase	1
7997	"	" ...	Greenstone from boulder	2
7998	"	" ...	Limestone from boulder	1
7999	"	" ...	Various boulders	20
8000	"	" ...	Dioryte	1
8001	"	" ...	Dioryte, coarse	1
8002	"	" ...	Dioryte	1
8003	"	" ...	Dioryte	1
8004	"	" ...	Dioryte	1
8005	"	" ...	Limestone	1
8006	"	" ...	Greenstone with rounded quartzes	1
8007	"	" ...	Granite from dike in mica schist	1
8008	"	" ...	Graphic granite	12
8009	"	" ...	Gneiss, biotitic	1
8010	"	" ...	Granite, coarse, gray	1
8011	"	" ...	Granite with pegmatite vein	3
8012	"	" ...	Biotite granite, coarse	1
8013	"	" ...	" " fine	1
8014	"	" ...	Granite, garnetiferous	1
8015	"	" ...	" coarse, greenish	2
8016	"	" ...	Quartz vein rock	3
8017	"	Donation.......	Granite	2
8018	"	"	Mica schist, reddish	4
8019	"	"	Granite, gray, medium grained	1
8020	"	"	" reddish, rather coarse	2
8021	"	"	" coarse	3
8022	"	"	" biotitic	1
8023	"	"	Mica schist	1
8024	"	"	Granite	4
8025	"	"	Mica schist	3
8026	"	"	Doryte	1
8027	"	"	Anorthosyte	1
8028	"	"	Diabase, magnetitic	1
8029	"	"	Syenite, very fine grained, porphyritic	1
8030	"	"	Graywacke	3

MINERALOGY AND LITHOLOGY.

MUSEUM SINCE THE LAST REPORT.

Locality.	Formation.	Collector and Remarks.
Big Fork river		J. E. Todd. (Locality B.)
" "		J. E. Todd. (Locality B.)
" "		J. E. Todd. (7 or 8 m. below junction of Big Fork and Sturgeon rivers.)
¼ m. E. of mouth of Rapid river.		J. E. Todd.
Rocky point, Lake of the Woods		" "
Long point, " " "		" " (Long Point is also called Elm Point.)
Lake of the Woods, S. shore		" " (Zipple's house, near mouth of Sand creek.)
" " " "		J. E. Todd. (Rock hummock 40 ft. high, ¼ m. S. W. of Zipple's, near the mouth of Sand creek or Winter Road river.)
Big Fork river, ½ m. below Sturgeon river		J. E. Todd.
Big Fork river, ½ m. below Sturgeon river		" "
Big Fork river, ½ m. below Sturgeon river		" "
Big Fork river, 4-5 m. below Sturgeon river		" " (Locality B.)
Barnesville, Minn		" "
Mississippi river, 3-4 m. below L. Bemidji		" "
N. E. of Elbow lake, E. Hubbard county	Drift	" "
Big Fork river, T. 61-26		G. E. Culver. "First exposure on Big Fork." (Note B., p. 23.)
" " "		G. E. Culver. "First exposure on Big Fork." (Note B., p. 23.)
" " "		G. E. Culver. Probably from first exposure on Big Fork. (Note B., P. 23.)
" " "		G. E. Culver. Probably from first exposure on Big Fork. (Note B., p. 23.)
" " "		G. E. Culver. Probably from first exposure on Big Fork. (Note B., p. 23.)
" " "		G. E. Culver. Vein-like in form.
Big Fork river, ½ between Rice and Deer rivers		" " (Note B., p. 28.)
Big Fork river, ½ m. below Sturgeon river		" " (Note B., p. 29.)
Big Fork river, ½ m. below Sturgeon river		" " " "
Big Fork river, 1½ m. below Sturgeon river		" " " "
Big Fork river, 10 m. below Big falls		" " " "
Between Sturgeon and BigFork rivers, 25 m. below Big falls		G. E. Culver.
" "		" "
" "		" "
Big Fork river, 25 m. below Big falls		" " (Note B., p. 40).
" "		" " (" ").
" "		" " (" ").
S. line of sec. 33, 66-21		C. L. Chase.
W. line of sec. 18, 66-21		" " Mica schist is all along the N. of the granite.
N. line of sec. 23, 66-21		" "
W. line of sec. 18, 66-21		" "
W. line (near N. edge) sec. 31, 66-21		" "
Sec. 9, 66-21		" "
" "		" " Schist is on the N. of the granite.
Sec's. 22, 23 and 24, 66-23		" " Country is full of granite ridges, with intervening swamps; the granite runs N. E. and S. W.
Sec's 22, 23 and 24, 66-23		C. L. Chase. The schist lies to the N. of the granite.
S. E. ¼ S. E. ¼ sec. 4, 56-9		" "
W. line sec. 5, 150 chs. N. of S. W. cor. T. 56-11		" " "Strike S. 70° W. Dip S. 70°".
N. line sec. 11, 56-11		" " About 5 chs. W. of river; about 25 chs. from E. corner.
S. W. ¼ S. W. ¼ sec. 15, 56-11		C. L. Chase. On river.
Sec. 20, 64-21		" "

MUSEUM ADDITIONS

SPECIMENS REGISTERED IN THE GENERAL

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens.
8031	1893	Donation.......	Gabbro...........	1
8032	"	"	Diabase, fine grained.........................	1
8033	"	"	Syenite, very fine grained, porphyritic...	2

