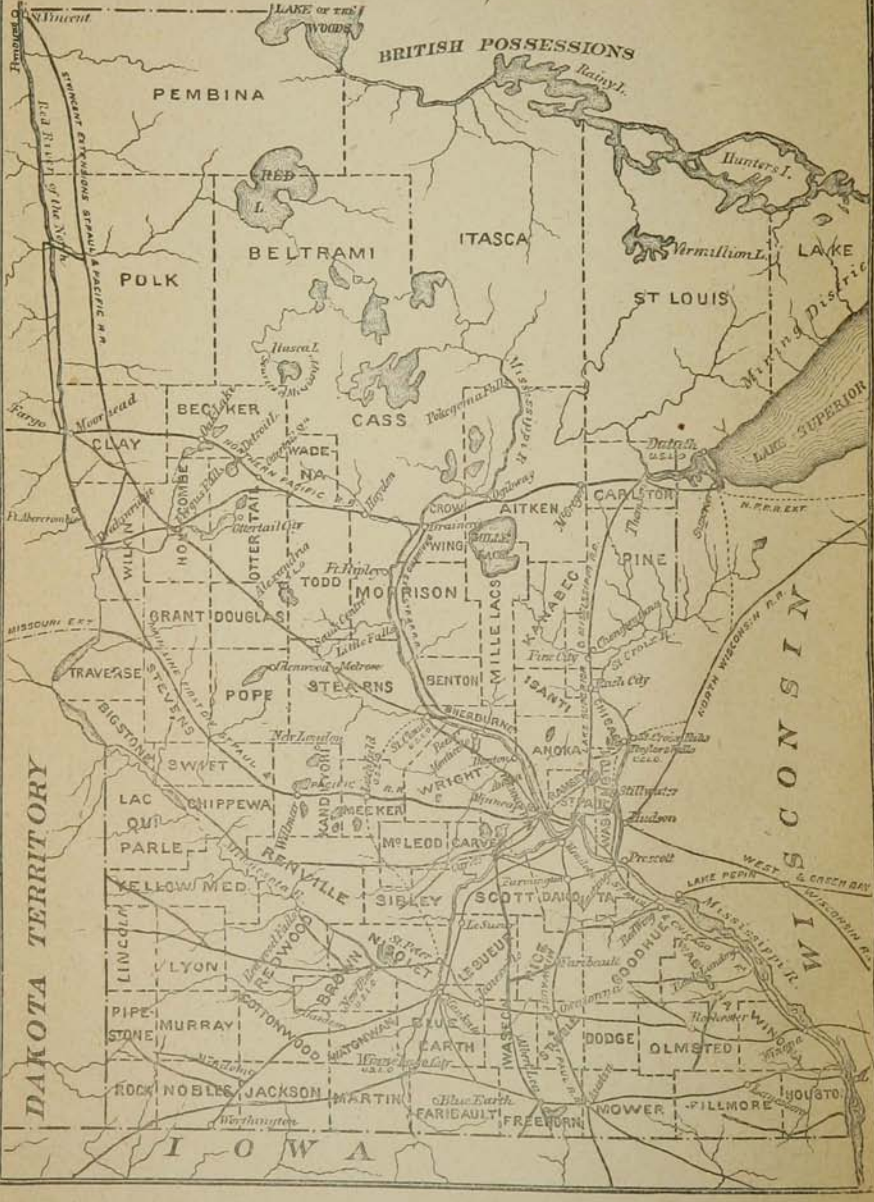
MAP OF MINNESOTA.

Showing the Location of the Counties.

Total area 84,286 square miles.



THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

THE ELEVENTH ANNUAL REPORT,

FOR THE YEAR 1882.

N. H. WINCHELL, STATE GEOLOGIST.

Submitted to the President of the University May 21, 1883.

MINNEAPOLIS:
JOHNSON, SMITH & HARRISON.
1884.

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ADDRESS.

To the President of the University:

I present herewith the eleventh annual report on the progress of the geological and natural history survey of the state. In the year 1882 the only field-work done was that performed by myself in the counties of Winona, Wabasha and Dakota, and the report thereon will be included in the first volume of the final report, now in press. The accompanying report embraces important matters coming within the purview of the survey in the northern part of the state, that have as yet only partially been worked up, and hence does not really embody the work of the year in full, a considerable portion of which has been devoted to maps and manuscripts on the southern and western counties.

Respectfully submitted,

N. H. WINCHELL,

State geologist and curator of the general museum.

MAY 21, 1883.

REPORT.

I.

THE MINERALOGY OF MINNESOTA.

[A report read before the Minnesota Academy of Natural Sciences, October, 1882.]

By N. H. WINCHELL.

During the year no special effort has been made to further a knowledge of the mineralogy of the state by this committee. But some advance has been made by the publication of work that had been done before by others. The committee has not had any meetings. This is partly due to the absence of the chairman, and partly to his neglect when not absent. The section consists of N. H. Winchell, T. B. Walker, A. F. Elliot, C. W. Hall, J. A. Dodge, A. H. Pearson, N. Butler, R. J. Baldwin and M. A. Morey.

In the inception of any systematic and thorough work on the mineralogy of Minnesota it is obvious that the first thing to do is to find out what has been done already. It is the object of this paper to accomplish that for the Academy. In other words this paper begins with a reference to publications on the minerals of the state so far as they can now be ascertained — a kind of *bibliography of the mineralogy of Minnesota* — and ends with an enumeration of such minerals as are known to occur in the state, and a statement of their localities, with notes on their characters and peculiarities.

Bibliography of the mineralogy of Minnesota.

The earliest mention of any minerals in Minnesota is to be found in the Relations of the Jesuit missionaries. The pious and venturesome fathers occasionally mention metallic copper in possession of the Indians, and in some cases attempt to give some idea of the whereabouts of the mines from which it was obtained, but their statements are of little scientific value. La Harpe's "History of Louisiana" mentions that Le Sueur saw a large mass of native copper near the mouth of a small lake at a point four leagues above the mouth of the St. Croix river. One of the early maps locates a coal mine on the Minnesota river some distance above its mouth. Le Sueur's fanciful copper-mining took place in 1700 and 1701 and was located at fort L'Huillier, near the mouth of the Blue Earth river. Carver in his "Travels" first alludes to the "red marble," of which the Indians made their calumets, now known as *catlinite*, and to various black, white and blue clays found in the same part of Minnesota.

Prof. Wm. Keating, however, in 1823 seems to have been the first to have identified any minerals by recognized and accepted scientific terms within the limits of Minnesota. This was during his expedition with major Stephen H. Long to the "source of the St. Peter's river and to lake Winnipeek," wherein he acted as geologist, mineralogist and general chronicler. It is true that major Long in 1817 in his narrative of a "Voyage in a six-oared skiff to the falls of St. Anthony" had enumerated sundry brilliant pebbles which he had gathered on the summit of Gwinn's bluff, in Winona county, saying they consisted of "*crystals of iron ore*, *siliceous crystallizations* beautifully tinged with iron, some of them purple, others reddish, yellow, white etc., crusts of sandstone strongly cemented with iron, and I think set with *solid crystals of quartz*;" and again at a point a few miles below the mouth of the St. Croix he mentions a bluff which he ascended on the slopes of which he observed a variety of pebbles and stones amongst which were the *agate* of various hues, *chalcedony*, *flint*, *serpentine*, *ruby* and *rock crystals*, etc.; but as major Long was not a mineralogist while Keating was, it will do Long no injustice to accredit the first accurate mineralogical observations to Keating.

His first observations were on the sands that compose the banks of the Mississippi below St. Paul (vol. 1, p. 304). He remarks that in these sands sometimes are found "carnelians, agates, jaspers, etc., which present characteristics analogous to those observed

on the Rhine below Oberstein, and in Scotland where they are distinguished by the name of Scotch pebbles."

* * * * "In one or two instances while examining the sand with a miscroscope, a white transparent topaz with its dihedral summit, could be well made out."

At the mouth of the Redwood river, Keating enumerates *quartz*, *feldspar*, *mica* and *amphibole*, and dwells on the great variety of combinations which they assume in the primitive rocks there *in situ*. At the lake of the Woods he mentions *iron pyrites* and veins of quartz; and on the authority of Dr. Bigsby, staurolite is said to occur in the slates of Rainy Lake river.

Mr. Featherstonhaugh mentions galena not far from Red Wing; salt springs east of the Pembina hills; and bituminous coal at lake Traverse.

Mr. George Catlin, whose work on Indian costumes and manners is well known, visited the famed red pipestone quarry in 1836, and was the first to procure and bring away for chemical examination a piece of the pipestone. This he submitted to Prof C. T. Jackson, of Boston, who gave it the name of *catlinite*, though Gen. H. H. Sibley insists that the Indian name (e-yan-shah) should be preserved. (Journal of the council of Minnesota 1849, p. 30.) The paper of Mr. Catlin is published in the American Journal, (1) XXXVIII, though it was read before the Boston Society of Natural History, Sept. 4th, 1839. Dr. Jackson's analysis is in the 35th vol. of the American Journal, p. 388. Of this pipestone the following analyses by Prof. Peckham have been published in the *sixth annual report of the geological and natural history survey of Minnesota*, p. 101.

	Silica	Alumina	Iron	Manganese	Magnesia	Lime	Alkalies	Water
Jackson,	48.20	28.20	5.00	0.60	6.00	2.60		8.40
Peckham, (light-colored)	58.25	35.90	trace	—	—	—		6.48
Peckham, (red)	57.43	25 94	8.70	—	trace	trace		7 44

The geological survey of Wisconsin, Iowa and Minnesota, by Dr. D. D. Owen, added largely to the accurate mineralogy of the state of Minnesota. This was carried on from 1847 to 1850. As we shall have occasion to refer considerably to this in the enumeration of the minerals of the state, as well as to some of the following publications, it is sufficient here simply to name them.

In Schoolcraft's volume giving an account of the final discovery of the source of the Mississippi in 1831 and 1832 is a short list by Mr. Schoolcraft of localities of minerals observed in the Northwest in 1831 and 1832. Among these localities are named the following in Minnesota:

Calcareous tufa in the gorge below the falls of St. Anthony.

Granular quartz, falls of Pokegama, upper Mississippi.

Agate, imbedded in trap-rocks of lake Superior.

Hornblende, as a constituent of the primitive rocks of the upper Mississippi.

Argillite, St. Louis river.

In Schoolcraft's volume entitled "Summary narrative of the discovery of the sources of the Mississippi," published in 1854, by Lippincott, of Philadelphia, may be found a report (p. 356) by Mr. Schoolcraft, to John C. Calhoun, secretary of war, on the geology and mineralogy of the region of the upper Mississippi, bearing date 1822. This report seems to have been published first in 1854. In giving a description of the pipestone, now generally known as *catlinite*, he applies the true mineral name *opwagonite*, saying it is the Algonquin word for calumet-stone or pipe-stone. Realizing that this Algonquin word is more appropriate than that applied by Dr. Jackson, and supposing that Schoolcraft's references would bear out his implied earlier use of this designation, I took the trouble to consult his earlier reports to which he refers with a view to the adoption of Schoolcraft's name should it prove to have antedated the word *catlinite*. But it was found that in his "View of the lead mines of Missouri," published in 1819, to which he refers, he does not make use of that designation, and is so far ignorant of the origin of the substance as to assign it to the Falls of St. Anthony. Again, when in 1820 he visited the falls of St. Anthony, he corrects, it is true, his statement that it is found here, and assigns it to the coteau des prairies, but still does not employ the term *opwagonite* in the report of that expedition, published under the title, *Narrative-journal of travels from Detroit northwest through the great chain of lakes to the source of the Mississippi river in 1820*, as a member of the expedition under governor Lewis Cass. It seems to be necessary, therefore, to conclude that Schoolcraft invented the word in 1854, and published it as if applied in 1822. If Mr. Schoolcraft made such a mineralogical report to Mr. Calhoun in 1822, it is remarkable that it was not

published, nor referred to by him in his volume on the discovery of lake Itasca, published in 1834 by Harper & Bros.

Mr. Schoolcraft, in 1854, also enumerates the following minerals and mineral localities in Minnesota:

Iron-sand, on the shores of Fond du Lac, lake Superior.

Micaceous ioxide of iron, among the debris of the St. Louis river, and of Fond du Lac.

Ochery red oxide of iron, "Is produced near the spot called Big Stone lake on the head of the St. Peter's river." It was employed as a pigment by the Indians.

Quartz is mentioned in various forms:

Arenaceous, the sandrock of many localities.

Pseudomorphous, shores of lake Pepin; having taken the crystalline impress and form of rhombohedral crystals of carbonate of lime.

Chcalcedony, shores of lake Pepin.

Carnelian, shores of the upper Mississippi.

Agate, shores of the upper Mississippi.

Basanite, (touchstone) along the banks of the upper Mississippi.

Mica,—in minute foliæ—in alluvial soil of the upper Mississippi.

Hornblende, at the "peace rock" on the upper Mississippi.

[This is in section 27, Watab.—N. H. W.]

Granular graphite, in a small vein in the clay slate of the St. Louis river, at the head of the nine-mile portage. It is coarse-grained and gritty.

Besides an occasional mention of native copper, gold, magnetic iron ore, coal and argentiferous galena, in the reports of the early so-called surveys of the state and territory of Minnesota, most of which are exaggerated for ambitious and speculative purposes, but little is added, in these reports, to the mineralogy of the state. Their authority and much of their material are taken from Owen's earlier *Report on the Geology of Wisconsin, Iowa and Minnesota.*

They may be enumerated, however, in the bibliography of the state; viz, *Report on Geology*, No. 12 of the legislative documents of 1861, Anderson & Clark. 26 pp., 8 vo.

Report of Hanchett and Clark on the geology and physical geography of the northwestern district of Minnesota. 1865, 82 pp., 8vo.

Report of H. H. Eames on the metallifereous region bordering on lake Superior. 1865, 23 pp., 8vo.

Geological reconnoissance of the northern, middle and other counties of Minnesota, by H. H. Eames. 1866, 58 pp., 8vo.

Geology and Minerals. Report of explorations in the mineral regions of Minnesota, in the years 1848, 1859 and 1864, by Col. Charles Whittlesey. 1866, 54 pp., 8vo. This phamphlet is more valuable for its geology than its mineralogy. Its errors are numerous, among which may be mentioned its identification of prehnite at French river with quartz, and of labradorite feldspar at Split-rock river with quartz. The summit of Carlton's peak is said to consist of gray quartz.

The following statement is quoted from this pamphlet, p. 41: "In the spring of 1858 a boulder was found on the north shore of the St. Louis river, at Rice's point below Oneota, having a metallic appearance, with a pale brass color, and which weighed about 100 pounds. Various accounts have been current as to the locality of this mass. Mr. R. B. Carlton said it was found by Joe Pose soon after the spring freshet, in the sand at the place just named. In size it is about a foot long, with two faces nearly parallel, as though it came from a vein with regular walls, four or five inches wide. Some persons regarded it as an artificial alloy of zinc and copper, which had been produced by melting a church bell. It is broken with difficulty, and in the interior has patches of a greenish tinge. The mass has a whitish-yellow color, a pyritous aspect, finely crystallized with small blotches of spar, showing it to be not an artificial compound. As I was sending a box of minerals to my friend, J. H. Boalt, Esq., of the School of Mines at Freyburg, in Germany, a piece of this boulder was forwarded, with the request that it should be analyzed. The arsenides of copper were then unknown on lake Superior, but I have since seen a specimen from Portage lake. Mr. Boalt reported that about the time of the arrival of my specimen, another was received from Chili, in South America. All parties were interested to know what ore of copper they represented. The analysis gave 83 per cent. of metallic copper and 17 of arseni', which approaches very near to the rare mineral, *algodonite* of Dana. The boulder, no doubt, came with the drift materials from the northeast, and represents a vein somewhere in that direction, perhaps not far distant."

In the *Minnesota Teacher* for June and July, 1871, Mr. J. H. Kloos has papers on *Geological rambles in Minnesota*, in which are found some discriminating remarks on the minerals constituting the crystalline rocks near Duluth. He mentions:—

Labradorite,
Diallage or hypersthene, or augite,
Magnetite,
Epidote,
Calcite,
Laumontite,
Chlorite,
Quartz,
Copper.

At Taylor's Falls he enumerates:—
Hornblende,
A transparent mineral of the color of chrysolite,
Labradorite,
Copper,
Dolomite,
Quartz,
Calcite,
Copper glance,
Earthy malachite.

In the syenites of the St. Cloud region he also enumerates the minerals which he expects to find on making a careful chemical and mineralogical examination, viz:

Orthoclase,
A triclinic feldspar,
Pyroxene,
Labradorite,
Anorthite,
Hyperite,
Hornblende,
Mica,
Protobarite,
Pyrite,
Quartz.

Mr. Kloos collected samples of some of the crystalline rocks, which he took to Germany. These were the subject of a series of papers by Streng and Kloos in the *Neues Jahrbuch fur Mineralogie* (Geol. u. Pal.) 1877. Mr. Kloos repeated his general observations, and extended them, in a paper published in 1871 in the *Zeitschrift d. d. geol. Gesell.*, p. 425.*

*A translation of the latter may be seen in the tenth annual report of the survey, 1881.

Minerals and mineral localities in Minnesota.

NATIVE ELEMENTS.