MUSEUM ADDITIONS

SPECIMENS REGISTERED IN THE GENERAL

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens.
8442	....	Geol. Survey...	Endoceras?	?
8443	....	" ...	"	"
8444	....	" ..	"	"
8445	....	" ...	"	"
8446	July, 1891	" ...	Rhychonella neenah Whit.....	2
8450	Sept., 1893	" ...	Aristerella nitidula Ulr......................	1
8451	"	" ...	Rhipidomella missouriensis...	6
8452	"	" ...	Productella pyxidata Hall.................	18
8453	"	" ...	Chonetes geniculatus White................	11
8454	"	" ...	Cyrtina acutirostris Shumard..............	11
8455	"	" ...	Chonopterium effusum	?
8456	"	" ...	Productus sp.?	5
8457	"	" ...	Phillipsia sp.?...................................	2
8458	"	" ...	Cryptoblastus melo O. & S....................	2
8460	"	" ...	Spirifera peculiaris Shumard?...............	2
8461	"	" ...	Phillipsia sp.?...................................	2
8462	"	" ...	Platyceras sp.?	3
8463	"	" ...	Fish coprolite....	1
8464	"	" ...	Pleurotomaria sp.?...........	4
8465	"	" ...	Platyceras sp.?	1
8466	"	" ...	Zygospira? sp.?.......	14
8467	"	" ...	Cornulites carbonarius Gurley...............	1
8468	"	" ...	Palæacis enormis M. and W....................	1
8469	"	" ...	Orthothetes lens..................................	6
8470	"	" ...	Euomphalus sp. ? (young of E. latus).......	2
8471	"	" ...	Leptæna rhomboidalis..........................	3
8472	"	" ...	Zaphrentis ida A. Winchell........	2
8473	"	" ...	Strophalosia scintilla...............	1
8474	"	" ...	Orthis testudinaria Dalman...........	12
8475	"	" ...	Fish teeth, gen. ? sp. ?......	5
8476	"	" ...	Zaphrentis calceola W. and W	2
8477	"	" ...	Spirifera marionensis Shumard..............	10
8478	"	" ...	Athyris hannibalensis Swallow............	3
8479	"	" ...	Spirorbis kinderhookensis Gurley...........	1
8480	"	" ...	Terebratula burlingtonensis White.........	5
8481	"	" ...	Chonetes ornata	6
8498	Aug., 1891	" ...	Hindia sphenroidalis Duncan.......	2
8499	"	" ...	Raufella filosa Ulrich.......	1
8500	"	" ...	Ischadites iowensis Owen.....................	1
8505	"	" ...	Rafinesquina alternata Conrad.............	1
8506	"	" ...	Orthis subquadrata Hall....................	3
8507	"	" ...	Strophomena filitexta Hall..........	1
8513	"	" ...	Orthis meedsi W. and S.........................	2
8514	"	" ...	Zygospisa uphami W. and S....................	5
8515	"	" ...	Platystrophia biforata Schlot.........	2
8516	"	" ..	Orthis ? subæquata var. gibbosa Billings..	1
8517	"	" ...	Orthis testudinaria var. meeki...............	1
8518	"	" ...	Rhynchotrema inæquivalvis...................	5
8519	"	" ...	Rhynchonella increbescens Hall	2
8520	"	" ...	Orthis subæquata var. perveta Conrad....	1

MINERALOGY AND LITHOLOGY.

MUSEUM SINCE THE LAST REPORT.

LOCALITY.	Formation.	COLLECTOR AND REMARKS.
N. E. ¼ N. E. ¼ sec. 4, 55-11		C. L. Chase. No. 8032 is in a wall 30 ft. high facing N. 50° E.; slopes S. 100 paces to the level of the ground. On the N. is No. 8031, making a small ridge E. and W., separated from the last by a ravine. No. 8033 is in a vein in No. 8031.
" "		
" "		

PALEONTOLOGY.

MUSEUM SINCE THE LAST REPORT.

LOCALITY.	Formation.	COLLECTOR AND REMARKS.
Decorah, Ia	Trenton limestone	Chas. Schuchert.
Minneapolis, Minn	" "	
Decorah. Ia	" "	Chas. Schuchert.
Hader, Minn	Galena	Scofield and Schuchert.
Iron Ridge, Wis	Hudson River	Chas. Schuchert.
Chatfield, Minn	Trenton sh'l's	Presented by E. O. Ulrich. Vol. III, p. 545.
Louisiana, Mo	Lith. lim'st'ne	R. R. Rowley. By exchange.
" "	" "	" " " "
" "	" "	" " " "
" "	" "	" " " "
" "	" "	" " " "
" "	L. Burl. ch...	" " " "
" "	" ...	" " " "
" "	" ...	" " " "
" "	" ...	" " " "
" "	" ...	" " " "
" "	" ...	" " " "
" "	" ...	" " " "
" "	" ...	" " " "
" "	Lith. lim'st'ne	" " " "
" "	" "	" " " "
" "	" "	" " " "
" "	" "	" " " "
" "	" "	" " " "
" "	" "	" " " "
" "	" "	" " " "
" "	" "	" " " "
" "	" "	" " " "
Near Edgewood, Pike Co., Mo.	Clinton group	" " " "
Louisiana, Mo	?	" " " "
" "	L. Burl. chert.	" " " "
" "	Lith. lim'st'ne	" " " "
" "	" "	" " " "
" "	" "	" " " "
" "	L. Burl. chert.	" " " "
" "	Lith. lim'st'ne	" " " "
	Niagara gr.	Scofield and Schuchert.
		" "
		" "
	Hud. Riv. gr.	
	Trenton sh'l's	
	Galena shales	
	"	
	Trenton sh'l's	
	Hud. Riv. gr.	
	Galena shale.	
	Trenton shale	

MUSEUM ADDITIONS

SPECIMENS REGISTERED IN THE GENERAL

Serial No.	Obtained.		Name.	Number of specimens.
	When.	Whence.		
8540	July, 1891	Geol. Survey	Conularia quadrata Walcott	
8541	"	"	Monotrypella subquadrata	
8548	Aug., 1891	"	Endoceras sp. undet	2
8549	"	"	"	1
8550	"	"	"	1
8551	"	"	" "	1
8556	May, 1879	"	Orthis biforata Schlot	2
8560		"	Chætetes petropolitanus Pander	2
8561		"	Bucania	1
8562		"	Asaphus megistus Locke	1
8563		"	Cyclonema ventricosum Hall	2
8564		"	Chætetes corticans Nich	2
8565		"	Murchisonia gracilis Hall	1
8566		"	Chætetes delicatulus Nicholson	
8567		"	Chætetes mammulatus Ed. and H	1
8568		"	Chætetes subpulchellus Nich	1
8569		"	Heterocrinus heterodactylus Hall	1
8570		"	Cyclonema bilix Conrad	3
8571		"	Pleurotomaria umbilicata Hall	2
8572		"	Bellerophon bilobatus Sow	3
8573		"	Chætetes onealli James	9
8474		"	Conchicolites corrugatus Nich	2
8575		"	Ortonia minor Nich	1
8576		"	Orthoceras byrnesi Miller	1
8577		"	Lichenocrinus crateriformis Hall	1
8578		"	Crinoid base	2
8579		"	Orthoceras	1
8580		"	Glyptocrinus decadactylus Hall	2
8581		"	Murchisonia	2
8582		"	Murchisonia bellicincta Hall	6
8583		"	Zygospira headi Bill	1
8584		"	Palæophyllum divaricans Nich	3
8585		"	Protaræa vetusta Hall	2
8586		"	Orthoceras	3
8587		"	Ortonia minor Nich	3
8588		"	Dalmanites carleyi Meek	1
8589		"	Constellaria antheloidea Hall	4
8590		"	Cyrtolites ornatus Conrad	3
8591		"	Chætetes frondosus Nich	3
8592		"	Chætetes rugosus Hall	6
8593		"	Chætetes fletcheri E. & H.	3
8594		"	Pleurotomaria ohioensis	1
8595		"	Stomatopora arachnoidea Hall	1
8596		"	Chætetes approximatus Nicholson	7
8597		"	Chætetes jamesi Nich	5
8599		"	Orthoceras dyeri Miller	1
8600		"	Chætetes discoideus James	1
8601		"	Chætetes clathratulus J. & N	3
8602		"	Chætetes gracilis James	6
8603		"	Chætetes dalei E. & H.	3
8604		"	Heterocrinus simplex Hall	3
8605		"	Chætetes ortoni Nich	1
8606		"	Calymene senaria Conrad	1
8607		"	Raphistoma lenticulare Emmons	3
8608		"	Protaræa vetusta Hall	1
8610		"	Columnaria alveolata Gold	2
8620	Aug., 1891	"	Lingula irene Billings	
8623			Thaleops ovatus Conrad	1
8624			Toxaster comanchesi	1
8625	Jan., 1894	Wm. Johnston	Elephas primigenius (tooth)	1
8626		Geol. Survey	Vanuxemia decipiens Ulr	
8627		"	Ctenodonta socialis Ulr	
8628		"	" calvini Ulr	

PALEONTOLOGY.

MUSEUM SINCE THE LAST REPORT.

LOCALITY.	Formation.	COLLECTOR AND REMARKS.
Granger, Minn	Hud. Riv. gr.	Scofield and Schuchert.
Florence, Iowa	Cincinnati gr.	Chas. Schuchert.
Neenah, Wis	Galena	" "
Janesville, Wis	L'w'r blue b'd	" "
McGregor, Iowa	Trenton shale	" "
6 m. S. of Cannon Falls	Galena shale.	Scofield and Schuchert.
Mantorville, Minn	Galena	Chas. Schuchert.
Cincinnati, O	Hudson River	
"	" "	
"	" "	Chas. Schuchert.
"	" "	" "
"	" "	" "
Oxford, O	" "	" "
Cincinnati, O	" "	" "
"	" "	" "
"	" "	" "
"	Cincinnati gr.	" "
"	Hudson River	" "
"	" "	" "
"	" "	" "
"	" "	" "
"	" "	" "
"	" "	" "
"	" "	" "
"	" "	" "
"	" "	" "
"	" "	" "
"	" "	" "
"	" "	" "
Waynesville, O	" "	" "
Oxford, O.	" "	" "
"	" "	" "
Cincinnati, O	" "	" "
"	" "	" "
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"	" "	" "
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"	" "	" "
"	" "	" "
"	" "	" "
Oxford, O	Cincinnati gr.	" "
Graf, Iowa	" "	" "
Norwood, N. Y		" "
Minneapolis, Minn	T'nt'n limest.	
Denison		[from the Sioux river.
Lincoln Co., S. D	Drift	10 ft. below surface in gravel. 1000 ft.
Minneapolis, Minn	Lower Trenton limest.	C. L. Herrick.
Cannon Falls, Minn	Trenton sh'l's	E. O. Ulrich.
Graf, Iowa	Hud. River gr	Chas. Schuchert.

XV.

ADDITIONS TO THE LIBRARY SINCE THE REPORT FOR 1892.

The present list consists of the additions made from Dec. 1, 1893, to April 1, 1894.

A

Albany. Bull. State Museum, iii, No. 11, 1893.

B

Baltimore. Amer. Chem. Jour., xv, 7–8, 1893; xvi, 1–2, 1894.
Johns Hopkins Univ. Circulars, xiii, 108–110, 1894.

Belfast. Report and Proc. Belfast Nat. Hist. and Philosophical Soc., 1892–1893.

Berkeley. Bull. Dept. Geology Univ. of Calif , i, pp. 72–160, Dec., 1893.

Berlin. Deutschen Geologischen Gesells. Zeitschrift, xlv, No. 2, 1893.

Bern. Mitth. Naturf. Gesells., Nos. 1279–1304, 1892.

Boston. Proc. Boston Soc. Nat. Hist , xxvi, No. 1, 1892–93.

Braunschweig. Jahr. de Vereins für Naturwissenschaft, No. 7, 1889–90 and 1890–1891.