GOLD.

Gold has been washed from the drift in noticeable quantities in various places in the state, particularly at Rochester, Oronoco, Spring Valley, sec. 31, Jordan, Fillmore county, and at several points in Wabasha county. As an ingredient of the bedded rocks it has been sought in the chloritic slates at Vermilion lake as reported by Mr. Eames in 1865, and somewhat in the same formation west of Moose Lake station in Carlton county. In these examinations, the former of which induced a general movement of miners and other hasty speculators to Vermilion lake, some gold may have been found if the assays published in Mr. Eames' report be true. Recent assays, however, do not give gold in any appreciable amount from the Vermilion quartz rocks nor from the slates containing the quartz veins.

Gold has lately been taken from the gravel at Willmar, as reported. The pieces are angular and appear to have been recently cut by some sharp instrument, indicating an artificial sprinkling in the naturally rounded gravel. It is 91 per cent. pure gold, the rest being copper. Gold is also found in the quartz veins of Rainy lake, but the shafts sunk have all been on Canadian territory, so far as I am informed.

SILVER.

Silver occurs native in the quartz veins of the slates in the northeastern part of the state, but no valuable deposits within Minnesota have yet been brought to light. This is the same formation that is wrought at Silver Islet and Thunder bay in Canada. Its most abundant occurrence is in the form of argentiferous galena. Several late enterprises have begun operations in the islands between Thunder bay and Pigeon river and one also is started on one of the islands south of Pigeon point, in Minnesota. Some of the float pieces of copper found in the central and northern part of the state also show small quantities of silver. The assays of the Vermilion gold ores reported by Mr. Eames show a small percentage of silver.

COPPER.

Copper has been mined at French river, at Snake river, at Sucker river, at Fall river, at Taylor's Falls, Chengwatana, and at several

other points. At French river it occurs with prehnite and is occasionally associated with small quantities of native silver. This metal is disseminated in nodules and other vein-fillings throughout much of the trap-rock of the region, but is at the same time principally aggregated in one or two metalliferous beds, or belts; a shaft that penetrated 43 feet revealing two such beds. Pieces weighing several pounds have been taken from this shaft. At Chengwatana it has been sought by shafting in the trap and amygdaloids. Small particles have been found in the mineral thomsonite, which fills amygdaloidal cavities in the trap at Good Harbor.

Pieces of native copper of considerable size are occasionally found distributed through the drift in the central and southern parts of the state. Mr. T. Elwell, of Granite City, Morrison county, reports fifty-six pieces found in that vicinity, and transmitted to St. Paul, in 1861, by Hon. Levi Wheeler, representative from the third district. Several pieces have been found at Minneapolis and others at St. Paul. Numerous pieces have been found in the valley of the St. Croix; other localities are Rochester, Zumbrota, White Bear Lake, and along the Mississippi below St. Paul. Le Sueur is reported by La Harpe to have seen a large mass of native copper at a point four leagues above the mouth of the St. Croix river, near the mouth of a small lake. Several hundred pounds of float copper were found between the Northern Pacific Junction and Knife Falls, during the construction of the Knife Falls railroad. These pieces lay usually among stones on the surface, and were probably derived from the general drift-sheet that may be supposed to have covered the region, the railroad following the ancient valley of the St. Louis all the way.

IRON.

No well authenticated instance of native iron in Minnesota is known, though such has been reported from St. Paul. It is true that grains of metallic iron are found in the drillings of the well near the Harvester Works. These certainly are not natural. They have the form of iron cuttings and drillings artificially made and on being allowed to remain among the rock drillings become rusty immediately, cementing the rock grains in small rusty clusters. Their chemical composition also indicates that they are not natural.

GRAPHITE.

This is found in considerable quantities at Pigeon point. It is disseminated in lumps through a metamorphic sandrock. The lumps vary from the size of a pin-head to flattened masses six or eight inches in diameter. The sandrock sometimes becomes gneissic and is of the same formation as that which holds the silver mines of Thunder bay, and of Silver Islet. Graphite also exists in a vein about a foot thick a short distance above Thomson, at the head of the nine-mile portage. Schoolcraft says it is coarse-grained and gritty.

SIMPLE SULPHIDES, &c.

ALGODONITE.

This arsenide of copper was found in a large transported mass in 1858 on the shore of the St. Louis river near Rice's point. The piece was about a foot long, with two faces nearly parallel, although it came from a vein with regular walls four or five inches thick. It was reported to have been analyzed by J. H. Boalt of the School of Mines at Freiberg, Germany, and was found to afford 83 per cent of metallic copper with 17 per cent of arsenic.

WHITNEYITE.

On the authority of Mr. Dana, the large mass of algodonite last mentioned was stated to be partly made up of *whitneyite*, which is a compound of copper and arsenic, but having less arsenic than algodonite.

GALENITE.

This sulphide of lead is common in the state. It has been found almost invariably in the trial shafts for silver in the lake Superior region. It is associated with calcite, barite, pyrite and quartz. It is also found in limited quantities in the Galena limestone in the southern part of the state and in the St. Lawrence and St. Croix formations at Dresbach in Winona county. In the St. Croix sandstone at Dresbach it is found as a matrix which cements considerable masses of rock that is made up of sand grains and linguloid shells. In that form it has been taken out of a shaft about 20 feet below the level of the Mississippi river.

BORNITE.

This is probably the ore found by shafting, about 3 miles west of the mouth of Cascade river, lake Superior, and on the island south of Pigeon point. It also occurs in a dark bed of metamorphic conglomerate, about 6 feet thick, at London, near Duluth.

SPHALERITE.

This sulphide of zinc is common in the shafts sunk for silver in the slate and quartzyte group at Pigeon point and along the international boundary. It is also reported from Stillwater.

CHALCOCITE.

In a vein near the water level at St. Croix Falls, opposite Taylor's Falls.

PYRITE.

A common mineral. It occurs in all mines, and as nodules in most of the rocks of the state. It is found in the common building-stone (Trenton) at Minneapolis, as little shining yellow specks, and in the Cretaceous shales in the western part of the state. Sometimes it weathers out of the latter and is found on the sloping bluffs where these shales outcrop. It is also common in the blue drift-clay or hard-pan of the western part of the state, derived originally from the Cretaceous, and in that situation it retains its metallic lustre unchanged, affording frequent clusters of crystals that are quite beautiful. In some cases it seems to be indigenous in the drift-clay, in the same manner as selenite crystals.

CHALCOPYRITE.

Common in the shafts sunk in the cupriferous rocks in the northern part of the state—as well as in the slate and quartzyte group of Pigeon point.

MARCASITE.

Very common in the southeastern part of the state, where it accompanies the Cambrian limestones. It is found in lumps, partly altered to limonite, on the tops of the bluffs in that part of the state, along the river valleys. It is evidently the result of denudation from some higher strata.

COMPOUNDS OF CHLORINE.

HALITE.

The only evidence of this mineral in Minnesota is the occurrence of saline springs, and of artesian salt water in the northwestern part of the state. The most noteworthy instance is the deep well at St. Vincent, where, however, the brine contains also some lime and some magnesia.

COMPOUNDS OF FLUORINE.

FLUORITE.

This occurs in small quantities at Lester river, on the north shore of lake Superior, and in much larger quantities in some of the veins that have been explored for silver in the northeastern part of the state.

COMPOUNDS OF OXYGEN.

CUPRITE.

This mineral was observed, mingled with malachite, coating a piece of metallic copper which was found on the surface or among the drift materials, near Rochester. It doubtless also exists in varying quantities wherever metallic copper is found in the rocks of the state.

WATER.

Within the state there is a superficies of 5,637 square miles of water; and at Minneapolis the average flow of the Mississippi is 25,000 cubic feet per second. The average rainfall at Minneapolis is about 29 inches.

HÆMATITE.

This exists in large quantities in the vicinity of Vermilion lake and in the Mesabi range. It also occurs as a red, ocherous deposit in numerous places. It has been employed as a pigment by the Indians, who obtained it at Big Stone lake, at Grand Portage, lake Superior, and in the valley of the Blue Earth river.

MAGNETITE.

This is found in large quantities in the northeastern part of the state. It is apt to bear titanium, but when found in large strata in the Huronian formation, it is wholly, or nearly free from it. It occurs also at Rainy lake.

MENACCANITE.

This seems to be the principal magnetic mineral which enters nto the gabbro and other igneous rocks of the Cupriferous in Minnesota. It is so abundant in the region of Iron lake, north of Grand Marais, and at Herman, near Duluth, that it has attracted attention as an iron ore. The titanium present is frequently not enough to constitute this mineral, which requires from 30 to 40 per cent. It is sometimes as low as three per cent., the mineral then being rather titaniferous magnetite. As iron-sand it gathers on the lake Superior shore at Black beach, about four miles west of Beaver Bay, and can be extracted from the gravel with a magnet in nearly all parts of the state.

LIMONITE.

This ore of iron is frequently found pseudomorphous after pyrite and marcasite. This is particularly the case in the changed marcasite found in the southeastern part of the state. As a bog-ore it is found frequently, and it often stains the earth and the peat about lakes and stagnant pools, when it cannot, from its impurity, be styled correctly *limonite*. It is found as a bog-ore in considerable quantities near Coon creek, in Anoka county.

OXIDES OF THE CARBON-SILICON GROUP.

QUARTZ.

This most common of all minerals exhibits itself in nearly all its forms in Minnesota. Its most remarkable and pure deposits are seen in the St. Peter and St. Croix sandstones with which all geologists are familiar, in the bluffs of the Mississippi river and its tributaries, where it constitutes 98 per cent. of the rock. As agate, carnelian and chalcedony, it exists in the trap-rocks in the northeastern part of the state, and is distributed in the gravel throughout the eastern half of the state. Agate bay is so named from the

great numbers of pebbles of agate that are found on its beach. But they are equally numerous in other places. Many may be found at Burlington bay and at the point next west of Knife island. As chalcedony it weathers out of the trap at Gooseberry river, and in the drift of the western part of the state it is in that form from fossil wood derived from the Cretaceous. It is less commonly found as amethyst in the Cupriferous, the only locality known in Minnesota, being on a small island a short distance east of Gooseberry river. Amethyst also occurs sometimes in the siliceous geodes of the Shakopee and St. Lawrence dolomites. As heliotrope or bloodstone, very fine specimens are sometimes found, but the prevailing color is brownish or black, rather than green. Moss-agate, which seems to come from agatized wood, is more common in the western part of the state, referable to the Cretaceous or Tertiary debris. Flint, hornstone, basanite, touchstone, red, brown and black jasper, as well as jasperoid hæmatite with beautiful banding, are common as pebbles throughout the state, particularly the eastern half. Agates and carnelians are so abundant that they are largely represented in every amateur collection, and thousands of specimens have been carried from the state. The amethysts that are sold so abundantly at Duluth are from Thunder bay, 150 miles further east on the north shore. Quartz occurs in perfect crystals in the quartz-porphyries on the north shore of lake Superior, in Minnesota, and in the form of prase it is found on the beach among the pebbles.

ANHYDROUS SILICATES.

HYPERSTHENE

Is a constituent of the rock at Black beach about four miles west of Beaver bay. Although this is the only point at which this silicate has been reported, though here subject to correction by more careful examination, it is probable that it occurs largely in the rocks of the north shore of lake Superior. It may be confounded with bronzite, since they show the same kind of metalloidal surfaces which glitter like mica in the sunlight. It has the same crystallization also.

BRONZITE (ENSTATITE.)

The rock composing Encampment island on the north shore of lake Superior has a metalloidal augite as an important constituent,

which is thought to be enstatite. It has, however, been examined only microscopically, and is subject to further analysis.

WOLLASTONITE.

A radiated white fibrous mineral from Scoville's point, Isle Royale, weathering from the trap of the region, is believed to be wollastonite, but the samples gathered have not been examined carefully. The same may be looked for in Minnesota between Grand Portage and Grand Marais, judging from the strike of the strata.

PYROXENE.

The only form of pyroxene within the state that has been identified is the variety known as augite; and much of that belongs to the sub-variety diallage. It comprises a large constituent of the igneous rocks of the cupriferous, and is disseminated from Chengwatana to Pigeon point. The regular form of pyroxene seems to pervade the rock known as trap-rock at Taylor's Falls, but that is also subject to further examination.

SPODUMENE.

This may be doubtfully named as a Minnesota mineral from the Mesabi range.

AMPHIBOLE.

Under this name are included all the varieties of hornblende found in the syenites and crystalline schists of the state. This is a very common mineral. It is found in the St. Cloud and Sauk Rapids syenites, in the syenite near Duluth, and in the same formation back of Grand Marais. It is abundant in a rock at West Gull lake, near Saganaga, where it is associated with quartz and a little plagioclase so as to constitute a rock styled amphibolyte. The same rock spreads widely west of that point. Actinolite appears as a microscopic mineral in many thin-sections from the rocks of Minnesota. Both actinolite and tremolite are reported from Rainy lake by Dr. Bigsby.

CHRYSOLITE.

This mineral, which is common in the igneous rocks of the cupriferous series, as one of their constituents, sometimes makes,

nearly alone, the entire rock. Such is the case in a rock on the iron trail north from Grand Marais, about half way between Little Trout lake and Brule river. (Sur. No. 677.)

GARNET.

Small garnets occur abundantly in the schists at Little Falls. Larger ones are in the same rock at Pike rapids, associated with staurolite. These are of the usual dark cinnamon color. But at Duluth in some of the metamorphic strata of the cupriferous is a wavy, honey-yellow garnet, pierced with microscopic actinolite. This is in small quantities in laminations in a metamorphic shale. (18 A.) Garnet occurs also at Rainy lake.

EPIDOTE.

A common mineral in the cupriferous rocks of lake Superior. It is known at Duluth, at Taylor's Falls, and abundantly on Isle Royale.

BIOTITE.

This is a common mineral in the syenites at St. Cloud, and as a microscopic mineral in the rocks of the cupriferous.

MUSCOVITE.

This is probably the mica that is mingled with the schists at Little Falls and at Thomson; and forms a constituent of most of the granites of the state. It is disseminated also through some of the sandstones, particularly the lower portions of the St. Croix at Dresbach. Along the northern boundary at Rainy lake and at lake of the Woods it has been seen in large foliæ.

WERNERITE.

This is found in the trap at the Island mine, Isle Royale, and doubtfully identified on the north shore of lake Superior at Lover's bay, in Minnesota. The form glaucolite is found also at the same place on Isle Royale.

ANORTHITE.

This accompanies orthoclase in the porphyries at Duluth and at Taylor's Falls.

LABRADORITE.

This the chief constituent of the Rice point gabbro, and of the range of hills that passes behind Duluth, and reaches to the international boundary. It forms the rock of Carlton's peak. It is embraced in basaltic trap at Split Rock point as transported light-colored boulders, making a curious pudding-stone. It occurs beautifully in large masses at Beaver Bay and constitutes low hills near the lake shore a few miles east of Beaver Bay. In some of these cases this mineral is nearly pure and makes up the whole rock. It does not, however, exhibit the internal opalescence, generally, which characterizes it in Labrador, and in Lewis county, New York. It is the chief feldspathic ingredient in the igneous rocks of the Cupriferous series.

ANDESITE.

This mineral occurs at Duluth, in the porphyries of the cupriferous.

ORTHOCLASE.

This is found abundantly disseminated porphyritically in the rocks at Duluth, and in the porphyry at Taylor's Falls, and is an essential ingredient in the granites everywhere in the state,—particularly those having a red color. It is perhaps as often found uniting with hornblende forming syenite, as with mica forming granite. It fills amygdaloidal cavities at Chester creek on the beach of lake Superior.

OLIGOCLASE.

This feldspar is found in an augitic quartz-dioryte at Watab, and in the syenitic granite at Sauk Rapids.

ALBITE.

It is disseminated porphyritically in some of the schists of the Huronian in the region about Vermilion lake, and is found also in

the granite at Watab. A large boulder of chloritic schist, having crystals of albite $\frac{3}{4}$ inch across, was found by Dr. Elliot near lake Calhoun.

TOPAZ.

Occasionally occurs in the sand of the drift along the Mississippi below St. Paul.

DATOLITE.

Is found on Isle Royale, in the trap rocks, and is likely to be found in Minnesota, but has not yet been certainly identified.

STAUROLITE.

Is found in the mica schist at Pike rapids on the Mississippi, and at lake of the Woods in a similar rock, associated with garnet. At the former place the crystals are frequently twinned, at least crossed so as to make symmetrical cruciform figures, and some are attached obliquely. The schist disintegrates easily, allowing the crystals to mingle with the gravel where they are found sometimes in most perfect form and preservation.

HYDROUS SILICATES.

PECTOLITE.

Fine specimens of pectolite occur on Isle Royale, but it has not yet been identified with certainty in Minnesota.

LAUMONTITE.

This crumbling, flesh-colored mineral is very abundant in the Cupriferous rocks. It is not only found in the red amygdaloids, (or pseudo-amygdaloids) in which it pervades beds that reach a thickness of 1 to 15 feet, but is also found more sparsely disseminated in the amygdaloids of the trap itself. Its rapid disintegration when exposed to the weather is the first and most efficient cause of the many purgatories and arched rocks that beautify the scenery of the north shore of lake Superior. It is disseminated in these crumbling beds through a shaly rock of a red color, which often presents the characters of sedimentation, and even among the red conglomerates of the Cupriferous; these sedimentary beds showing fucoidal fossils.