C

Cambridge. Appalachian Mountain Club, Appalachia, vii, No. 3, Mch., 1894. Register, 1894.
Peabody Acad. Science, Annual Reports, i-vi, 1869–1873.
Harvard College, Mus. Comp. Zool., Annual Rep. of Curator, 1892-93; Bull., xxv, Nos. 5–6, 1894.

Chicago. Univ. of Chicago, Jour. of Geology, i, Nos. 1–8, 1893; ii, Nos. 1–2, 1894.

Cincinnati. Jour. Cincinnati Soc. Nat. Hist., xvi, Nos. 1–4, 1893–1894.

D

Darmstadt. Mitth. Geol. Landesanstalt zu Darmstadt, i, No. 1, 1893.

Denver. Colorado Sci. Soc., ext. from Proc., 1893–1894.

Des Moines. Annual Rep. Iowa Geol. Survey, 1892.

Dresden. Jahr. des Vereins f. Erdkunde, xxiii, 1893.

E

Edinburgh. Trans. Edinburgh Geol. Soc., vi, No. 5, 1893.
Proc. Royal Soc. Edinburgh, xix, 1891–92.

G

Glasgow. Proc. Philosophical Soc. of Glasglow, xxiv, 1892-1893.
Good Hope. American Antiquarian, xv, No. 6, 1893; xvi, Nos. 1-2, 1894.
Göttingen. Konigl. Gesells. der Wissens. zu Gottingen, Nachrichten, 11-14, 1893.

H

Heidelberg. Mitth. der Geol. Landesanstalt, I Erganzung zum I Bande, 1893.

I

Iowa City. Bull. Laboratories of Nat. Hist. State Univ., ii, No. 4, 1893.

K

Kiel. University, 88 pamphlets, mostly inaugural dissertations.
Naturw. Vereins für Schleswig-Holstein, Schriften, ii, No. 2, 1877; vii, No. 2, 1891; x, No. 1, 1893.

L

Leipzig. Kong. Sach. der Wissenschaften zu Leipzig, Berichte, iv-vi, math.-phys. Classe., 1893.
Liverpool. Proc. Geol. Soc. Liverpool, vii, No. 1, 1892-93.

M

Madison. Proc. Wisconsin State Historical Society, xxi-xxxiv, 1875-1887; xli, 1893.
Meriden. Trans. Meriden Scientific Association, v, 1893.
Metz. Jahr. Vereins für Erdkunde zu Metz, xv, 1892-93.
Mexico. Memoires y Revista Sociedad Cientifica "Antonio Alzate," vii, Nos. 1-6, 1893-1894.
Milwaukee. Trans. Wisconsin Acad. Sciences, ix, No. 2, 1892-93.
Minneapolis. Agr'l Experiment Station Bulletins, xxix-xxx, Dec., 1893.
American Geologist, xiii, 1-3, 1894.
Moscow. Societé Imp. des Naturalistes de Moscou, Bulletins 1-3, 1893.
München. Bayerisches Industrie & -Gewerbeblatt, xxv, Nos. 48-52, 1893; nos. 1-6, 1894.

N

New York. American Geog. Soc. Bulletin, xxv, No. 4, pt. 1, Dec., 1893.
Memoirs Amer. Mus. Nat. Hist., i, No. 1, 1893;
Bull. Amer. Mus. Nat. Hist., v, 1893.
Annals N. Y. Acad. Sci., ii, Nos. 1-2 and 4; also 4 odd Nos., 1884-1885; viii, Nos. 1-3, 1893.
Trans. N. Y. Acad. Sci., i, Nos. 1-3, 5, 6-8, 1880-1881.
Nürnberg. Abhandlungen der Naturh. Gesell., x, No. 1, (Duplicate) 1892.

O

Ottawa. Catalogue of rocks at the Columbian Exposition, 1893.
Annual Rep. Geol. Sur. Canada, v, pts. 1-2, 1890-1891, with case of maps.

P

Paris. Soc. des Sci. Nat. de l'Ouest, Bulletin, iii, Nos. 2-3, 1893.

Philadelphia. Tenny's Geology for teachers, classes and private students, 1871.

Proc. Acad. Nat. Sci., Ser. 3, xxiii, pt. 2, 1893; Journal, Ser. 2, i-viii, 1847-1881.

American Naturalist, xxvii, Oct.-Dec., 1893; xxviii, Jan.-Mch., 1894.

Reports of Progress Geol. Sur. Pa., C. C. to Z, inclusive, 1875-1889.

R

Rio de Janiero. Archivos Museo Nacional de Rio de Janeiro, viii, 1892.

S

Sacramento. Annual Rep. State Mineralogist of California, xi, 1891-1892.

San Francisco. Proc. California Acad. of Sci., 2 Ser., iii, No. 2, 1893; occasional papers, iv, 1893.

Santiago. Actes de Société Scientifique du Chile, iii, Nos. 1-2, 1893.

St. Louis. Annual Report St. Louis Public Library, 1891-1892.

Stockholm. Handlingar der K. Svenska Vetenskaps-Akad., xiii-xvii, Nos. 2-4, 1888-1892; xviii, Nos. 2-4, 1893; also xii, Nos. 2-4, 1887.

Abhandlingar zu Sveriges Geologiska Undersokning, Ser. C., Nos. 112, 116-134, 1892-1893.

T

Tacoma. Proc. Tacoma Acad. Sci., Tacoma, Wash., "Is it Mt. Tacoma or Rainer?" Hon. Jas. Wickersham.

Topeka. Trans. Kansas Acad. of Science, xiii, 1891-1892.

Toronto. Annual Rep. Canadian Institute, v, 1892-1893.

Trans. Canadian Institute, iii, pts. 2, 6, 1893.

U

Upsala. Arsskrifpt Upsala Universitet, 1892.

W

Washington. U. S. Nat'l Museum, Bulletin No. 45, 1893; Proc. U. S. Nat'l Museum, xvi, Nos. 950-958, 963, 965, 967-974, 1893.

Smithsonian Report, 1891.