CHRYSOCOLLA.

This occurs occasionally on the north shore of lake Superior and in the Cupriferous rocks of Pine county. It is generally associated with chalcopyrite.

PREHNITE.

At French river, containing native copper. It is here abundantly scattered through certain beds in all their cavities and veins, comprising, perhaps, one-tenth of the rock. It is radiated and fibrous, of a light color, slightly greenish in larger masses and appears like quartz, for which it has been mistaken. It is the gangue of native copper which has been taken out at French river.

CHLORASTROLITE.

At Rock Harbor, Isle Royale.

ZEOLITES.

THOMSONITE.

Of this section of the silicates probably the most noteworthy in Minnesota is the thomsonite which is found abundantly in the trap-rocks, from Terrace point to Poplar river, and even further west, on the north shore of lake Superior. It was brought to light by the Mayhew brothers of Grand Marais, who have bought of the squaws many hundred dollars worth gathered from the beach of the lake, where they are found smoothed by the waves among the gravel, thus showing their beautiful markings, and have sent them to eastern dealers in minerals and gems. Eclipse beach and Terrace point are the chief localities.

LINTONITE.

This is found associated with thomsonite, and seems to be a variety of that mineral. It is green, generally amorphous, and, although it frequently encloses the thomsonite amygdules, it also constitutes amygdules alone.

NATROLITE

Exists at Beaver Bay, on the north shore of lake Superior. It

is in seams in the labradorite rock at the west point of the bay, and is taken out in crusts about ½ inch thick.

STILBITE

Is a zeolite common along the north shore of lake Superior, between Poplar river and Grand Marais. It occurs abundantly at Eclipse beach, and at Sugar Loaf point as far as Two Island river. It is also abundant about two miles west of Little Marais.

HEULANDITE

Occurs as coatings, very generally along the shore of lake Superior, in the joints of trap-rocks, according to the determination of Norwood. It is not certain but this mineral is the same as the next.

MORDENITE

Occurs with stilbite quite abundantly as amygdules on Sec. 29, T. 57, 6, a few miles west of Little Marais.

MARGAROPHYLLITES.

TALC.

This is the basis of the talcose schist, which plays a conspicuous part in the stratigraphy of the Huronian at Vermilion lake and on the International boundary; but no important deposits of the unmixed mineral have yet been discovered in Minnesota. It seems to be the chief ingredient in the greenish pipe-stone cut by the Indians from Pipe-stone rapids, and at Rainy lake.

GLAUCONITE

Is said to occur in the sandstones of the St. Croix, as at Red Wing and in the St. Lawrence limestone at St. Lawrence. But the characters of the Lower Silurian greensand do not agree with those of the Cretaceous greensand, nor with that from igneous rocks.

SAPONITE.

Under the name thalite, a mineral from the mouth of Knife river, was described by Dr. Owen as new to science, but Genth has

shown it to belong under saponite. It is soft and nearly white, filling cavities in amygdaloidal rock at the very water's edge. It is also found in the same kind of rock on Kettle river, in Pine county. Owen regarded it, however, at the latter place, as a magnesian harmotome.

HALLOYSITE?

Whether the decomposed granites of the Minnesota valley can be included under this term or not, they certainly should be placed in this section of the silicates. The most of this deposit, which occurs characteristically at "Birch Cooley," is amorphous, earthy, soft, greenish and ferruginous on analysis; but in some places it is more nearly white, approaching kaolinite in outward characters.

DELESSITE.

Common as a product of decay in the trap-rocks of the north shore of lake Superior. It also fills amygdaloidal cavities and cracks. It gives a soft and slippery feel to the green traps when undergoing incipient decay near the water-line. It has a velvety radiated crystallization.

PROCHLORITE.

This term is here employed for all the chlorites and chlorite-like minerals that occur in the Cupriferons rocks, except delessite. Very often a chlorite-like mineral results from the decay of hornblende or augite. This is often called viridite, which signifies the same thing, but is used to avoid the appearance of exact knowledge of its mineral nature. The chlorite schists can hardly be distinguished from the talcose, and hardly from the hydro-mica schists without minute chemical or miscroscopic investigation. Hence it must be understood that the term here is used without intending to apply closely to that class of crystalline rocks, although there can be no doubt but the chloritic schists form an important group of the crystalline strata.

PHOSPHATES.

APATITE.

At present this is known only as an unimportant ingredient of the igneous rocks. It exists not only in the trappean beds of the

Cupriferous, where nearly every thin-section reveals, under the microscope, numerous needle-shaped crystals, but also in the igneous dykes that cut the rocks of the so-called Huronian at Thomson and the syenites of Sauk Rapids. The well known fertility of the soils derived directly from the decomposition of the igneous rocks seems to be due largely to the presence of this mineral.

SULPHATES.

BARITE.

Barite is common in the northern part of the state as a gangue rock in the veins that have been explored for silver and copper, particularly for silver. It is associated with calcite, pyrite, amethystine quartz and galenite. On Pigeon point is a conspicuous dyke or vein of white barite which crosses from one side of the peninsula to the other about one foot in width. This has long been known, having been described by Norwood, an assistant on Owen's survey.

GYPSUM.

This accompanies the Cretaceous rocks in the western part of the state and is found on the slopes of some of the bluffs made of the Cretaceous shales, as at Big Stone lake. It is frequently found in perfect, transparent, selenite crystals in the drift-clay in digging wells in the drifted western counties; where it seems to have been formed by segregation from the clay.

EPSOMITE.

On account of the easy solubility of this mineral it is not known to have been found in its crystalline condition in the state, but it is in solution in the alkaline waters of the western part of the state, in noticeable amounts. Mingled with some common salt it seems to have been the basis on which the so-called salt springs of the state were located. It is also found on the lower side of some projecting shelves of magnesian limestone, as a delicate white efflorescence, the sulphur being probably derived from oxidation of pyrite. This is the case along the bluffs of the Galena limestone at Mantorville

MELANTERITE.

This is also a product of the oxidation of pyrite or marcasite, and in limited quantities exists in the same situations as epsomite,

as a coating on the under surface of projecting strata of dolomite, but its color is apt to be yellowish instead of white.

CHALCANTHITE.

This has not been identified in the state, but undoubtedly exists in the northern portion. It results from the oxidation of chalcopyrite and is apt to be carried away in solution by waters that come in contact with it.

CARBONATES.

CALCITE.

As the essential and principal ingredient of all limestones, this is an abundant and very important mineral in Minnesota. The only pure limestones, however, are those of the Trenton formation (the building-stone beds) as seen at Minneapolis and St. Paul, and the Niobrara limestone of the Cretaceous. So far as examined this contains a small percentage of carbonate of magnesia also; while all the others are highly magnesian, or quite dolomitic. Calcite also occurs in veins in the crystalline rocks, where it sometimes exhibits perfect crystalline forms. At Pigeon point some perfect specimens have been obtained in the shaft sunk by Kindred and Baker. At Crystal bay, near Duluth, a modified red shale has numerous nests of perfect crystals enveloped in a recent red clay, loosely embraced in cavities in the rock. Nail-headed and cockscomb forms of crystals occur in the Niobrara beds at Redstone, near New Ulm. At Chatfield some of the calcite in the Shakopee limestone embraces much quartz-sand in translucent grains, giving it the characters of the Fontainbleau limestone of France. Near Caledonia in Houston county is a large deposit of argentine or lamellar calcite, lying on the sloping bluff of the St. Peter sandstone. It has a grayish-yellow and brownish, undulating lamination varying to nearly white. A large piece of the same once existed near St. Charles, in a similar situation, but it has been exhausted for hand-specimens. Calcareous tufa or travertine is abundant in Minnesota, being the deposit of calcareous spring water. It has been mentioned on the east bluff of the Mississippi, just below the falls of St. Anthony, whence thousands of specimens have been removed by visitors. At Osceola, (or the St. Croix lake), calcareous tufa has been burnt for

quicklime for forty years at least. Marl is sometimes found in swamps and beneath peat beds. Sometimes, as at St. Cloud, it shows its origin by containing, still, fragments of the fresh water shells from which it was derived. In other cases it is an impalpable, pulpy mud, which passes gradually into calcareous clay.

DOLOMITE.

This is the characteristic mineral of the dolomitic limestones of the state—and they include by far the greater number of our limestone strata. In its crystalline, pure form, dolomite is rarely seen separated from the rock-masses. Sometimes as brown spar it is seen lining cavities or associated with calcite in geodic aggregations, as at St. Lawrence.

ANKERITE.

This is simply a ferruginous dolomite, and has been reported only from the St. Lawrence limestone at Clear Grit, in Fillmore county, where it fills cavities in the limestone. It there has a slightly grayish color.

SIDERITE.

This is found in occasional loose boulders in the drift, more or less converted to limonite in the condition of clay iron-stone. In this form its origin is referable to either the Cretaceous (or Tertiary), or to the Devonian strata. Such lumps occur abundantly at Austin, and are easily recognized by their weight. In a purer state it has been found filling cavities in other boulders, somewhat in the form of an amygdaloid, the outer surfaces becoming spotted with limonitic depressions, due to the weathering out of the siderite after its conversion to an oxide. The boulders that are thus marked are quartzitic. As a pure carbonate it is found in important quantities in the iron strata of the Mesabi range, in northern Minnesota.

MALACHITE

Occurs sparingly in numerous instances in connection with the Cupriferous rocks of the state, in the lake Superior region. It is found also at Taylor's Falls and at Chengwatana, as coatings on the protected surfaces of seams in the rock.

HYDRO-CARBON COMPOUNDS.

MINERAL COAL.

That which is popularly known as "coal" in Minnesota and in Dakota, is lignite or "brown coal" from the Cretaceous, or from the Tertiary. It embraces not only impressions of woody fiber, but frequently considerable undecayed wood as well as charcoal, which shows the grain and cellular structure of the original wood. The best of it, however, is clean, black, amorphous and hard. On drying, this cracks in innumerable places and slowly crumbles to finer pieces, and these again to finer—a quality which renders it difficult to transport on cars or handle for fuel because of the waste. It occurs in the Cretaceous strata at Redwood Falls, on Crow creek, at Fort Ridgely, and on the Cottonwood river southwest of New Ulm, and has been found in the drift in nearly every county in the state. It also occurs at Namekan lake, on the northern boundary. These strata are frequently penetrated in sinking deep wells in western Minnesota and in Dakota.

II.

THE CRYSTALLINE ROCKS OF MINNESOTA.

By A. STRENG, of Giessen, and J. H. KLOOS, of Hanover.

[Extracted from the *Neues Jahrbuch für Mineralogie*, 1877.]

TRANSLATED BY N. H. WINCHELL.

The following work has been performed by us both, but in such a manner that the one who gathered the rock-samples has described the outward appearance and manner of stratification, and the other has labored on their mineralogical, microscopical and chemical investigation.

In respect to the nomenclature of the rocks, it should be remarked at the outset that it was not our intention to create new rock species, and that consequently it became necessary, in the changing condition of petrography, brought about by the microscope, to select designations, which, it is true, are in accord with the old system of nomenclature hitherto used, but at the same time express, although briefly, that which distinguishes the rocks examined from those hitherto known. More extensive investigations only will be sufficient to determine whether the newly named rocks should be regarded as special rock-species or only as varieties of those to which they are most nearly related. If, for instance, a dioryte which, besides hornblende, contains an augitic mineral, shall be designated an *augite-dioryte* (if exact observations and investigations shall point to another dioryte) whether the presence of augite is a common property of dioryte, or whether it is limited to a few rocks, which, in that case, can be set off from the true diorytes as a distinct rock. We regard these names therefore only as provisional designations.

GENERAL DESCRIPTION OF THE APPEARANCE OF THE ROCKS.

The crystalline rocks which form the basis of this work were derived partly from the upper course of the Mississippi river, and one of its tributaries known as Sauk river, partly from the western extremity of lake Superior and near the mouth of the St. Louis river, and partly from the St. Croix river, on the boundary between the states of Minnesota and Wisconsin.

If one reach the shore of the great Mississippi above Prairie du Chien, in the state of Wisconsin, by any one of the railroads leading from the east, he notices immediately on both sides of the wide valley, perpendicular walls of sandstone which are capped with layers of dolomite of little thickness. These are the western representatives of the Lower Silurian formations named *Potsdam* and *Calciferous* sandstones in New York state. David Dale Owen has distinguished them, in his geological report for the year 1852, as *Lower sandstone of the upper Mississippi*, and *Lower Magnesian limestone.*

As one ascends the river toward the state of Minnesota, gradually the sandstone disappears, cut through in many ways by the streams and tributary rivers, so that by the time the St. Croix river is reached the banks consist entirely of layers of dolomitic limestone. These also have a slight northern dip, and give place, in the neighborhood of St. Paul, to the next higher members of the Silurian, the *St. Peter sandstone* and the *Upper Magnesian limestone.* The latter has been determined to be the undoubted equivalent of the *Trenton limestone*, or *Llandeilo flags* of England, by its numerous organic remains. The whole range of strata, through which one passes between Prairie du Chien and St. Paul, the end of steamboat navigation on the Mississippi, belongs therefore to the oldest fossiliferous formations.

From here heavy layers of diluvium (the *drift-formation* of North America) cover all the older rocks, and other outcrops are found only at 75 (English) miles higher up the river. Here, however, the rocks are crystalline, and appear in low ranges, which fall away gradually toward the land and disappear in swamps or sandy prairies. Here the Mississippi flows over an extent of 20 miles* through heavy crystalline rocks, with numerous windings and angles; further north is encountered a similarly wide zone of metamorphic schist—mica, talc and clay slates—and of gneiss-like rocks.

* In this paper English miles are always meant.

This system of rocks corresponds to the Laurentian, and in the northern part, probably to the Huronian formation. It consists in great part of the most diversified granitic, syenitic, dioritic and gabbro-like rocks, while they seem to lack diabase entirely. Here belong the rocks from St. Cloud, Sauk Rapids, Watab and Little Falls, which below are fully described. It is remarkable that to the south from this zone of massive rocks there are no schists in outcrop, though it is probable that they are covered by the drift which constitutes the greater part of the surface of Minnesota and attains to a considerable thickness.

In the neighborhood of St. Cloud the Sauk river empties into the Mississippi. It has its rise in the lakes of northwestern Minnesota, and flows in its lower part, diagonally across the zone of Laurentian rocks a distance of 25 miles. These here constitute long, but low ranges of hills, generally covered by thick forests, but actually appear only in small areas in the river itself. Here the water flows rapidly, causing everywhere little water-falls and rapids. If one goes back from the shores of the river, the hills flatten out, and every trace of the older rocks disappears at once, under a heavy covering of debris and drift. From this region are derived the rocks from the west of St. Cloud, from Rockville, Cold Spring and Richmond.

Beyond the latter point the zone of the crystalline rocks cannot be traced, and at the same time here begins the area of the western prairies. The river cuts but few feet into the table-land, and affords no more outcrops of rock. From here one can travel all day in a westerly direction without seeing anything but deposits of drift, either of sand or clay, perfectly flat and without fossils, or somewhat greater accumulations of gravel and boulders, which latter are always to be seen in great quantities about the shores of the numerous lakes. So far as known to me, solid rock is exposed at but one point west of Richmond. In the thriving little town of Sauk Center, peopled mainly by Germans, I learned that stone-quarries had lately been opened in the neighborhood. The place lies 43 miles west from the Mississippi. At a distance of ¼ mile south from the town can be seen a gentle elevation extending from northwest to southeast. On approaching this, one sees the soil and drift thrown out, and a little stone-quarry opened in two wholly different crystalline rocks—one a granite of a red color and somewhat gneissic texture, and the other a dark rock which in an earlier work* I distinguished as a diabase, but which now is known

* J. H. Kloos: *A Cretaceous basin in the Sauk valley, Minnesota;* Dana and Silliman's Journal, 1872, p 26.

as a dioritic rock, and in our special investigation of these rocks, is proved to be a quartz-dioryte (No. 14).

As concerns now the outcrops of the separate rocks which are fully described in this work, the syenitic-granite (No. 20) is derived from St. Cloud and from Sauk Rapids (Nos. 18 and 19), and was designated as such in an earlier paper.§ They constitute sometimes rounded, somewhat elongated, gently rising hills, the intervals between them being filled with diluvial deposits, and sometimes low reefs in the river bed, or isolated knobs in the swampy lowlands along the river. The rapids in the Mississippi above St. Cloud, known as Sauk Rapids, are caused by syenite-granite. In the village so named may be seen in the syenite-granite three parallel small dykes of black melaphyr (No. 4) which also can be followed to the opposite shore; but here they are not in the syenite-granite, but penetrate a beautiful, exceedingly hard, syenitic granite-porphyry.

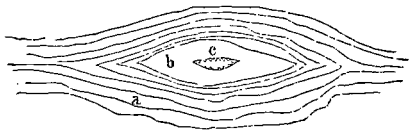
Six miles further north, at the small town of Watab (already half forgotten) several fine rocks outcrop. The hills here rise higher and are larger and the rocks rougher and wilder; unfortunately the region is heavily wooded, and only at isolated points could the rocks be freshly broken. From Watab were examined and described: augite-quartz-dioryte, (Nos. 16 and 17) syenite-granite (No. 22), and a melaphyr-like rock (No. 5). The white granite from Watab described in the *Geological Notes on Minnesota* (see above) is different from these, and outcrops only to a small extent. Furthermore the outcrops here are too limited to enable one to judge of the relations of the rocks to each other. One gets the impression, however, on the spot, that the coarse-grained granitic rocks penetrate through the fine-grained hornblendic rocks in the manner of dykes. Certainly that is the case at one spot where a fine-grained hornblendic rock, which besides two kinds of feldspar contains quartz and mica, is penetrated by very small granite dykes and veins.

At the village of Little Falls, which in part is inhabited by Indian half-breeds, the Mississippi reaches a slaty formation and forms, in passing over the outcropping beds, a series of rapids which produce a superior water-power, while the banks of the river here are high, and the channel is narrowed by a number of small islands through which opportunity is afforded for improvement by dams and locks. Inasmuch as the water generally has taken

§ Geological notes on Minnesota. Zeit. d. d. geol. Ges. 1871 p. 428: Tenth annual report of the geol. and nat. hist. sur. Minn. 1881, p. 175.

the direction of the strike of the rock-beds, it is difficult to determine the thickness of this slaty formation. It must however be very considerable. From a number of observations at various places I ascertained the strike of the bedding, N. 35° to N. 40°,* the dip toward the NW. 65° to 72°, while on the other hand the slatiness has a dip in the opposite direction at an angle of 70° to 80°. The nature of the beds is changeable, both in the direction of the strike and in the dip. Roofing-slates are widely disseminated: north from this place mica-schists prevail; toward the south the beds assume the character of a fine-grained gneiss, which is interbedded with layers of a beautiful angite-dioryte (Nos. 9, 10, 11, and 12). The first outcrops of this rock appear somewhat down the river, southwest from the village at the mouth of a little creek. They are twelve to fifteen feet high, and show the augite-dioryte variously developed. In the creek, farther up, rocks come to light which have a somewhat different character. They are described further on as augite-dioryte No. 13. In what relation these rocks stand to each other could not be determined.

In the crystalline roofing-slates at Little Falls are small lenticular parts, a foot in size, of a crystalline rock which was analyzed, and below is designated a quartz-dioryte (No. 15).



a. Crystalline schists. *b.* Quartz-dioryte. *c.* Drusy quartz.

This woodcut shows the appearance of these septaria of quartz-dioryte in the slates. They reach quite frequently a length of several feet. The rock contains little garnets disseminated through it, which along the margins of the septaria are in greater abundance. When the septaria are large they have a cavity in the center, the sides of which are very often clothed with crystals of quartz. The slates bend completely round the septaria.

Whether the slate formation here described must be reckoned as a part of the Laurentian formation, or of the Huronian, must remain undecided. In any case it presents a totally different character from the syenitic knobs at St. Cloud and Watab, and the slates appear not to have any connection at all with them.

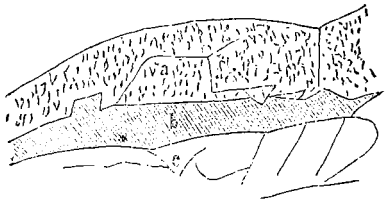
* Whether to the east or west of north the author does not state.—*N. H. W.*

Toward the north from Little Falls the firm rocks immediately disappear again under a heavy covering of sand and gravel. The banks of the river, which are in general heavily wooded, nowhere afford any outcrops of rock. The first rocky layers that are seen, are much further toward the north, at the well-known Pokegoma falls, and consist of banks of granular sandstone.

If one pursues the road from St. Cloud which leads up the fertile valley of the Sauk, (in which very many Germans are settled) he finds the first outcropping rock in the woods, three and a half miles west of the town, at a point where the road first reaches the river. It is a medium-grained syenite-granite, of a reddish color, with a structure somewhat porphyritic. Granitic rocks now remain a constant object in sight, sometimes in the bed of the river, and sometimes in the wooded bluffs along both shores. The finest outcrops are found by a little village named Cold Spring, fifteen miles from St. Cloud. Here the river has cut through a nearly parallel range of hills, the strike of which is about east and west. A finely granular porphyritic granite changes to a very coarse-grained syenite-granite. The latter in this region is very widely distributed, and extends even to Richmond.

The village of Richmond lies on a little sandy but well-tilled prairie, which on all sides is surrounded by high, wooded hills. Here appear Cretaceous beds in some thickness, and they have a character which unites them with those on the upper Missouri. The plastic clays of the Cretaceous rest immediately upon kaolinized granite. In the vicinity of Richmond is abundant opportunity to examine the coarse-grained granite in its relation with the augite-dioryte. For a mile southeast of the village are knobs of this rock in the immediate neighborhood of granite; and in the same region, a little farther away, is a stone quarry where, as the following woodcut shows, the dark, fine-grained augite-dioryte is overlain by a coarse-grained much weathered granite.

The bed *c*, which rises up so as to form a terrace, consists of a firm, hard-weathering rock, and dips toward the hill at an angle of about 45°, passing under the granite. It is exposed a thickness of about ten feet. The line of contact with the granite is covered with a lot of decayed debris from the granite. Under the bed *b* the granite cannot be found, inasmuch as the rock has been laid bare and followed only so far as it has proved useful for building stone; but it is very probable that the augite-dioryte exists in the granite in the form of a dyke. Similar appearances were fre-



a. Granite.
b. Debris from the easily weathered granular granite.
c. Augite-dioryte, forming an evident terrace-like bench.

quently encountered in the surrounding fields and farms; the augite-dioryte here is certainly so displayed that it must be styled a dyke cutting through the granular granite.

We pass now to the description of the field-appearances of those rocks which were procured from the neighborhood of lake Superior.

The St. Louis river rises in northeastern Minnesota, south of Vermilion lake, in a region of granite, gneiss and crystalline slates, which form a branch from the Laurentian formation as it is displayed in the region north of lake Superior. Shortly before the river empties into lake Superior it makes a sharp turn toward the east, and here passes through a picturesque, heavily-wooded region known under the name of "the dalles of the St. Louis river." The water has broken through the steeply tilted slates, and rushes over them in a long series of the most romantic falls and rapids; in the distance of a few miles the descent of the water amounts to 370 feet.

The beds consist of a series of roofing-slates and of a gray fine-grained rock which at first glance seems to be a dark quartzyte, or a fine-grained graywacke sandstone, the more exact nature of which it is however not possible to state. This formation, which occupies a great extent of country, forms, very probably, the representative of the Huronian as it has been described in northern Michigan, by H. Credner.* Further down the valley, toward lake Superior, the lower part of the Potsdam sandstone lies in unconformable position on the outcropping knobs of these old schists.

Going by the *Lake Superior & Mississippi railroad* to the foot of the plateau which locks in the mouth of the St. Louis river (which here spreads very widely) one beholds high cliffs of a coarse-grained rock. It is known under the name of *Duluth granite*, and as such it is far and widely distributed, and is worked into monuments. This rock has been designated in *Geological notes*

* Compare Zeit. d d. geol. Gesel. 1871. p. 438; and Credner's article, 1869, p. 523

on Minnesota a gabbro, or hypersthenyte, and has received, in the following descriptions, the name hornblende-gabbro (No. 6.)

The distance from the highway, where the rock is very finely exposed, to the most westerly point of lake Superior, may amount to a mile and a half or two miles, on the side of the hill, and upon the alluvium of the river at the foot of it, has been established within a few years a new city which has acquired a considerable renown as the beginning point of the Northern Pacific railroad, under the name of Duluth. In the vicinity of Duluth which was originally covered with heavy forest, only imperfect observations could be made a few years ago, yet enough to convince one that here the crystalline rocks greatly prevail, and that the old sedimentary rocks are entirely wanting.

The leading variety of rock at Duluth, which is washed by the waves of the lake, has already been described as a porphyry.* This rock now, after a searching investigation, has received the name of melaphyr-porphyry (No. 1.) In some places it changes to a beautiful amygdaloid, but without showing at any place a sharp line of separation. Besides the hornblende-gabbro and the melaphyr-porphry, there is still a third rock at Duluth, which is separated from the melaphyr-porphry by a sharper boundary. It was seen only in a little quarry, and is certainly also a melaphyr (No. 3), although of a darker color, and similar to those small dykes which cut through the syenite-granite and granite-porphyry on the Mississippi at Sauk Rapids. At the point of contact with the melaphyr-porphyry it becomes firm and compact; at a distance from it it has a middling coarse, granular structure, and the lines of the striated feldspar can be seen without difficulty.

The rocks at the western end of lake Superior belong without doubt to the age of the Potsdam sandstone, and form a part of the solidified outflows of basic crystalline rock which took place at the end of the Huronian and at the beginning of the Silurian ages. They are to be compared to the dykes and overflows of basalt and doleryte which took place in later times, and which can be traced, in the western part of the American continent, over extensive areas.

On the St. Croix river, the boundary between the states of Minnesota and Wisconsin, at a distance of 100 miles from the last described locality, appears a similar melaphyr-porphyry (No. 2), which lies immediately below the sandstone and conglomerate of

* Z. d. d. g. G. 1871, p. 441, and the ninth report of the Minnesota geological survey.

the age of the Lower Silurian. In conjunction with these it forms here a narrow valley, which on account of the romantic forms of its cliffs attracts there yearly many tourists. It bears the name: *Dalles of the St. Croix river*. The bedded rocks have, in great numbers, *Lingula antiqua* and *prisca*, as well as *Orbicula prima*, and the small bucklers of *Conocephalus*, and these fossils are altogether unchanged in the granular sandstone which lies immediately on the melaphyr-prophyry. The presence of an evidently bedded conglomerate consisting of great water-worn masses from the latter rock, which in the neighborhood of the town of Taylor's Falls underlies unconformably the sandstone, points to the Huronian age of this melaphyr-prophyry.* It differs from that of lake Superior only in color. This forms frequently an amygdaloid in which the cavities are filled, it is true, solely with quartz, while the amygdaloids of lake Superior exhibit, in connection with a more changed groundmass, also calcite, epidote and a crumbling mineral rich in iron and manganese, in the amygdaloidal cavities.

We will now at the close of this brief account of the appearance in the field of these crystalline rocks, which we are about to describe further, bring together concisely, for the purpose of quick classification, observations made concerning their age, *viz:* The granite, syenite-granite, syenite-granite-porphyry and the augite-granite, as well as the quartz-dioryte and the augite-quartz-dioryte in the Mississippi region, probably all belong to the Laurentain formation; while the hornblende-gabbro and melaphyr-porphyry of lake Superior, and from the St. Croix river, are to be ranked in some later period, and probably to the end of the Huronian and beginning of the Silurian.

SPECIAL DESCRIPTION OF THE ROCKS.

By A. Streng.

These crystalline rocks from Minnesota can be divided, from a petrographic standpoint, into seven rock-species:

1. MELAPHYR. These are basic, augitic rocks free from hornblende.

2. Basic rocks, which, besides hornblende, contain much evident diallage as well as a great deal of magnetic and titanic iron. These are distinguished as HORNBLENDE-GABBRO.

* Compare *Zeit. d. d. g. G.* 1871, *p.* 433. Here this rock is likewise distinguished as porphyry.

3. Basic rocks which are like the foregoing in their mineralogical composition, and besides very much hornblende contain some diallage, which, however, for the most part, is intimately associated with the hornblende. These are distinguished as AUGITE-DIORYTE.

4. Quartzose dioryte, without augite—QUARTZ-DIORYTE—this is a siliceous more wide-spread species of rocks.

5. Quartzose diorytes with augite, are also wide-spread siliceous rocks, and are designated AUGITE-QUARTZ-DIORYTE.

6. Hornblendic granites are grouped under the name SYENITE-GRANITE.

7. GRANITE, *i. e.* without hornblende.

I. MELAPHYRS.

The melaphyrs appear in two varieties :

(*a.*) *Melaphyr-porphyry.*

(*b.*) *Compact or granular melaphyr.*

(*a*) *Melaphyr-porphyry* (epidote-melaphyr.)

This rock is found in outcrop in two places, viz: at Duluth on lake Superior, and on the St. Croix river on the boundary between Minnesota and Wisconsin.

1. *Melaphyr-porphyry from Duluth.*—The freshest of these rocks is on a hand-sample in which it appears along with a compact melaphyr and is sharply separated from it. Unfortunately there was present only so small a piece of this contact rock that an analysis of it could not be made. The other specimens which had been exposed to the disintegrating and changing effect of penetrating water, are not so fresh as this, and contain almost uniformly, epidote, while the before-mentioned contact-rock is free from it.

This rock consists, macroscopically, when in fresh condition, of a nearly black, or dark-green, groundmass, which is fine-grained and very compact, but which when less fresh is of a dark greenish-brown color, with numerous porphyritic bands, and contains the following minerals:

(1) A triclinic feldspar in elongated separate crystals, 5-15 mm. long, and from 0.5 to 3 mm. wide, flesh-red to colorless, brightly glistening, and strongly striated. Generally a crystal-grain consists of several rather wide bands, the first of which grows together with the second, and this again with the third, etc.

according to the rule: "The twinning axis the principal axis." The first, third and fifth bands have consequently the same position with respect to each other, as well as the second, fourth and sixth; but the first group stands to the second in the relation of the above mentioned twinning-law. The cleavage surface oP therefore reflects light in the bands 1, 3 and 5, all at the same time, while the bands 2, 4 and 6 do not reflect. But each separate band consists again of a great number of very fine lamellæ which stand to each other on the plane $\infty\breve{P}\infty$ according to the law—"the twinning axis a normal;" it is the usual polysynthetic twinning of the triclinic feldspars. The principal cleavage surfaces appear therefore striated, and the striation is parallel to the twinning lines which the broad bands make in conformity to the other law of increase.

Sometimes, though rarely, a striation of the plane oP cannot be seen; that this non-striated plane is actually oP, can easily be discovered, so long as the crystal concerned exhibits a Carlsbad twinning. But these few non-striated instances differ in no respect from the other triclinic feldspars, inasmuch as in them the striation is frequently too dim to be distinguished. Furthermore there appear isolated crystals of a sharply defined outline, regularly six-sided, which show no striation on their cleavage planes, and from their somewhat different luster appear to be a different feldspar, and probably consist of orthoclase.

(2) Far less frequent are angular, isolated, crystals, of diameters up to 7 mm., of a dark greenish-black color, which consists of a granular aggregate of a chlorite-like mineral. They are tolerably soft, and have a bright greenish-gray streak. Unfortunately in the freshest of the rock-samples nothing of this aggregate was to be seen. Sometimes little grains of iron pyrite are set in it. This chloritic mineral is here evidently the product of change from some earlier existing mineral.

(3) Associated with this dark-green mineral and often bound up within it, is also found at present a bright, greenish-yellow one, which consists of a group of small glittering individuals which must be considered epidote. Sometimes epidote-clusters, however, have become quite soft through change; and there are now parts of the rock so changed that they contain these bright greenish-yellow, softened masses, in great numbers. This epidote penetrates everywhere into the dark-green mineral, and it seems almost as if it were a product of change of the latter. In the freshest of the altered rocks it is not found.

(4) Frequently there are black grains that have a greasy or metallic luster and a conchoidal fracture. These might be either magnetic or titanic iron. In order to relieve this doubt, the finely powdered rock was subjected to a systematic washing-process, from which was obtained a black, metallic, perfectly magnetic residue. This was dissolved with acid potassium-sulphate, the solution was treated with cold water, and the filtered solution, containing sulphuric to saturation, was boiled. From this there arose scarcely a trace of turbidity, so that the mineral is not titanic iron, but magnetite, of which sometimes the octahedral form can be seen.

Sometimes this rock has the form of an amygdaloid, in which the irregulariy shaped amygdules consist of more or less weathered, fine-grained clusters of epidote near the surface, and have a compact central portion of a larger feldspathic crystal, or are filled sometimes with quartz. Generally these amygdules are not so distinctly limited as those of most melaphyrs. Other roundish inclosures consist of an aggregate of two minerals—one clear, and the other entirely black but affording a reddish-brown streak; both are so weathered that they cannot be determined.

The microscopic examination gave the following :

(1.) The feldspars appear sometimes mixed through the groundmass, and sometimes in larger enclosed grains. Between crossed Nicols they are very plainly and sharply striated. But seldom are any wholly non-striated feldspars to be seen. Their color is light-brown, although the crystals are for the most part filled with substances of other colors, namely :

(*a*) Clear-brown or gray, exceedingly fine grains which permeate the feldspar, and color it brown. Only exceptionally is the feldspar free from them; and it appears then colorless ; especially is this the case in the farthest parts.

(*b*) Clear, bluish-green scales, grains and needles of the augitic portion of the groundmass.

(*c*) Bright yellow or grayish-green epidote in irregular, angular aggregations or crystals, but which are wanting in the freshest portion of the rock.

(*d*) Here and there lie black clusters of irregular grains of magnetic iron.

(*e*) Little fluid-inclusions sometimes appear, containing movable bubbles.