Z

Zurich. Naturf. Gesell. Neujahrsblatt, xcvi, 1894.

XVI.

THE EXHIBIT OF THE SURVEY AT THE COLUMBIAN EXPOSITION.

BY N. H. WINCHELL.

The Minnesota survey had no independent agency in the State's exhibit at the Columbian Exposition, but aided through correspondence with the state board of managers in every way that was feasible. The survey also prepared a series of typical rock samples, numbering 100, dressed to the usual museum size of 3 in. by 4 in., which were fully labelled and well shown in a suitable vertical wall case, the various specimens being secured in position by brass clamps screwed into the case so as to hold both labels and specimens in position. This suite included all the sedimentary formations, with some special phases, and most of the crystalline rocks.

The survey also exhibited twenty unpublished maps designed to show the physical features of the state. These were essentially the same series of maps as those exhibited at the New Orleans Industrial and Cotton Centennial Exposition at New Orleans in 1884, but after damage by fire at Pillsbury hall they had been redrawn, and in some particulars had been corrected in accordance with later information. The judges who examined the exhibits of the Mines and Mining building awarded a diploma to this set of rocks and maps. It is signed by George H. Williams.

At the New Orleans Exposition the Minnesota survey had a much larger exhibit. Whether any award was made for this exhibit is not known. That Exposition broke up in confusion, the committee of awards did not make known its conclusions, and the directors never carried out its determinations. The Minnesota State Commissioner's report, covering a detailed report of the operations of the Minnesota survey, and of various other departments of the state exhibit, was never published, though filed with the governor.

At the Universal Exposition at Paris, in 1889, a set of the publications of the survey was on exhibition and received a bronze medal and a diploma.

In addition to the general award as above by the judges at the Columbian Exposition, special diplomas were awarded to Mr. Warren Upham and to Mr. Louis Ogaard for expert assistance in the preparation of the survey exhibit.

After the close of the Exposition the Board of State Managers of the Columbian Exposition decided to dispose of the State's exhibit in the Mines and Mining building by depositing it in the General Museum of the University, on condition that it should be re-erected in Minneapolis in the same form as it had at Chicago. This served as a nucleus about which were gathered numerous other exhibits, donated by individuals and by State Commissioners, the whole being designed to make a large addition to the University Museum, especially illustrative of economical geology. The whole collection, after shipment to Minneapolis, was stored in the Colosseum building on the University grounds, and was almost entirely ruined when the building was destroyed recently by fire. Fortunately, however, the above series of maps had been removed to Pillsbury hall a short time before the conflagration.

INDEX.

A

B

PUBLICATIONS OF THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

I. ANNUAL REPORTS.

(Distributed by the State Geologist.)

THE FIRST ANNUAL REPORT, FOR 1872. 112 pp., 8vo.; with a colored map of the state. By *N. H. Winchell*. Published in the Regents' Report for 1872; contains a sketch of the geology of the state, as then known, and a list of earlier reports. Second edition (1884) identical.

THE SECOND ANNUAL REPORT, FOR 1873. 145 pp., 8vo.; with illustrations. By *N. H. Winchell* and *S. F. Peckham*. Published in the Regents' Report for 1873. Second edition (1893) identical.

THE THIRD ANNUAL REPORT, FOR 1874. 42 pp., 8vo,; with two county maps. By *N. H. Winchell*. Published in the Regents' Report for 1874. Second edition (1894) identical.

THE FOURTH ANNUAL REPORT, FOR 1875. 162 pp., 8vo.; with four county maps and a number of other illustrations. By *N. H. Winchell*, assisted by *M. W. Harrington*. Also in the Regents' Report for 1875. Out of print.

THE FIFTH ANNUAL REPORT, FOR 1876. 248 pp., 8vo.; four colored maps and several other illustrations. By *N. H. Winchell;* with reports on Chemistry, by *S. F. Peckham;* Ornithology, by *P. L. Hatch;* Entomology, by *Allen Whitman;* and on Fungi, by *A. E. Johnson*. Also in the Regents' Report for 1876. Out of print.

THE SIXTH ANNUAL REPORT, FOR 1877. 226 pp., 8vo.; three geological maps and several other illustrations. By *N. H. Winchell;* with reports on Chemical analyses, by *S. F. Peckham*; on Ornithology, by *P. L. Hatch;* on Entomology, by *Allen Whitman;* and on Geology of Rice county, and *L. B. Sperry*. Also in the Regents' Report for 1877. Out of print.

THE SEVENTH ANNUAL REPORT, FOR 1878. 123 pp., 8vo.; with twenty-one plates. By *N. H. Winchell;* with a field report, by *C. W. Hall;* Chemical analyses, by *S. F. Peckham;* Ornithology, by *P. L. Hatch;* a list of the plants of the north shore of lake Superior, by *B. Juni;* and an Appendix by *C. L. Herrick* on the Microscopic Entomostraca of Minnesota; twenty-one plates. Also in the Regents' Report for 1878. Out of print.

THE EIGHTH ANNUAL REPORT, FOR 1879. 183 pp., 8vo.; one plate (Castoroides). By *N. H. Winchell;* containing a statement of the Methods of Miscroscopic Lithology, a discussion of the Cupriferous Series in Minnesota, and descriptions of new species of Brachiopoda from the Trenton and Hudson River formation; with reports on the Geology of Central and Western Minnesota, by *Warren Upham;* on the Lake

Superior region, by *C. W. Hall;* lists of birds and of plants from Lake Superior, by *Thomas S. Roberts;* Chemical Analyses, by *S. F. Peckham;* Report by *P. L. Hatch;* and four Appendixes. Also in the Regents' Report for 1879 and 1880. Out of print.