(2) Only in the freshest portions of the groundmass are to be seen crystals of pure unchanged augite. It is colorless to light-brown, but colored a light-green in the few fresh rocks. It is

either entirely homogeneous, or slightly fibrous, shows often regular outlines, which correspond to the forms of augite, inasmuch as the angle $\infty P : \infty P\infty$ of augite was found to be about 135°, and the angle $\infty P : \infty$ about 90°. The colorless and light-brown grains show in polarized light bright colors, but they are almost non-dichroitic. In these pure augites are found irregular fractures, also rounded, rather large opaque grains, as well as very-fine, often numerously aggregated, round or elongated cavities with immovable bubbles. Even in the freshest rock can be seen numerous augites that are more or less filled with irregular grains of viridite.* Still more markedly is this the case in those portions in which the augite appears light-green and somewhat fibrous, without being dichroitic. These augites are changed; since it can be seen plainly in what way the green grains, or fibrous substance, more and more enters into them. In consequence of which the augites in many parts are replaced by a mass of viridite which is altogether homogeneous in appearance, and between the Nicols appears only light and dark, and exhibits no color at all.

Occasionally there are also larger crystals of this mineral. In reflected light they are dark, in transmitted light they are light bluish-green, but between crossed Nicols either granular or confusedly fibrous without marked color-characters. They are but slightly dichroitic or entirely non-dichroitic. Since these larger crystals correspond to the augite that is impregnated with viridite one would be warranted in regarding those grains which appear macroscopically as aggregates of fine chlorite-scales, as changed augite. These larger grains of the much-changed augite are everywhere intimately connected with quartz and epidote.

(3) In nearly all portions except the freshest, epidote is found, sometimes in large aggregates, sometimes as a portion of the groundmass or lodged in the feldspar. In the former case it is united, as already mentioned, with accumulations of viridite, and with grains of quartz. The epidote is light greenish-yellow in reflected light, in transmitted light faintly yellow, sometimes nearly colorless; it exhibits in polarized light very brilliant colors, but is not strongly dichroitic, which may stand in close connection with its bright coloration. It is not, besides, very pure, inasmuch as it is filled generally with gray granules. The larger individuals show small fissures which are parallel with the long axis, and correspond with the principal cleavage plane. In some places the epi-

*The name viridite is used to designate a chloritic or delessite-like mineral the nature of which is not accurately determined.

dote was in columnar, plainly outlined, separate little crystals, with their terminal planes set obliquely, answering to hemi-pyramids.

(4) Quartz is found only very scatteringly in small, or sometimes larger, grains which fill the interstices between the other minerals. It is associated especially with the viriditic and epidotic grains. It is sometimes wholly clear, and nearly free from inclusions, but sometimes contains scales of augite or grains of magnetite, or spicules of apatite. Sometimes there are fluid inclusions, occasionally with bubbles that are visibly in motion. In one such cavity were seen two black grains, besides the movable bubble, which were continually thrown hither and thither upon the bubble. In the freshest part of the rock were impure grains of quartz which contained numerous needles of apatite, as well as green grains in great quantity which like amygdules were surrounded by a coating consisting of grayish-green viridite.

(5) Rarely there are rather large clusters, more frequently distinct crystals, of magnetite with sides of four or six angles.

(6) A mineral of irregular outlines, which is white or yellowish in reflected light and but slightly translucent, and filled with granular substance, is certainly a product of change from epidote or feldspar.

(7) Slender, but generally very long, nearly colorless spicules, which have pyramidal terminations, or basic pinacoids, and also very shapely six-sided sections, are apatite. They often penetrate several minerals. But sometimes these crystals are so short and thick, that it was doubtful whether they should be regarded as apatite, or might be regarded, perhaps, as nepheline, as they are soluble in acids. By treating several of the thicker crystals in nitric acid solution, with molybdate of ammonia, and others with nitric and sulphuric acids, the determination could be reached, under the microscope, that they were certainly apatite. Moreover, the sections of this apatite sometimes consist of equal-sided triangles, the angles of which are occasionally rounded, and sometimes are not. The hexagonal crystal here appears, therefore, to take a hemihedral form.

The apatite here is not everywhere entirely pure, but sometimes contains individual cavities, or a fine needle-shaped small crystal, which lies in the middle of the larger crystal, parallel to the longer axis. Very frequently are the needle-shaped apatites seen to be fissured, and even broken, and the parts a little displaced from each other.

(8) Very rarely yellow metallic grains of pyrite make their appearance.

The chemical analysis of the melaphyr-porphyry No. 1, from Duluth, gave the following result :—

Silica,	50.03
Alumina,	15.38
Sesquioxide of iron,	11.78
Protoxide of iron	3 90
Cal ium oxide	5 39
Magnesium oxide,	3 60
Potassium oxide,	1.14
Sodium oxide,	5 01
Water	2 73
Carbonic acid,	0.98
	99 94
Phosphoric acid,	0.33

From this analysis it appears that the rock is comparatively very basic, at least as compared with the porphyries, in which the proportion of silica generally exceeds 60 per cent. At the same time it contains so little potash that the amount of orthoclase can be only very slight—at the highest, 6.74 per cent.—while in the porphyries it is present in far greater amount. In connection with this small amount of orthoclase, also appears the low per cent. of silica. As a part of the lime is required by the augite and epidote, only a portion of it is left for the triclinic feldspar: the sodium would, therefore, exceed the lime in this mineral. But since this feldspar is filled completely with a granular substance, which can be regarded only as a product of its own decomposition ; since, moreover, the content of carbonic acid in the rock gives evidence that the lime is no longer in its original condition, and a part of it can, therefore, be removed entirely from the stone ; and since, also, finally, the high percentage of water points to a high degree of decay and weathering, by means of which, first of all, the lime would be carried away, therefore it is necessary to conclude that the feldspar has also lost a portion of its lime. This also follows from the low per cent. of silica in the rock, since if the plagioclase contained considerably more soda than lime, it would also possess a content of silica which would exceed 60 per cent. But still the rock is too basic. Therefore it is permissible to conclude that the originally highly-calcareous plagioclase stood very near labradorite, perhaps, also andesine. The similarly high content of iron, which in part is due to the not

insignificant amount of magnetite, must be mainly set down to the credit of the augitic ingredients in proportion as they are altered, since the amount of magnesia is remarkably low, and the lime may be embraced principally in the epidote and the plagioclase. There remain, therefore, for the unchanged augitic mineral, besides magnesia and some lime, especially the oxides of iron, so far as they are not used in the formation of magnetite. The per cent. of apatite amounts to 81.

As it has been said already that the epidote seems to be a product of change from the green chlorite mineral, so it is necessary to hold it as highly probable, according to the microscopic examination, that the original augitic mineral decayed in various ways, sometimes forming basic epidote with the separation of free silica, and sometimes the chloritic mineral. These were deposited in the place of the augite, or in other places. These three minerals therefore are to be regarded as secondary products.

2 *Melaphyr-porphyry from Taylor's Falls*, or St. Croix Falls, on the St. Croix river, a tributary of the Mississippi. Macroscopically this rock appears porphyritic throughout, sometimes also amygdaloidal. Occasionally, however, all porphyritic structure is wanting, as, for instance, on the right shore of the St. Croix river, although decidedly porphyritic rocks exist very near. These consist of a greenish-gray to brownish, finely granular and crystalline groundmass, with numerous porphyritic crystals of brown plagioclase. In immediate proximity are found abundantly quartzose secretions that are frequently furnished with dark-green coatings, so that this is certainly to be regarded as an amygdaloid. Further there appear distinct secretions of a greenish black, chlorite-like mineral. Sprinkled in the groundmass can be seen also, with the naked eye, numerous fine grains of a bright yellowish-green mineral, which, as appears under the microscope, consists of epidote. Sometimes this epidote is liberally disseminated in those portions which are not porphyritic, so that by means of it the whole rock is rendered green. Even macroscopically it can here be seen that the plagioclase becomes changed to the dark-green chlorite-like mineral, inasmuch as it takes itself a green color even when the cleavage planes still retain their luster. Here also appear distinct sparkles of pyrite.

The microscopic examination led to the following determinations:

(1) Plagioclase, generally brown, colored by means of brown and gray particles. Besides these it contains small grains and scales of the augitic substance changed to viridite or chlorite,

which sometimes so much prevails that it nearly fills the whole plagioclase crystal, leaving only a little feldspathic residue. Further, crystals of epidote are also formed abundantly in the feldspar. The plagioclase constitutes a part of the groundmass sometimes, and sometimes it is disseminated prophyritically.

(2) The augite parts are wholly changed to viridite. The larger crystals of this mineral, which are connected closely with epidote and quartz, more rarely appear; while the smaller ones are very abundant, such as usually only fill the interstices between the laminæ of the feldspar, even constituting sometimes a part of the groundmass. In polarized light the mineral appears granular and either radiately or confusedly fibrous.

(3) One of the most common parts is epidote, which rarely occurs in large grains, but generally in rather small crystals of a bright yellow color. These are of imperfect shapes, but sometimes of regular forms. They are feebly dichroic, but show very brilliant polarization colors. Generally they are tolerably pure; sometimes they contain inclusions of quartz. Very often they are penetrated by irregular brown cracks. Rarely is the epidote filled with viridite; in nearly all cases it resists the spreading of the viriditic substance even when the feldspar itself is filled completely with it.

(4) Quartz secretions, large and small, appear in polarized light as aggregates which are enveloped in a granular green substance, and for that reason they must be considered as of amygdaloidal character.

(5) Also a white granular substance is here visible.

(6) Magnetite, and

(7) Apatite in slender needles also appear.

From the foregoing it follows that the melaphyr-porphyries from Duluth and Taylor's Falls have an undoubted porphyritic structure. The porphyritic portions consist of plagioclase, in connection with which very little orthoclase occurs; of an aggregate of chlorite-like grains (viridite) which are believed to be a product of change from augite; of an aggregate of epidote; of small amygdaloidal quartz masses, but which do not occur everywhere; and of small sparkling grains of pyrite. Aggregates of two much weathered minerals could not be determined exactly; they certainly form concretions in the two principal parts. The groundmass consists principally of plagioclase (probably also some orthoclase); augite, which, however, is principally changed to viridite; magnetite; apatite; epidote, often present in large quantity; a little quartz, and a grayish-white

granular substance that has resulted from change. When the rock is amygdaloidal, quartz fills the cavities, as well as calcite and epidote.

According to this the rock is such that it is embraced with the melaphyrs; and as it has a decidedly porphyritic structure, it may be designated *melaphyr-porphyry.* Now, in most parts, except in the freshest, epidote plays a very important role; it can therefore also be designated an *epidote-melaphyr.* But because the epidote is a secondary product, as well as the viridite, which has come from a change in the augite, this latter name can be applied only to the changed melaphyr-porphyry.

(*b*) *Compact and granular melaphyr.*

This rock exists at several places.

3. Of *melaphyr from Duluth* there were only a few small pieces. It is found in close contact with the fresh melaphyr-porphyry. The definition of it is very distinct. Unfortunately the pieces for examination were too small to make an analysis of them, and the microscopic examination had also to be made on a series of fragments in order to characterize the rock definitely.

One of the two pieces, *a*, is derived from the border close by the melaphyr-porphyry; the other, *b*, is from a point further removed from it.

The contact-rock, *a*, exhibits itself as a dense, dark grayish-black rock in which under the loop can be distinguished only very fine needles.

Under the microscope can be seen, in a very fine-grained groundmass fine, slender, colorless crystalline, needle-shaped feldspar crystals, which show very seldom any twinning striation, and give no bright colors when tested in polarized light. They are not very sharply separated from the groundmass; while in the colorless, felsitic ground-paste, they blend without showing any boundaries, but in which there are enclosed numberless light-green, colorless very fine grains of an augitic mineral, as well as some large, four-angled crystals of magnetite. The colorless ground-paste hardly shows any change in polarized light; between crossed Nicols it remains dark when the stage is revolved.

The other rock, *b*, derived from the midst of the melaphyr, consists of a middling to a fine-grained mixture of tolerably bright triclinic feldspar, and an augitic mineral which is mostly lusterless

and colored black, or sometimes shining with a yellowish metallic luster, and under the microscope is translucent and brownish green, and which is penetrated by numerous partly parallel or sometimes irregularly disposed, dark fissures, and is filled with pores of very irregular shapes. Occasionally grains of magnetite and spicules of apatite appear. The feldspars are often partly filled with brownish green clouds derived from the augites. Notwithstanding the brightness of the feldspar, this rock is very much changed, so that it is very soft and crumbling.

Accordingly this melaphyr in general is middling to fine-grained, but on the margins of contact it is very fine-grained. Hence one may draw the conclusion that at Duluth the melaphyr cuts through the melaphyr-porphyry, inasmuch as the latter is unchanged on its margin alongside of the melaphyr, but the former is rendered dense along this contact.

4 *Melaphyr from Sauk Rapids on the Mississippi.* This rock consists of a fine-grained, anamesite-like greenish-black groundmass of very fresh appearance, in which are enclosed narrow slender crystals, more rarely large ones, of very bright triclinic feldspar. The number of the larger crystals is so small that the rock at first sight hardly has the appearance of a porphyry.

Under the microscope the contrast between the crystalline groundmass and the larger crystals is very evident. Nevertheless it is observed at once that the crystals are of two kinds—triclinic feldspar and augite. The ingredients of the rock are, under the microscope, the following:

(1) Triclinic feldspar, with clear and nearly everywhere visible, sharp twinning lines, appears sometimes in large, sharply defined crystals, and sometimes in small bands as a portion of the groundmass. This mineral is very clear and pure, and contains only rarely in its interior a large accumulation of gray grains; sometimes are seen in it also fine needles of augite and little crystals of magnetite.

(2). Large, more or less regular crystals, are seen but seldom in perfect form, which are surrounded by a bright green hardly dichroitic border. The inside consists of a very clear-brown or brownish-violet substance which is not dichroitic or soluble in acids, and shows but very rarely brilliant polarization colors. The purest portions are penetrated by irregular fissures, (though sometimes these stand at right angles to each other,) which are filled with a black substance. The most frequent occurrence of this mineral shows it filled almost wholly with black crystals of mag-

netite, which often are placed in two fine linear systems perpendicular to each other. Occasionally also pyrite appears in it. Other portions are filled completely with green, confusedly-fibrous masses which are more strongly dichroitic than the unchanged mineral. This latter consists of augite which is converted through fibrous viridite into the green substance. The green border on the unchanged augite is also such a product of change.

As a part of the groundmass, augite is crowded into the angles between the feldspars. It is bright brownish-green to completely colorless, but is here also converted into a light-green, finely fibrous, mineral, so that an augite-crystal sometimes appears wholly converted to a fibrous mass; and the separate bundles of fibres are projected into the surrounding feldspar. A change here also takes place to fibrous viridite. In other places the augite is colored more brown, and then becomes either fibrous or granular, the latter by reason of the occurrence of fine dark points. Sometimes such changed augites are more strongly dichroitic, but not so that they could be shown to change to hornblende. In this augite are included now, occasionally, well-formed apparently cubic or rhombic crystals of a bright, grayish-violet color, which, unfortunately, it was not possible to determine exactly.

(3) Four-sided magnetic grains, sometimes separate, and sometimes grouped. From the pulverized rock it is possible to bring out with a magnet numerous grains of this mineral.

(4) Fine needles of apatite are seen clustered in several places.

(5) Very rarely are there scattered aggregates of quartz.

The chemical analysis of melaphyr No. 4 gave the following result:

SiO_2	48.97
Al_2O_3	16.50
Fe_2O_3	4.14
FeO	6.58
CaO	10.93
MgO	9.85
K_2O	0.69
Na_2O	2.69 (with traces of Li_2O)
H_2O	1.14
	101.49
P_2O_5	1.18

From this analysis it appears that the rock is basic, more basic than many other melaphyrs. It agrees in the composition nearly with Bunsen's normal pyroxenic rocks; it differs from them

especially in a too small content of alumina, iron oxide and protoxide, and in a too high content of magnesia. The small ingredient of potash shows that if orthoclase is at all present in the rock, it plays a very inferior part, the highest per cent. of it possible, being only 4.08. But, furthermore, the small content of soda, as well as the high per cent. of lime indicates that the plagioclase will approach nearer to anorthite than albite. Inasmuch as abundant magnetite is found in the rock there can be left, of the small content of iron oxide seen in the general analysis, but little iron for the augitic portion. This, therefore, must be the richer in magnesia and lime, which are present in large quantities. In the presence of the fresh appearance of the fieldspar everywhere, it will be necessary to charge the high per cent. of water to the account of the green secondary product of the augites. The content of phosphoric acid answers to a per cent. of apatite of 0.44.

From the foregoing it appears that the melaphyr from Sauk Rapids consists of a groundmass which holds a basic plagioclase; augite in changed and in unchanged conditions; also, in smaller grains, magnetite and apatite; and very seldom a little quartz; and that in this groundmass larger crystals of triclinic fieldspar and augite are sparsely disseminated. Hence this rock can also be designated a melaphyr-porphyry ; since, however, the prophyritic structure is not everywhere apparent, the rock may be designated simply a melaphyr.

This rock differs from the melaphyr-porphyry, of Duluth and Taylor's Falls, mineralogically only in the smaller amount of porphyritic structure, the lack of orthoclase and epidote, the very little amount of quartz and the greater purity of the general mass, and especially of the plagioclase; chemically it differs in the smaller per cent. of alkali, water and carbonic acid, and the evidently high per cent. of lime and magnesia.