THE NINTH ANNUAL REPORT, FOR 1880. 392 pp., 8vo., three appendixes, two wood cut illustrations and six plates. By *N. H. Winchell.* Containing field descriptions of 442 crystalline rock samples, and notes on their geological relations, from the northern part of the state, new Brachiopoda, the water supply of the Red River valley, and simple tests of the qualities of water; with reports: on the upper Mississippi region, by *O. E. Garrison;* on the Hydrology of Minnesota, by *C. M. Terry*; on the Glacial Drift 'and its terminal moraines, by *Warren Upham;* Chemical analysis, by *J. A. Dodge;* a list of the birds of Minnesota, by *P. L. Hatch;* and of the winter birds, by *Thomas S. Roberts.* Also in the Regents' Report for 1879 and 1880. Out of print.

THE TENTH ANNUAL REPORT, FOR 1881. 254 pp., 8vo., with ten wood cut illustrations and fifteen plates. By *N. H. Winchell.* Containing field descriptions of about four hundred rock samples, and notes on their geological relations, continued from the last report; the Potsdam sandstone; typical thin sections of the rocks of the Cupiferous series; and the deep well at the "C" Washburn mill, Minneapolis; with geological notes, by *J. H. Kloos;* Chemical analyses, by *J. A. Dodge;* and papers on the Crustacea of the fresh waters of Minnesota, eleven plates, by *C. L. Herrick.* Also in the Regents' Report for 1881 and 1882. Out of print.

THE ELEVENTH ANNUAL REPORT, FOR 1882. 219 pp., 8vo., with three wood cut illustrations and one plate. By *N. H. Winchell.* Containing a report on the Mineralogy of Minnesota, and a note on the age of the rocks of the Mesabi and Vermilion iron districts; with papers on the crystalline rocks of Minnesota, by *A. Streng* and *J. H. Kloos;* on rock outcrops in central Minnesota and on lake Agassiz, by *Warren Upham;* on the iron region of northern Minnesota, by *Albert H. Chester;* Chemical analyses, by *J. A. Dodge;* and an Appendix containing Minnesota laws relating to mines and mining, abstracted by *C. L. Herrick.* Also in the Regents' Report for 1881 and 1882.

THE TWELFTH ANNUAL REPORT, FOR 1883. Summary report, containing paleontological notes and a paper on the comparative strength of Minnesota and New England granites, twenty-six pages, by *N. H. Winchell;* final report on the Crustacea of Minnesota, included in the orders of Cladocera and Copepoda, 192 pages and 30 plates, by *C. L. Herrick;* and a catalogue of the Flora of Minnesota, 193 pages, with one map showing the forest distribution, by *Warren Upham.* Also in the Regents' Report for 1883 and 1884. Out of print.

THE THIRTEENTH ANNUAL REPORT, FOR 1884. 196 pp. Geological reconnoissances, the Vermilion iron ores, the crystalline rocks of Minnesota and of the Northwest, the Humboldt salt-well in Kittson county, records of various deep wells in the state, fossils from the red quartzyte at Pipestone, reports on the New Orleans Exposition and on the General Museum, by *N. H. Winchell;* Geology of Minnehaha county, Dakota, by *Warren Upham;* Chemical report, by *Prof. J. A. Dodge;* Minnesota geographical names derived from the

Dakota language, by *Prof. A. W. Williamson;* Insects injurious to the cabbage, by *O. W. Oestlund;* Geological notes in Blue Earth county, by *Prof. A. F. Bechdolt;* and on a fossil elephant from Stockton, by *Prof. John Holzinger;* papers on the Cretaceous fossils in the boulder clays in the Northwest, by *George M. Dawson* and by *Woodward* and *Thomas;* and notes on the Mammals of Big Stone lake and vicinity, by *C. L. Herrick.* Out of print.

THE FOURTEENTH ANNUAL REPORT, FOR 1885. 354 pp.; two plates of fossils and two wood cuts. By *N. H. Winchell.* Containing summary report, notes on some deep wells in Minnesota, descriptions of four new species of fossils, a supposed natural alloy of copper and silver from the north shore of lake Superior, and revision of the stratigraphy of the Cambrian in Minnesota, with the following papers by assistants, viz: List of the Aphididæ of Minnesota with descriptions of some new species, by *O. W. Oestlund;* Report on the Lower Silurian Bryozoa, with preliminary descriptions of some new species, by *E. O. Ulrich;* Conchological notes, by *U. S. Grant*; Bibliography of the Foraminifera, recent and fossil, by *Anthony Woodward.*

THE FIFTEENTH ANNUAL REPORT, FOR 1886. 493 pp., 8vo.; 120 diagram illustrations and sketches in the text, and two colored maps; embracing reports on observations on the crystalline rocks in the northeastern part of the state, by *Alexander Winchell, N. A. Winchell* and *H. V. Winchell*; Chemical report by *Prof. J. A. Dodge;* additional railroad elevations by *N. H. Winchell*; list of Minnesota geographical names derived from the Chippewa language, by *Rev. J. A. Gilfillan*; and notes on Illæni, describing three new species, by *Aug. F. Foerste.* Also as supplement II of the Regents' Report for 1887–1888. Out of print.

THE SIXTEENTH ANNUAL REPORT, FOR 1887. 504 pp., 8vo.; two plates and 83 other illustrations. Contains reports on the original Huronian area, the Marquette iron region, on the Gogebic and Penokee iron-bearing rocks, on the formations of northeastern Minnesota (including the physical aspects, vegetation, quadrupeds and other vertebrates), the geology of the region northwest from Vermilion lake to Rainy lake and of the Little and Big Fork rivers; also notes on the Molluscan fauna of Minnesota.

THE SEVENTEENTH ANNUAL REPORT, FOR 1888. 280 pp., 8vo.; ten text illustrations. Contains: Report of *N. H. Winchell*, the crystalline rocks of Minnesota, a general report of progress made in the study of their field relations, with a bibliography of recent works on the crystalline rocks; report of *H. V. Winchell,* field observations in the iron regions; report of *U. S. Grant,* geological observations in northeastern Minnesota.