5 *Malaphyr from Watab on the Mississippi.* This rock forms a fine-grained mixture of a colorless feldspar, a bright yellowish-green augitic mineral, and of isolated, small black grains. As a secondary product pyrite is disseminated in considerable amount. The whole rock is of a greenish-gray color, and has a fracture that is irregular and even splintery.

Under the microscope the feldspar can be distinguished as triclinic, the augite is of a bright greenish-brown color, which often becomes green by viridite; it is not dichroitic, is cut by irregular fine fissures, and embraces often an abundance of small

black grains. Large, four-cornered, black grains of magnetite are seen only very rarely. Also needles of apatite are sprinkled here and there.

Melaphyr No. 5, therefore, consists also of plagioclase, augite, and a little magnetite and apatite.

II. HORNBLENDE-GABBRO.

This rock is found only on the *St. Louis river near Duluth.* It has at first glance the appearance of a granular hypersthenyte. Upon exact examination it proves to be a granular assemblage of the following minerals :

(1) Strongly predominating is a brilliantly glittering gray *plagioclase* with very evident twinning lines and blue iridescence exactly like that from Labrador. Sometimes also the polysynthetic twinning is formed according to the Carlsbad law.

(2) Occasionally are seen crystals of bright red feldspar without twinning lines, with a reddish reflection similar to sunstone. This mineral is certainly *orthoclase.*

(3) A dark brownish-green, or tombac-brown, slightly lustrous, almost metallic-looking mineral, which appears fibrous and possesses two similar cleavage directions, which form with each other an obtuse angle. A great number of casual measurements gave for this angle about 125°. Since this mineral, moreover, is rather easily fusible to a black glass, it can only be *hornblende*, notwithstanding its somewhat different appearance from ordinary hornblende. This is in many places manifestly impregnated with small scales of chlorite, and it attains by that means a somewhat different nature.

(4) Light tombac-brown, metallic-lustered crystals are somewhat more seldom to be distinguished easily, with only one strongly marked cleavage direction. A second very inconspicuous cleavage plane, with faint lusterless surfaces, stands nearly at right angles with the first. Before the blowpipe this mineral fuses with tolerable ease to a dark shining glass. It is therefore, without doubt, *diallage.* It is somewhat more rare than the hornblende, but it appears to stand in no relation with it.

(5) Large black, slightly metallic grains, sometimes with perfect octahedral forms, with irregular to conchoidal fracture. The fragments drawn from the powdered rock with a magnet were dissolved in acid potassium sulphate ; the aqueous solution was boiled with addition of sulphuric acid, by which a rather heavy

white precipitate of *titanic acid* ensued. Since the distinct octahedrons give no titanium reaction, but the magnetic powder is only partly dissolved in muriatic acid—the rest being titanic acid—therefore, titanic iron certainly is connected so intimately with magnetite that it follows with it to the magnet.

(6) Very rarely is seen a light, greenish-yellow mass with conchoidal fracture, and greasy luster, which is insoluble in muriatic acid, and before the blowpipe is almost infusible. The hardness is about 5 to 6. This mineral appears to be *epidote*, whose cleavage planes could not always be recognised.

(7) Very seldom occurs a sparkling grain of *copper pyrite*.

The microscope revealed the following minerals:

(1) Very prevalent triclinic feldspar, generally tolerably pure; but sometimes wholly filled with granular masses, so that the striation in it is very difficult to observe. Also black angular grains, probably of magnetite, are disseminated here and there. The mineral is insoluble in hydrochloric acid, after standing twenty-four hours; also its powder gave after long treatment with hydrochloric acid, no trace of jelly. The triclinic feldspar, therefore, is not anorthite, but evidently comes nearer to labradorite.

(2) In several places appear feldspars which are completely filled with yellowish or reddish grains, sometimes hornblende granules changed to green viridite, but more rarely bright yellow epidote. This mineral corresponds to the red sunstone-like feldspars, in which a twinning-striation can be seen neither macro- nor microscopically. This might now be obscured possibly wholly by reason of the numerous inclosures; but when it is observed that the rock contains 1.61 per cent. of potash, it is necessary to consider it very probable that some orthoclase is present.

(3) Hornblende. This is mostly of a light to dark green color, more rarely of a brownish-green. The former is produced by viriditic substance, which often completely fills the hornblende and impairs its dichroitic character. This green viriditic hornblende is formed sometimes of parallel fibers, but sometimes of confused or radiate fibers, as appears especially between crossed Nicols. The brownish-green hornblende, without viridite, is strongly dichroitic, and appears parallel-fibrous. Sometimes it is penetrated by regular, dark, parallel, fine lines, which run at right angles with the fibrous structure, and have nothing in common with the cleavage, which, singularly, is wholly absent. Since, moreover, the margins of the hornblendes are very irregular, and always are dependent upon the feldspars between which they are embraced, it might be

doubtful, in consequence of their often weakly dichroitic character, whether they be hornblendes or not. But the above-mentioned numerous measurements of the two similar cleavage planes show, with complete certainty, that the mineral consists of hornblende, which, by the intrusion of viriditic or chloritic substance, has acquired somewhat different characteristics.

(4) Diallage appears in grayish-brown sightly translucent crystals, which sometimes are isolated between the feldspars, and sometimes are connected with the hornblendes like a mosaic, where, however, its outlines are everywhere sharp. As the grains of diallage do not encroach at all upon the hornblende, the latter must be, it seems, an original mineral ingredient, and not at all a product of change from diallage. The diallage is almost entirely non-dichroitc; it is generally delicately fibrous in parallel threads, and shows abundantly a system of parallel, sharply defined fissures, which run, however, through the fibrous structure nearly at right angles. Parallel to the fibers, which between crossed Nicols show an irregular striping of colors, is sometimes a fine black hatching to be noticed, which seems to consist of grains of magnetite arranged in lines. Only rarely does the diallage exhibit a non-fibrous center, which then is free from the dark lines which fill the remaining portion of the crystal.

(5) Large, black, metallic, angular crystals of magnetite and menaccanite. Smaller grains are embraced in the above-mentioned minerals.

(6) Irregular patches and grains of epidote of a light yellow color, slightly dichroitic, appear very rarely.

(7) Chalcopyrite is very seldom visible.

(8) Rather frequent colorless prisms, sometimes 0.4 mm. in width and over 0.8 mm. in length, can be seen in thin sections. These are occasionally six-sided. They show very brilliant polarization-colors, and contain numerous fluid inclusions, with and without moving bubbles. They are soluble in acids, give with the molybdate solution a phosphoric acid reaction, with sulphuric acid a lime-reaction, while with the treatment in hydrochloric acid no cubes of chloride of sodium appear. The mineral is therefore apatite, in thick short crystals, while fine needles of it seldom appear.

(9) The most rare are colorless grains with numerous large fluid inclusions, which generally contain slightly movable bubbles, and are broken by irregular fissures that are filled with a green

substance. They stand in close connection with bits of epidote, and are, in spite of these impurities, to be considered as quartz.

The chemical composition of the hornblende-gabbro No. 6, is as follows:

Silica	49.15
Alumina	21.90
Sesquioxide of iron	6.60
Protoxide of iron	4.54
Lime	8.22
Magnesia	3.03
Potash	1.61
Soda	3.83
Water	1.92
	100.80
Phosphoric acid	0.33
Titanic acid	0.18

It is, therefore, a basic rock, whose high per cent. of alumina corresponds closely with its abundance of triclinic feldspar. If this feldspar were anorthite, the content of lime would have to be higher, and that of soda necessarily less. Furthermore, if this feldspar were oligoclase or andesite, the per cent. of silica of the whole rock would be higher, since the 1.61 per cent. of potash presupposes a content of orthoclase of about 9.52, which drives the silica to a high percentage. Therefore, the triclinic feldspar comes nearest to labradorite. While the silica per cent rises by reason of the orthoclase, it is reduced again by reason of the percentage of magnetite and menaccanite. The meager percentage of magnesia corresponds to the low content of hornblende and diallage in the rock. The apatite amounts to 0.81 per cent.

Therefore, the hornblende-gabbro from the St. Louis river near Duluth consists of strongly predominating plagioclase (labradorite), a little orthoclase, some hornblende, diallage, magnetite and menaccanite, as well as apatite, and a very small amount of chalcopyrite, and epidote, the last occasionally associated with quartz.

III. AUGITE-DIORYTE.

This rock occurs at Richmond on the Sauk river, and at Little Falls, above Watab on the Mississippi.

7. *Augite-Dioryte from Richmond.* This rock consists macroscopically of a coarse-grained mixture, apparently of predominating black hornblende and a grayish-white triclinic feldspar, besides an augitic mineral. In addition to these there are also biotite, pyrite and perhaps zircon.

The hornblende is sometimes in distinct large crystals from 2 to 3 centimeters wide, and from 3 to 4 centimeters long; while the most of it appears in crystals of only a few millemeters in diameter. It is of a deep, black color, has a bright luster, and appears in general very fresh. Very frequent small scales of dark brown or black biotite, of irregular shapes, nestle within the cleavages of the hornblende. The latter fuses rather easily to a black shining glass.

The triclinic feldspar is clear, grayish-white, nearly colorless, in brightly lustrous crystals, with regularly angled cross-sections, and evident twinning striations. When the back-ground is dark, the feldspars often appear transparent as well as black.

The augitic mineral is only very slightly apparent, being mostly covered by hornblende. It is light, yellowish-brown or grayish brown in color, and slightly lustrous; but it becomes much brighter when the rock is wet, since it then acquires a yellowish, metallic lustre. Two cleavage planes can be seen cutting each other, nearly at right angles, but which are not very distinct, and appear not to be exactly similar. The mineral is somewhat fibrous, and fuses not very easily, in fine splinters, to a gray bead. It exists in less amount than either of the other constituents, and is itself to be seen under the lens with great difficulty.

Biotite, in thin brown or nearly black scales, is mingled especially with the hornblende.

Magnetite is recognizable, but without certainty; pyrite sometimes is disseminated in small grains.

Very rarely can be seen small crystals of a hyacinth-red color, which are brightly shining, but whose form cannot be ascertained. Perhaps they are little zircons.

The microscopic examination gave the following:

(1) The plagioclase shows very distinct color bands; it is generally very clear and pure. Here and there appear little needles of apatite in it: also shreds of hornblende and grains of magnetite; also gray kernels of irregular shapes are seen sometimes in groups. But very rarely does the feldspar appear without striping.

(2) The hornblende is of green and brown colors, strongly dichroitic with parallel cleavage, or with two cleavage systems that cross each other at a small angle. Its outlines are irregular. It sometimes embraces little grains, but in no great quantity; and very rarely cavities with movable bubbles.

(3) The augitic mineral is chiefly in immediate but irregular contact with hornblende. It can be traced out sharply in distinc-

tion from it, but its outline is irregular. Sometimes also specimens of this mineral lie in the feldspar, and also often little crystals of hornblende are in the center of the augite in such a manner that they intersect each other like a patience-play (Geduldspiel). It is only rarely that the augitic mineral is somewhat regularly outlined, but not so that the measurements of angles could be taken. It could only be discovered that the angle between two sides of such a section was more obtuse than the columnar angle of hornblende. The mineral is cut by irregular fissures which are only occasionally nearly parallel, but generally they go in all directions, cutting each other at all possible angles. It is generally very finely parallel-fibrous—that is to say it consists of a series of lamellæ parallel to each other, but which often wedge out in both directions, so that the fibers sometimes are in right lines, and sometimes appear slightly undulatory. The cracks which cut the mineral appear generally to have no reference to the direction of the fibers. Here and there is an appearance as if the cracks ran preferably at right angles to the fibrous structure. This augite is of a very bright brownish-red color. Between crossed Nicols it shows bright polarization colors, particularly in those spots where it is not remarkably fibrous. In the fibrous portions also there is a fine color-striping apparent, though this does not always appear distinct. It is therefore probable that a polysynthetic twinning structure is the fundamental cause of the fibrous structure.

This mineral is remarkably and strongly dichroitic in bright green and red colors. Beginning at the fissures which penetrate it, and along the margins, it undergoes a change which gradually embraces the whole mineral, so that the different stages of this change can be seen in the different thin-sections. The fissures are filled, for instance, with a bright grayish-green, non-dichroic substance which encroaches more and more on both sides, so that only the central parts, or kernels of the mineral, of more or less size, are visible, in its unchanged red color; and in many instances they are entirely faded out. At the same time the fibrous portions undergo no change, although they frequently appear more distinct. In many instances the augitic mineral consists only of bright green fibrous crystals. When the mineral is so changed it is not dichoric; so that it can with all certainty be seen to be augite. But the original red mineral can be only augite. The absence of a clearly defined cleavage-system, as it appears in connection with the adjoining hornblende, the very distinct optical characters in

common and polarized light, the fibrous structure, the difficult fusibility, the presence of two cleavage surfaces nearly at right angles, visible even with the naked eye, distinguish this mineral from hornblende, and show it to be augite. Microscopically it appears very much like diallage, in which professor Zirkel, who had the goodness to make an examination of it at Jena, agrees with me. Besides, individual crystals appear which are pierced by parallel hornblende-lamellæ, in such a manner that augite and fibrous hornblende alternate with each other.

(4) Biotite appears in bright, grayish-brown, transparent, angular sheets.

(5) Quartz is very distinct in small grains in which sometimes are fluid inclusions with rapidly moving bubbles.

(6) In places numerous crystals of apatite appear, especially in the feldspar, but those places are rare. Sometimes the apatite is in isolated crystals.

(7) Magnetite is for the most part only scattered and rare. Only occasionally is it in somewhat thicker and crowded large irregular masses. The larger portion of a slide is free from it. For that reason it was, that no metallic residue could be obtained from the wet powdered rock. With a magnet only could individual grains be drawn out.

The chemical analysis of the augite-dioryte No. 7, gave the following result:

Silica	48.87
Alumina	18.72
Sesquioxide of iron	3.28
Protoxide of iron	5.55
Calcium-oxide	11.93
Magnesium oxide	9.53
Potassium oxide	0.73
Sodium oxide	2.10
Water	0.93
Carbonic acid	trace.
	101.64
Phosphoric acid	0.08

This rock therefore is also basic, and agrees with the normal pyroxenic rocks of Bunsen. Yet some free quartz is present. The high per cent. of lime and magnesia agrees with the abundance of plagioclase, hornblende and diallage; likewise the low per cent. of iron oxides with the meagerness of the magnetite, the low

per cent. of potash with the absence of orthoclase, of which at the most 4.21 per cent of the rock could consist. The small per cent. of soda and the large per cent. of lime, considered in respect to the large amount of plagioclase present, warrant the conclusion that the latter comes nearer anorthite than albite, that it therefore is either labradorite or andesine. The small amount of water, which in a great measure consists of hygroscopic water, shows also that the rock is not entirely fresh. The apatite amounts only to 0.19 per cent.

The augite-dioryte No. 7 from Richmond therefore consists of a coarse to middling coarse-grained mixture of plagioclase, hornblende and diallage, with which is mingled biotite, a little pyrite and magnetite, a very little quartz, apatite, and very rarely perhaps zircon.

8. *Augite-dioryte from Richmond.* (Bareman's farm.) Although most intimately related to the foregoing in its outward appearance, this rock nevertheless shows a difference.

Macroscopically it appears as a fine to middling coarse-grained mass of very brilliantly shining, colorless, plagioclase, which sometimes also exhibits the Carlsbad twinning; also of black, very brightly lustrous hornblende, within which also very rarely isolated scales of biotite are visible; and of an augitic mineral, gray to browish-green in color, which appears in little grains. This last mineral is recognized plainly in places where the plagioclase forms white granular aggregates, in the neighborhood of which these greenish-brown grains are plainly secreted. They possess, so far as can be seen, not the cleavage planes of hornblende. Small black specks are magnetite, since such can be drawn out of the powdered rock with a magnet.

Isolated masses are seen that reach three centimeters in length and two in width, which consist of an aggregate of light-gray feldspars which sometimes are plainly striated, sometimes show no striation, but yet in other respects can not be distinguished one from the other.

From the foregoing therefore this rock differs in its lack of large hornblende crystals, in the presence of large aggregates of feldspar, and in its greater richness in magnetite.

Under the microscope can be recognized the following mineral ingredients:

(1) Very clear, wholly colorless, strongly striated plagioclase, which contains apatite in remarkable quantity, black grains of magnetite, separate little crystals of hornblende, and augite. Occasional non-striated crystals might perhaps be orthoclase.

(2) Quartz is apparently rare, in irregularly outlined masses lying between the feldspar crystals, with numerous cavities which contain sometimes movable bubbles.

(3) Hornblende, of a dark greenish-brown color and strongly dichroitic; which is cut by cleavage planes that are either parallel or form an obtuse angle with each other. Its outlines are very irregular. Only the little crystallites which lie scattered in the plagioclase, show sometimes regular forms.