THE EIGHTEENTH ANNUAL REPORT, FOR 1889. 234 pp., 8vo. Report of further field observations in the regions of the crystalline rocks of the state and in the area of the original Huronian, by *N. H. Winchell;* and a review of American opinion on the older rocks, by *Alexander Winchell.*

THE NINETEENTH ANNUAL REPORT, FOR 1890. 255 pp., 8vo.; with illustrations. Translation of Boricky's elements of a new Chemico-microscopic method of analysis of rocks and minerals, and of Kloos' Geognostic and Geographical observations in Minnesota in 1877, by *N. H. Winchell;* Chemical report by *Prof. Dodge;* the woods of Minnesota, by *H. B. Ayers;* Museum and library additions; List of meteorities in the museum; Petrography and geology of the Akeley lake region, *W. S. Bayley;* New Lower Silurian Lamellibranchiata, *E. O. Ulrich.*

THE TWENTIETH ANNUAL REPORT, FOR 1891. 344 pp., 8vo.; 12 plates and 33 text illustrations. Summary statement; The crystalline rocks—some preliminary considerations as to their structures and origin, by *N. H. Winchell;* Field notes in 1890, by *N. H. Winchell;* Additional rock samples to illustrate notes, by *N. H. Winchell;* Field observations on certain granitic areas in northeastern Minnesota, by *U. S. Grant;* Catalogue of rock specimens, by *U. S. Grant;* The Mesabi iron range, by *H. V. Winchell;* Sketch of the coastal topography of the north side of lake Superior, with special reference to the abandoned strands of lake Warren (the greatest of the late Quaternary lakes of North America), by *A. C. Lawson;* Diatomaceæ of Minnesota inter-Glacial peat, by *B. W. Thomas,* (with list of species and some notes upon them, by *H. L. Smith,* and directions for the preparation and mounting of Diatomaceæ, by *C. Johnson* and *H. L. Smith);* Oxide of manganese, by *N. H. Winchell;* Museum additions; Additions to the library.

THE TWENTY-FIRST ANNUAL REPORT, FOR 1892. 171 pp., 8vo.; 2 plates and 21 text illustrations. Summary statement and comparative nomenclature, with a table of the Pre-Siluran rocks of Minnesota and their equivalents; The geology of Kekequabic lake in northeastern Minnesota, with special reference to an augite soda-granite, by *U. S. Grant;* Catalogue of rock specimens, by *U. S. Grant;* Field observations in 1892, by *N. H. Winchell;* Some problems of the Mesabi iron ore, by *N. H. Winchell;* Additional rock samples to illustrate report, by *N. H. Winchell;* Additions to the library.

THE TWENTY-SECOND ANNUAL REPORT, FOR 1893 210 pp., 8vo.; 7 plates and 3 text illustrations. Summary statement; Preliminary report of field work during 1893 in northeastern Minnesota, chiefly relating to the glacial drift, by *Warren Upham;* Preliminary report of field work during 1893 in northeastern Minnesota, by *U. S. Grant;* List of rock samples collected in 1893 by *U. S. Grant;* List of rock samples collected in 1893, by *A. D. Meeds;* Preliminary report of a reconnoissance in northwestern Minnesota during 1893, by *J. E. Todd;* Notes on the geology of Itasca county, Minnesota, by *G. E. Culver;* Preliminary report of field work done in 1893, by *J. E. Spurr;* List of rock samples collected in 1893, by *J. E. Spurr;* Preliminary report of levelling party, by *C. P. Berkey;* Preliminary report of field work during 1893 in northeastern Minnesota, by *A. H. Elftman;* List of rock samples collected in 1893, by *A. H. Elftman;* Museum additions; Additions to the library since the report for 1892; The exhibit of the survey at the Columbian Exposition, by *N. H. Winchell.*

II. FINAL REPORT.

(Distributed by the State Geologist.)

THE GEOLOGY OF MINNESOTA. VOL. I OF THE FINAL REPORT. 1872—1882 xiv and 697 pp., quarto; illustrated by forty-three plates and fifty-three figures. By *N. H. Winchell;* assisted by *Warren Upham.* Containing an historical sketch of explorations and surveys in Minnesota, the general physical features of the state, the building stones and the Geology of Houston, Winona, Fillmore, Mower, Freeborn, Pipestone, Rock and Rice counties, by *N. H. Winchell;* the Geology of Olmsted, Dodge and Steele counties, by *M. W. Harrington;* and the Geology of Waseca, Blue Earth, Faribault, Watonwan, Martin, Cottonwood, Jackson, Murray, Nobles, Brown, Redwood, Yellow Medicine, Lyon, Lincoln, Big Stone, Lac qui Parle and Le Sueur counties, by *Warren Upham.* Distributed gratuitously to all public libraries and county auditors' offices in the state, to other state libraries and state universities, and to leading geologists and scientific societies; the remainder are held for sale at the cost of publication, $3.50 per copy in cloth, or $5 in grained, half roan binding, upon application to Prof. N. H. Winchell, Minneapolis.

THE GEOLOGY OF MINNESOTA. VOL. II OF THE FINAL REPORT. 1882—1885, xxiv and 695 pp., quarto; illustrated by forty-two plates and thirty-two figures. By *N. H. Winchell*, assisted by *Warren Upham.* Containing chapters on the Geology of Wabasha, Goodhue, Dakota, Hennepin, Ramsey and Washington counties, by *N. H. Winchell;* and on Carver, Scott, Sibley, Nicollet, McLeod, Renville, Swift, Chippewa, Kandiyohi, Meeker, Wright, Chisago, Isanti, Anoka, Benton, Sherburne, Stearns, Douglas, Pope, Grant, Stevens, Wilkin, Traverse, Otter Tail, Wadena, Todd, Crow Wing, Morrison, Mille Lacs, Kanabec, Pine, Becker and Clay counties, by *Warren Upham.* Distributed according to law, in the same manner as Vol. I above.