(4) A dichroitic mineral (dichroitic in light green and red colors) appears in great quantity, perhaps even exceeding the hornblende in amount, which is colored light grayish-green to brownish-green. This differs from hornblende essentially, both in common light, on account of its bright colors, and between the Nicols by reason of its brilliant polarization, since hornblende appears very dark between crossed Nicols. It is either not at all fibrous, or slightly so, or completely fibrous. The fissures which cut it are generally irregular, and not entirely in right lines. Sometimes they run nearly parallel, and then pass through the fibrous structure nearly at right angles. But with a higher power a system of fine cleavage can be seen, which runs parallel with the fibrous structure. This latter is made apparent by the occurrence of fine parallel light or dark brown lamellæ and needles, but also partly by the existence of very fine cleavage lines. The outlines are very rarely entire, and preserved in lines. They are then quadratic and rectangular forms with imperfect or dulled corners: so that such a section could be produced only by the combination $\infty\breve{P}$. $\infty P\infty$ $\infty P\infty$ $\infty P\infty$ of augite, but not of hornblende. The fibrous structure and the fine linear cleavage run parallel to that line which corresponds to a plane $\infty P\infty$. Occasionally this mineral is more grayish-green, and little dichroitic. In spite of the dichroitic character of this mineral as seen in most of its individual grains, it cannot be considered hornblende, but must be referred to augite, possibly diallage. There are, moreover, in it fluid inclusions with movable bubbles.

(5) Rather frequent grains of magnetite are seen. These are more isolated, and are four or six angled.

(6) Apatite in extraordinary amounts, in fine needles, especially in the plagioclase, has been mentioned already.

(7) Yellow metallic opaque grains are certainly pyrite.

Chemical analysis of augite-dioryte No. 8 from Richmond.

Silica	52.00
Alumina	15.75
Sesquioxide of iron	3.55
Protoxide of iron	12.84
Calcium oxide	7.39
Magnesium oxide	3.42
Potassium oxide	1.24
Sodium oxide	3.37
Water	0.35
Carbonic acid	0.11
	100.02
Phosphoric acid	1.06

Hence it appears that this rock is richer in silica, protoxide of iron, phosphoric acid, and alkali than the foregoing, but poorer in lime, magnesia and alumina. Its combinations must therefore be different. The feldspar here appears the richer in soda, since the high content of soda comes in connection with a much lower amount of alumina. Hence the feldspar may in this case also belong in the acidic portion of the feldspar series. The potash ingredient corresponds to a per cent. of orthoclase at least of 7.33. The high amount of protoxide of iron must be attributed in part to the magnetite present, and partly to hornblende and diallage, because the rock is remarkably poor in magnesia. The large amount of phosphoric acid is a very distinctive character; it requires apatite to the amount of 2.59.

The fresh condition of the rock is evident here also in the small amounts of carbonic acid and water.

The second augite-dioryte from Richmond (No. 8) consists therefore of a compound of plagioclase (with perhaps some orthoclase), hornblende, diallage, magnetite, apatite, very little biotite, quartz and pyrite.

At Little Falls, furthermore, are distinct augite-diorytes, with several modifications, from the same range of rocks, each of which we will particularly describe.

9. *Augite dioryte (a) from Little Falls.* This rock constitutes a granular mixture of plagioclase, which is light-red to white, in small amount, and but slightly lustrous, very abundant black, shining, fibrous hornblende, in large crystals, and bright grayish-green augite, with parallel fibers. The last is also in less amount than the hornblende; it is dull, or slightly shining, and often has a border of shining hornblende. Occasionally, this min-

eral is somewhat more bright and lustrous, and then exhibits a very evident cleavage, which cuts directly through the indistinct boundary which outlines the border of the hornblende prism. These minerals, therefore, are regularly built upon each other, and the augitic mineral is diallage.

This stone contains no magnetite, since nothing can be drawn from its powder with a magnet. Furthermore, titanic iron is not present, inasmuch as in the same powder no metallic residue is found on washing.

Biotite appears only very rarely.

Under the microscope the rock shows the following composition :

(1) Feldspars, which appear mostly as aggregates of smaller crystals. They are generally striated, but often the striation can not be distinguished, especially if they are filled with a gray granular substance. Sometimes there is only a narrow border that is free from this granular structure, while the inner portion is filled with it.

(2) Quartz appears only subordinately, and in small, crowded pieces.

(3) Hornblende is in larger, generally clustered, united crystals, whose outer borders are sometimes regular and sometimes irregular. They are of a greenish-brown color, strongly dichroitic between crossed Nicols, showing brilliant colors, are plainly cleavable, and are rich in inclusions of granular plagioclase and little crystals. Sometimes in polarized light they exhibit twinning lines, by means of which one crystal is separated into two parts placed closely alongside of each other, which show different polarization colors. Sometimes on the border of these are several narrow lamellæ, so that in place of one of the twinning-bands may be seen several very fine color-bands.

(4) Augite appears in the thin section much more abundant than in the hand sample. It is mostly grouped in clusters of several crystals, generally by itself, but sometimes intimately connected with hornblende. It is partly entirely colorless, and partly colored bright green, in one place very pure, and in another having a gray granular substance or dark yellowish-brown spots of hydrated iron oxide, with which indeed it is often wholly filled. It appears either wholly compact, or cut through by numberless clefts, which are sometimes parallel, but also run sometimes very irregularly. The augitic mineral is but little or not at all dichroitic,

shows bright polarization colors, is very frequently perfectly fibrous, and has irregular outlines.

(5) Here and there appear short prismatic crystals, about 0.18 mm. thick, with regular six-sided outlines, and often numerous diagonal cleavage-lines parallel to the plan oP, which would hardly be taken at the first glance for apatite, because they are short and thick. Inasmuch as this mineral, which is soluble in acids, gives no cubic precipitate of salt with concentrated hydrochloric acid, but with sulphuric acid a lime reaction, and with molybdic acid a phosphorous reaction, it must be apatite. Slender crystals of the same, moreover, also occasionally are found.

(6) Some black metallic grains, very sparsely distributed, and of irregular form, are probably magnetite or titanic iron.

The chemical analysis of the augite-dioryte, No. 9, gave the following :

Silica	46.52
Alumina	13.87
Sesquioxide of iron	3.71
Protoxide of iron	8.79
Lime	11.00
Magnesia	10.04
Potash	1.01
Soda	2.13
Water	1.05
Carbonic acid	0.47
Total	98.59
Phosphoric acid	0.32

The rock is, therefore, a very basic one, notwithstanding its content of quartz, and is remarkable for its high percentage of magnesia, lime, and protoxide of iron, owing to the predominating abundance of hornblende. But since generally hornblende contains more magnesia than lime, and diallage is present in too small quantity to lay any claim to the amount of lime indicated, a part of the lime must belong to the plagioclase. Hence it might be concluded, from the petty amount of quartz seen in the thin section, that the plagioclase comes nearer anorthite than albite. The small percentage of potash in the rock might be referred to the presence of orthoclase, amounting at most to 5.96 per cent.; but is more probably only an accidental ingredient of the plagioclase. The content of apatite amounts to 0.78 per cent. That

the rock is not entirely unchanged is shown by the presence of water and carbonic acid.

The augite-dioryte No. 9, from Little Falls, consists, therefore, of a basic plagioclase (perhaps with some orthoclase) very much hornblende, some diallage, isolated large apatite crystals, a very little quartz and biotite, and a very small quantity of magnetite and titanic iron.

10 *Augite-dioryte (b) of Little Falls.* Like the foregoing, this rock also consists of a granular mass; embracing abundant, brightly lustrous, black hornblende; white to reddish fine grained feldspar on the cleavage planes of which there can be seen generally no twinning lines; scattered gray quartz; occasional scales of biotite, and specks of pyrite, as well as a light-grayish-green to light-brown augitic mineral which has a border of lustrous hornblende, but which is very much changed. For that reason although the relation of its cleavage-planes to those of the hornblende-band surrounding it cannot be learned with certainty, yet it has the appearance here as if the cleavage-planes of the augite cut off the cleavage edges of the hornblende; and hence the mineral can be considered diallage.

Under the microscope can be seen occasionally rather large, apparently pure crystals without any trace of striation. These can probably be considered orthoclase. This mineral embraces sometimes numerous gray or white grains, so thickly crowded that it becomes now translucent. The triclinic feldspars appear in numerous smaller crystals which often are apparently pure, but also are filled sometimes with grayish grains. Quartz appears scattered in larger or smaller kernels embraced between the crystals of feldspar; it is uncommonly rich in fluid-inclusions of many forms, and often with rapidly moving bubbles. The hornblende is of a green-brown color. It is strongly dichroic, and in all respects as in number 9. The augite is rarely visible. It forms the center of hornblende crystals, is either light-greenish-gray, nearly colorless and non-dichroic, or green, granular and fibrous, and then somewhat dichroic; and is cut by irregular fracture lines. Quite common are isolated crystals of apatite, which have a thickness exceeding 0.2 mm. They can be distinguished by the reactions already mentioned. Brown biotite scales, as well as black grains of magnitite or of titaniferous iron, are rare.

The chemical analysis of the augite-dioryte No. 10 gave the following result.

SiO_2	52.35	
Al_2O_3	15.72	
Fe_2O_3	2.90	
FeO	7.32	
CaO	8.98	
MgO	7.36	
K_2O	1.32	(with a small trace of Li_2O)
Na_2O	2.81	
H_2O	1.35	
CO_2	0.23	
	101.34	
P_2O_5	0.30	

The higher content of silica in this rock above the former is in consequence of the greater amount of quartz present. That the amount of orthoclase cannot be very great is shown by the small amount of potash. It reaches therefore not to exceed 7.8 per cent. The lower percentage of lime and magnesia in comparison with No. 9 is in consonance with a somewhat less amount of hornblende, and perhaps also with a lower amount of lime in the plagioclase. The apatite reaches 0.73 of the rock.

Augite-dioryte No. 10 consists therefore of plagioclase, probably some orthoclase, some quartz, much hornblende, a littte diallage, a very little apatite, biotite and magnetite or titanic iron.

11. *Augite-dioryte (c) from Little Falls.* Makes a medium-grained mass of white, triclinic feldspar whose striation cannot always be distinguished; abundant hornblende; bright grayish-green to bright-green diallage, which appears to be present in but small amount, and rather frequent brown scales of biotite.

Under the microscope it can be seen that the feldspar is generally striated, and that it is pure and clear only about its edges, but its interior is filled with granular substance; that quartz is but seldom present, and the hornblende is the same as in Nos. 9 and 10. The diallage is colored light-green, or flecked with light and darker green. It is sometimes as grains in the center of hornblende, sometimes regularly connected with it, and sometimes existing alone in the feldspar. Sometimes the external borders of the crystals are formed so sharply that they could be measured. The angle found amounted to about 137°, which answers to the angle $\infty P : \infty \breve{P} \infty$ of augite. The diallage is not in the least dichroic; it is cut by fissures that run sometimes parallel to the long axis of the

crystal, and sometimes in every direction. Diallage here is found in remarkably large amount, so that it falls but little below hornblende. Sometimes are seen bright greenish brown scales of biotite; finally, apatite appears in short thick crystals, and long slender needles.

The augite-dioryte, No. 11, differs, therefore, from No. 9 and No. 10, especially in its richness in diallage.

12. *Feldspathic augite-dioryte (d) from Little Falls.*—This rock consists macroscopically, of a medium-grained mass made up of an abundant white or grayish-white feldspar, which appears very dense ; that is to say, like a dense mass of very fine grains of feldspar, and of black, brightly lustrous elongated crystals of hornblende, which, however, is less abundant than the feldspar. Mingled with both these principal ingredients is a bright green augite, which forms the central kernel in the hornblende grains. Unfortunately, the cleavage of the augite is not sufficiently evident to show with certainty whether there is a regular passage in the hornblende. Quartz and biotite are not present.

Under the microscope it can be seen at once that the feldspar consists constantly of very numerous small crystals intact on all sides, generally showing a clear, bright, narrow border, and an impure center filled with a gray granular substance. Border and center are sharply defined, especially in polarized light, and the boundary corresponds exactly with the outer surface. Both are triclinic uniformly, and it is seldom that no twinning-striation can be distinguished.

Embraced between the feldspar crystals can be seen, much more rarely, isolated segregations of quartz, which contain fluid-inclusions with moving bubbles.

The hornblende appears brownish-green, is strongly dichroic, and suffers on all sides from the encroachments of the forms of the feldspar crystals, so that but few opportunities are found to see the natural borders of the hornblende itself. Many crystalline grains of plagioclase are also included.

The augite is quite colorless, or light-green. It appears only as kernels within the hornblende, and is pierced with fissures that are nearly parallel, or wholly irregular, It is not dichroic, generally very pure, but embraces dark, granular impurities along some of its fissures and on its edges. The surrounding band of hornblende generally is complete for each individual.

Apatite appears, sometimes in thick and sometimes in needle shaped crystals, which often are in groups.

Small scattered grains that are opaque and have a metallic luster, are probably magnetite or titanic iron.

The chemical composition of augite-dioryte No. 12 is as follows:

SiO_2	51.27	
Al_2O_3	23.72	
Fe_2O_3	1.35	
FeO	3.81	
CaO	10.50	
MgO	3.30	
K_2O	0.65	
Na_2O	3.35	(with a very small trace of Li_2O)
H_2O	1.23	
CO_2	0.35	
	99.53	
P_2O_5	0.37	

This rock contains, notwithstanding its scattered grains of free quartz, only a low percentage of silica. The high percentage of alumina and lime corresponds with its large amount of lime-feldspar; that this is not anorthite is declared by the percentage of soda. The plagioclase hence comes very near labradorite. Orthoclase appears to be wanting—the small amount of potash could be embraced in the triclinic feldspar; it would at the most require a percentage of 3.84 of orthoclase. The small amount of magnesia gives a datum for calculating the amount of hornblende in the rock. Apatite reaches 0.90 per cent. Notwithstanding its very fresh appearance, this rock still has evidently some contained water and carbonic acid.

The augite-dioryte No. 12 consists, therefore, of plagioclase, hornblende, augite (probably diallage), a little quartz, very little magnetite or titanic iron, and apatite.

According to the foregoing the augite-diorytes consist, in general, of a combination of plagioclase, which approaches nearest to labradorite (perhaps with some orthoclase), hornblende, which very commonly is associated with and regularly changed into diallage, biotite, magnetite (perhaps occasionally a little titanic iron), and apatite; along with which only a very small amount of quartz is also embraced. The rock approaches hornblende-gabbro, but is very poor in augite; which, however, can be observed in the form of diallage though not in all cases, while true hornblende-gabbro contains very distinct diallage in noticeable quantity, as well as a large amount of magnetite and titanic iron, which is not the case with augite-dioryte.

Accompanying the diorytes from Little Falls (and appearing in that vicinity) is a rock which perhaps is only a modification of the same species, though it differs from them in several particulars; so that it possibly may be pronounced another rock. More exact investigation in the region and *in situ* can alone determine this. It therefore will provisionally be classed as an augite-dioryte.

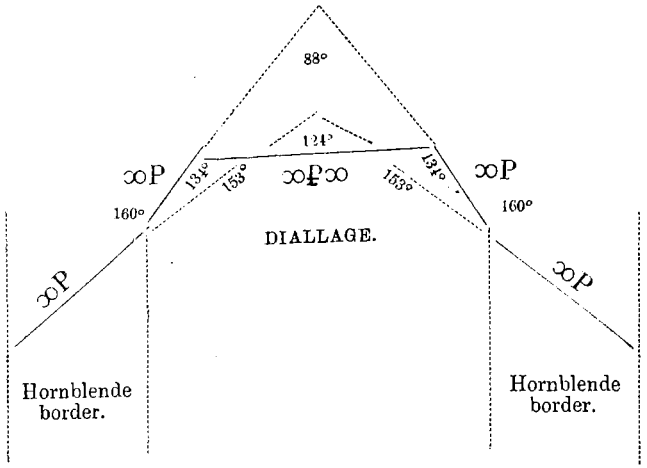
13. *Augite-dioryte (e) from Little Falls.*

This singular rock appears, macroscopically, to consist of a medium-grained assemblage of the following minerals:

(1) Feldspar grains of a bright yellowish-gray, or dirty-white color, sometimes reflecting the light brightly, though principally but slightly lustrous; for the most part with evident twinning-striation, rarely without it.

(2) Diallage. This mineral is present in very large amount, sometimes in rather small grains, sometimes also in large individual crystals, with four angles, eight to ten millimeters in size. It is of a light green, or brownish-green, or yellowish-green color, lustrous or but slightly so, often only shimmering; it fuses with some difficulty in thin slivers, under a feeble flame, to a grayish-green glass; and possesses three rather evident cleavage-directions. Those two that are less evident form with each other an angle of about 88 degrees. That which is most distinct cuts directly across the apex of the other two, that is, it forms with each of them an angle of about 134 degrees. Should the two former planes be considered ∞P, then the principal cleavage-plane would be equal to $\infty \breve{P} \infty$, as is the case in other diallages. The fusibility of the mineral prevents its being styled enstatite; if it were hypersthene it would be fusible with more difficulty, also the color of the bead would show a high content of iron, which is not the case. It must therefore be pronounced diallage, of which, it is true, the principal cleavage-plane is generally far more perfect than in this mineral, while the tendency of cleavage in accordance with the columnar planes is usually hard to distinguish, though here it is quite prominent.

This diallage here never appears alone, but it is constantly furnished with a lustrous brownish-black border of hornblende, which grows upon the central grain of diallage in such a manner that the cleavage-plane $\infty \breve{P} \infty$ of the latter exactly forms a right angle with the columnar planes of the hornblende — that is to say, forms an angle in both directions with the cleavage-planes of the hornblende of about 153 degrees, while these latter make external angles of 160–161 degrees with the cleavage-planes ∞P of the diallage, as can be seen in the following diagram:



The width of this border of hornblende is very variable; sometimes it is very narrow, in other places it is wider, even so wide that but a very small nucleus of diallage remains. Here obviously the hornblende results from the diallage, and it is possible that wherever hornblende, in the rock, exists without a central grain of diallage, it may also have been produced from diallage, because it differs in no respect from the hornblende borders. Unfortunately, it was not possible to extract a sufficient quantity of the diallage, free from hornblende, for analysis of each separately.