THE PALEONTOLOGY OF MINNESOTA. VOL. III OF THE FINAL REPORT. In press.

III. MISCELLANEOUS PUBLICATIONS.

(Distributed by the State Geologist.)

1. CIRCULAR NO. 1. A copy of the law ordering the survey, and a note asking the co-operation of citizens and others. 1872.
2. PEAT FOR DOMESTIC FUEL. 1874. Edited by *S. F. Peckham.*
3. REPORT OF THE SALT SPRING LANDS DUE THE STATE OF MINNESOTA. A history of all official transactions relating to them, and a statement of their amount and location. 1874. By *N. H. Winchell.*
4. A CATALOGUE OF THE PLANTS OF MINNESOTA. Prepared in 1865, by *I. A. Lapham*, contributed to the Geological and Natural History Survey of Minnesota, and published by the State Horticultural Society in 1875.
5. CIRCULAR NO. 2. Relating to botany, and giving general directions for collecting infomation on the flora of the state. 1876.
6. CIRCULAR NO. 3. The establishment and organization of the Museum. 1877.
7. CIRCULAR NO. 4. Relating to duplicates in the Museum and exchanges. 1878.
8. THE BUILDING STONES, CLAYS, LIMES, CEMENTS, ROOFING, FLAGGING AND PAVING STONES OF MINNESOTA. A special report by *N. H. Winchell.* 1880.
9. CIRCULAR NO. 5. To Builders and Quarrymen. Relating to the collection of two-inch cubes of building stones for physical tests of strength, and for chemical examination, and samples of clay and brick for the General Museum. 1880.
10. CIRCULAR NO. 6. To owners of mills and unimproved water-powers. Relating to the hydrology, and water-powers of Minnesota. 1880.

[The miscellaneous publications are mostly out of print.]

IV. BULLETINS.

(Distributed by the State Geologist, except No. 9, which is distributed by the State Botanist.)

No. 1. History of Geological Surveys in Minnesota. 8vo., pp. 37. 1889. by *N. H. Winchell.*

No. 2. Preliminary description of the Peridotytes, Gabbros, Diabases and Andesytes of Minnesota. 8vo., pp. 158; 12 colored plates. 1887. By *M. E. Wadsworth.*

No. 3. Report of work done in Botany in the year 1886—1887. 8 vo., pp. 56. By *J. C. Arthur.* Out of print.

No. 4. A Synopsis of the Aphididæ of Minnesota. 8vo., pp. 100. 1887. By *O. W. Oestlund.*

No. 5. Natural Gas in Minnesota. 8vo., pp. 39. 1889. By *N. H. Winchell.*

No. 6. The Iron Ores of Minnesota. Their geology, discovery, development, qualities and origin, and comparison with those of other iron districts, with a geological map, 26 figures and 44 plates. 8vo., pp. 430. 1891. By *N. H. Winchell* and *H. V. Winchell.*

No. 7. The Mammals of Minnesota. A scientific and popular account of their features and habits, with 23 figures and eight plates. 8vo., pp. 300. 1892. By *C. L. Herrick.*

No. 8. The Anorthosytes of the Minnesota coast of Lake Superior, by *A. C. Lawson.* The laccolitic sills of the northwest coast of Lake Superior, by *A. C. Lawson.* Prefatory note on the Norian of the Northwest, by *N. H. Winchell.* 8vo., pp. xxxiv, 48; 7 plates and 8 text illustrations. 1893.

No. 9. Part I. Prefatory note. On the occurrence of Sphagnum atolls in central Minnesota, by *Conway MacMillan.* Some extension of plant ranges, by *E. P. Sheldon.* On the nomenclature of some North American species of *Astragalus,* by *E. P. Sheldon.* List of fresh water Algæ collected in Minnesota during 1893, by *Josephine E. Tilden.* On the poisonous influence of *Cypripedium spectabile* and *Cypripedium pubescens,* by *D. T. MacDougal* 8vo., pp., 1-38, three plates. Jan. 16, 1894.

Part II. Nitrogen assimilation by *Isopyrum biternatum,* by *D. T. MacDougal.* On the morphology of hepatic elaters, with special reference to branching elaters of *Conocephalus conicus.* by *J. E. Tilden.* Revised descriptions of the Minnesota *Astragali,* by *E. P. Sheldon.* Synonymy of the North American species of *Juncodes,* with further nomenclatural notes on *Astragalus,* by *E. P. Sheldon.* Further extensions of plant ranges, by *E. P. Sheldon.* Determinations of some Minnesota lichens by *W. D. Frost.* 8vo., pp. 39-85, three plates. March 21, 1894.

Part. III. A revision of the *Mucoraceæ,* with special reference to species reported from North America, by *Roscoe Pound.* Revision of the Minnesota grasses of the tribe *Hordeæ* by *Francis Ramaley.* A perliminary list of the North American species of *Astragalus,* by *E. P. Sheldon.* 8vo., pp., 86-176. June 8, 1894.

Part IV. On a new registering balance, by *A. P. Anderson.* On a new electrical auxanometer and continuous recorder, by *W. D. Frost.* Titles of literature concerning the fixation of free nitrogen by plants, by *D. T. MacDougal.* 8vo. pp. 177-222, four plates. Sept. 27, 1894.

No. 10. The Iron-Bearing Rocks of the Mesabi Range in Minnesota. With 22 figures and 12 plates. 8vo., p. viii, 268. 1894. by *J. Edward Spurr.*

V. BOTANICAL SERIES.

(Distributed by the State Botanist.)

The Metaspermæ of the Minnesota Valley, a list of the higher seed-producing plants indigenous to the drainage basin of the Minnesota river, by *Conway MacMillan.* 8vo., pp. 826. 1892.

VI. ZOOLOGICAL SERIES.

(Distributed by the State Zoologist.)

First Report of the State Zoologist, accompanied with notes on the birds of Minnesota, by *P. L. Hatch.* 8vo., pp. 387. 1892.

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