(3) Hornblende. This appears sometimes alone, and sometimes as borders about the diallage. It is present in large quantity, of a brownish-black color, brightly lustrous, fibrous, and plainly cleavable.

(4) Biotite, in numerous, brightly-lustrous scales, of a dark-brown color.

(5.) Quartz can be distinguished with certainty, in light gray grains.

The microscopic examination gave the following result:

The feldspars, in by far the greater number of cases, are marked by very beautiful, remarkably distinct, lines of twinning striation. They are tolerably pure, and contain generally only small, irregular specks and scales, but at the same time also granular aggregations which often form an inner nucleus with a distinct outline, parallel with the outer clear border, and especially when the twinning lines are wanting. Sometimes these crystals, particularly

the impure ones, are formed of successive layers, each layer being very thin, placed over each other like numerous laminæ ; which have the deceptive appearance of a twinning striation; and since the stone has a high percentage of potash, one would be justified in considering these feldspars without twinning lines as orthoclose.

The hornblende is brown, sometimes also green, in the latter case impregnated with viridite, strongly dichroic, cut either with parallel cleavage, or with systems of cleavage, that make an angle with themselves of about 125 degrees. The outlines of the hornblende are sometimes very irregular; especially in the larger grains that are associated with diallage ; for the most part exhibit the forms of long, slender, rather straight crystals (cut lengthwise,) in which, however, cannot be seen the characteristic form of hornblende ; sometimes thin sections appear, though not often, accidentally parallel to oP, in which the sides run parallel to the cleavage lines, which intersect each other at 125 degrees. These are, therefore, forms that are peculiar only to hornblende, and they cannot be present in augitic minerals. Such hornblendes, therefore, are in no case secondary products of change from augite, because they are present in their own forms.*

Diallage is visible almost entirely as internal central grains within the hornblendes. It is then colored very light-green, or is colorless, but sometimes also darker green by reason of a mingling of viridite; it is not dichroic, but shows between the Nicols bright polarization colors. It is cut by fissures which seldom are parallel to each other, but for the most part run very regularly. The hornblende borders either form somewhat large crystallites lying thickly upon each other, or consist of a fibrous collection mingled with diallage and filled with viridite, or they are formed very perfectly so that the individuals that constitute them have everywhere a parallel position. The regular outline is lost where it adjoins the diallage, as it is continually and very irregularly changing outward and inward, in proportion as the hornblende encroaches more or less on the augite; indeed it advances along the fissures very much like veins far into the interior of the diallage, so that one cannot escape the conviction that the hornblende is here a product of change from the diallage. This conviction might also be made more general, so as to hold the smaller hornblende crystals as completely changed augite; contrary to which however the fact remains that these smaller hornblende crystals have their own independent forms.

* Compare, however, more recent statements by Prof. Irving.—*Am. Jour. Science and Arts*, 1883.—N. H. W.

It is necessary therefore to conclude that the hornblende in this rock is sometimes an original and sometimes a secondary product.

The diallage sometimes is twinned, several wide laminæ alternating with each other conformably to the orthopinacoid. Parallel to this twinning the first fissures run.

Magnetite, or titanic iron appears but very rarely.

On the other hand quartz is rather abundant, embraced between the straight borders of the feldspar crystals. It is also here very pure, and contains fluid-inclusions in which, however, but very rarely can be seen any moving bubbles.

The apatite crystallites are narrow and long. as well as short and wide, and rather abundant. The latter would be known as apatite by their chemical reaction.

Biotite is known by its dark greenish-brown, entirely non-translucent plates, which have always an irregular outline.

The augite dioryte No. 13, from Little Falls has the following composition :

SiO_2	56.49	
Al_2O_3	17.49	
Fe_2O_3	3.51	
FeO	3.72	
CaO	6.64	
MgO	4.01	
K_2O	3.20	(with a trace of Li_2O)
Na_2O	4.49	
H_2O	1.14	
CO_2	trace	
	101.19	
P_2O_5	0.18	

Here it appears, at the outset, that this rock no more belongs to the class of basic rocks than the foregoing rocks, but, indeed, has a content of silica somewhat higher, because, as has been found, it possesses a notable amount of free quartz. The small quantity of iron is due to the presence of a little magnetite or titanic iron. Very noticeable is the high percentage of potash, which, if it were turned entirely to the formation of orthoclase, would supply to the rock a percentage of 18.92 of this mineral, which would be nearly one-fifth of the whole. But the microscopic examination teaches that by far the largest part of the feldspar is plagioclase, and that

only a few of the larger crystals consist of orthoclase. Therefore, it appears that a large part of the potash must belong to the plagioclase. The small amount of lime seen in the rock is divided between diallage and hornblende on the one side, and the plagioclase on the other. To the latter, therefore, belongs only a portion of the lime present, but nearly the whole of the soda, amounting to 4.49 per cent., to which also a part of the potash must be added. The plagioclase, therefore, which composes a predominant portion of the rock, is rich in alkali, and comparatively poor in lime; it will, therefore, come nearer to albite than to anorthite, and it would not be amiss if it should be reckoned as oligoclase, or perhaps, as andesite. That diallage and hornblende are less in amount than feldspar, is shown by the low percentage of magnesia. As there is almost no magnetite nor titanic iron, nearly the whole of the iron-oxide is due to the diallage and hornblende, which also lay claim to a part of the lime, and very likely, also a part of the soda. Apatite reaches 0 44 per cent.

The augite-dioryte (e) from Little Falls, No. 13 consists, therefore, of plagioclase (oligoclase or andesite), some orthoclase and quartz, of hornblende and diallage, intimately associated with each other, biotite, a very little apatite, magnetite or titanic iron. The rock is distinct therefore, in its mineralogical and chemical composition, from the other augite-diorytes from Little Falls by reason of its high per centage of silica, its comparative richness in quartz, its content of potash and orthoclase, as well as of oligoclase and and esite, while the rocks of the vicinity contain labradorite, at least a basic plagioclase, and finally by reason of its greater richness in diallage. In consequence of which this rock is related to hornblende-gabbro by reason of its diallage, to augite-quartz-dioryte by its containing quartz, but to the syenitic rocks by its containing quartz and orthoclase. Therefore there might be a temptation to separate it from the augite-diorytes, as a different rock, standing between syenite and gabbro. The fact that the augite-diorytes from Little Falls are themselves very changeable in their composition. and that the rock in question appears to be associated with them, was sufficient, instead, to determine us to unite it *provisionally* to the augite-diorytes.

IV. QUARTZ-DIORYTE.

This rock occurs at Sauk Center and Little Falls, at the latter

place, though, only in a few limited courses in the midst of mica schists.

14. *Quartz-dioryte from Sauk Center.* This comprises, macroscopically, a medium grained mixture of the following minerals.

Feldspar is generally grayish-white, sometimes brightly lustrous, but generally dull and not very fresh. Wherever the principal cleavage-plane is sufficiently bright the twinning-striation can be seen, and hence the feldspar seems to be triclinic.

Quartz is abundant in gray, irregularly shaped grains.

Hornblende is of a dark brownish-black color, but not so strongly lustrous as other fresh hornblendes. It is fibrous, and only rarely appears in independent grains, but generally in groups. In amount it is about the same as the feldspar.

Titanic iron is in very small, dark gray, nearly black, grains, with a black metallic luster. In order to determine this mineral with care the powdered rock was carefully washed. The last remaining grains, with metallic luster, were, it is true, somewhat magnetic, but they gave before the blow-pipe an evident titanium reaction, and were entirely insoluble in muriatic acid.

Pyrite in scattered specks.

Epidote in secretions that are small, scattered, and of a bright green color.

The microscopic examination gave the following :

The feldspar is for the most part only translucent, and is filled with a white granular mass. These granular inclusions also generally obscure the color lines in polarized light, which, nevertheless, here and there come out very evident. The mineral therefore might be taken either for a triclinic feldspar or orthoclase. But the latter certainly can be present in only very small quantity, on account of the small percentage (1.02) of potash found in the aggregate analysis. But the feldspar contains, besides the fine white grains, also very numerous green grains and scales of a substance like viridite.

The hornblende appears in dark-brown, or greenish-brown individuals generally bounded by right lines, or irregular groups of the same. It is strongly dichroic, cut by numerous cleavages, which are parallel or so directed as to intersect each other at obtuse angles. Sometimes it shows itself in linear or nettedly-fibrous aggregates, which often are crowded with viriditic substance. This granular viriditic substance also encroaches on the hornblende in so large masses, in some parts, that it is no longer recognizable. The

hornblende here also sometimes contains frequent cavities with movable bubbles.

It would seem as if here also, in some of the hornblendic grains, an augite center exists, and in some cases the center acts, especially in polarized light, differently from the border. But, as in these cases the inner portion is often filled with viridite, it is impossible to know the presence of augite with absolute certainty, though it can be considered very probable.

The quartz is embraced between the feldspar and hornblende crystals in considerable amount, but appears also sometimes in original hexagonal outlines. It contains rarely numerous pores and little sacks, with movable bubbles, or with colorless cubes, or with both at the same time; rarely with many needles of apatite, and sometimes inclusions of viridite.

Epidote is of a light greenish-yellow color, and at the same time but little dichroic, but shows between the Nicols lively polarization-colors. In direct light, it appears yellowish-white. Generally it is pierced by numerous irregular, very fine cracks and cleavages, and often is tolerably pure; yet very often grains of viridite show themselves, sometimes entirely filling it. Likewise, sometimes, brownish-colored or fine gray grains are very numerous in it. The outer boundary of the epidote is very seldom straight, but on the contrary, very jagged.

The titanic iron is quite often in six-sided individuals, sometimes in groups.

Also, apatite is in comparatively large amount, being, indeed, in all parts; it is sometimes in fine needles, sometimes in rather large crystals, over two-tenths of a millimeter long and seven-hundredths of a millimeter wide, or in hexagonal thin-sections. Not only does the angle P : ∞ P, which many times was determined at about 130 degrees, identify this mineral as apatite, but also its chemical reaction. The larger crystals are not pure, but show numerous small cavities, though without bubbles.

The chemical composition of the quartz-dioryte No. 14, is as follows:

SiO_2	56.59
Al_2O_3	12.41
Fe_2O_3	5.39
FeO	10.28
CaO	6.70
MgO	2.02
K_2O	1.02

Na_2O	4.27
H_2O	1.45
CO_2	trace.
	100.13
P_2O_5	0.44
TiO_2	0.22

The following conclusions result from this analysis :

The low percentage of potash points to a small per cent. of orthoclase (at most 6.03), if all the potash is not embraced in with the triclinic feldspar. The comparatively high percentage of soda, and the small amount of lime, which latter belongs in part to the hornblende, the epidote and apatite, point conclusively to the presence of a feldspar rich in soda and poor in lime, which therefore will come near to andesite or oligoclase. Although the hornblende is present in notable amount, yet there is only a low percentage of magnesia. It must therefore be poor in this respect. But, also, it cannot contain much lime, which is claimed partly by the other minerals. Consequently it must be very rich in iron-oxide, and perhaps contains also some soda. Very remarkable is the low percentage of silica, notwithstanding the presence of a notable amount of quartz. This can only be accounted for in that the hornblende is poor in silica, and that through the presence of titanic iron the percentage of silica of the whole rock is reduced. The apatite amounts to 1.07 of the rock. Without regard to the appearance of the individual minerals, the water present amounting to 1.45, shows that the rock is no longer entirely fresh.

The foregoing examination teaches that the quartz-dioryte No. 14, from Sauk Center, consists of a mingling of plagioclase (andesite or oligoclase), hornblende (apparantly sometimes with an augitic center), and quartz, in medium-sized grains, with which are found, in subordinate amounts, orthoclase (doubtfully), epidote, titanic-iron, apatite, and a very little pyrite.

15. *Quartz-dioryte from Litlle Falls.* This rock consists, macroscopically, of a coarse-grained mixture of the following minerals.

(1) Black hornblende. The crystals are frequently perfectly formed, so that notably the planes ∞P and $\infty \breve{P} \infty$ are nearly everywhere plainly visible, according as one or the other is displayed tabularly, while the terminal planes are wanting. They are fibrous, and therefore but slightly lustrous, or merely shimmering. Before the blow-pipe the hornblende fuses, after a slight intumescence, to a black glass.

(2) A dense fine-grained gray mass, apparently consisting of an impure, dense, or rather fine grained crystalline feldspar, which only fills the interstices between the hornblende crystals.

(3) Quite frequently are seen scattered, well formed rhombic dodecahedrons of brownish-red garnet.

The pulverized rock contains no trace of a magnetic substance. In the slime appear no heavy, black, metallic grains, but only light flakes of biotite.

With the microscope, the following can be discerned :

(1) The hornblende crystals are very sharp, and wholly bounded by right lines. They are sometimes of a greenish brown color, and then they are strongly dichroic; or they are green, and appear flecked, apparently impregnated with viridite, and then they are less dichroic, but yet more strongly than the augite. A difference between the inside and the outer border cannot be discovered. This hornblende is now possessed of numerous inclusions, among which appear, particularly, colorless angular kernels of quartz, as well as of feldspar. Hence, the mineral appears, especially between crossed Nicols, like a sieve, in which the hornblende looks very black, but the abundant included grains shine out in variegated colors. The hornblende is cut sometimes by parallel cleavage running lengthwise, and sometimes by very fine irregular fissures.

(2) Between these regularly developed crystals of hornblende is a fine-grained aggregate of quartz, feldspar, and of little black angular grains, that are sometimes also brown. The quartz grains are small, very clear, and with very few cavities. The feldspar makes little irregularly angular kernels which cannot be distinguished, as to whether monoclinic or triclinic. What the abundant opaque black specks consist of could not be determined more exactly. The translucent brown grains, or blades, certainly were biotite. Very slender, minute needles of apatite were very sparingly visible.

(3) Regularly six-sided, or quadratic, bright red crystals of garnet. It is penetrated by irregular fissures, and embraces irregularly-shaped gray grains, and also cavities of the same form.

(4) There are also a very few scattered black metallic secretions, perhaps some of titanic iron, the forms of which are very various.

The following shows the chemical composition of the quartz-dioryte No. 15, from Little Falls :

SiO_2	66.88
Al_2O_3	11.69

Fe_2O_3	1.68
FeO	8.94
CaO	5.45
MgO	3.55
K_2O	0.20
Na_2O	1.25
H_2O	1.03
CO_2	trace.
P_2O_5	trace.
	100.67

Very remarkable is the high per cent. of silica in this rock, which in connection with the low per cent. of alumina, shows that it is poor in feldspars and rich in quartz. That the feldspars are plagioclase is evident from the very low percentage of potash. As the rock contains very little magnesia and lime, but still much hornblende, this latter must be very rich in iron; perhaps it contains also, further, alumina and soda.

The quartz-dioryte No. 15, from Little Falls, consists, therefore, of a mixture of large hornblende-crystals, between which is embraced a fine-grained aggregate of quartz, plagioclase, black grains and biotite. In it are found a few perfectly formed crystals of garnet, alongside of which the hornblende outlines fall away, and more rarely a very little apatite. Everywhere this rock appears in such relations as leave it doubtful whether it can be considered as an independent rock-formation.

V. AUGITE-QUARTZ-DIORYTE.

16. *Augite-quartz-dioryte (a) from Watab.*

Macroscopically this rock appears as a medium-grained mass made up of: —

(1) Triclinic feldspar of bright luster and very distinct striation; (2) orthoclase, very fresh, and sometimes faintly red; (3) irregular gray quartz grains; (4) scattered black scales of biotite: (5) greenish-black hornblende, not very bright, but in about equal abundance with the feldspar. Upon closer examination of the hornblende grains they can be seen frequently to contain a center of a different nature. This is of a green color, shows no luster at all, though having a shimmering surface passing to dull, and possesses a more distinct cleavage, which forms an angle of

about 153 degrees with the cleavage of the surrounding hornblende. The cleavage of the center therefore truncates the broad columnar edge of the hornblende; and hence here also the center consists of diallage,

Under the microscope can be seen, in the quartz, which is very abundant, along with the needles of apatite and crystallites, little fluid inclusions with and without bubbles, which often are in very lively movement. The orthoclase is rather impure by reason of many gray included grains; the same is true of the plagioclase the striation of which often appears particularly distinct by reason of lines of black specks. The biotite is in brown-translucent or opaque scales. Magnetite, or titanic iron, is rare. The hornblende constitutes light to dark brown crystals, that are cut by parallel cleavage but with imperfect outlines. Larger hornblende forms possess a center of augitic mineral, that is diallage. This is colored light yellowish-green, but becomes impure by reason of fine brown or opaque granular flecks, or even by brown-translucent scales of biotite or green grains of viridite. sometimes, distributed among these, can be seen little reddish scales with a faint metallic luster. It is wholly non-dichroic, sometimes is pierced by entirely systemless fissures, or is again very fibrous so that in its larger masses it looks like an assemblage of lighter and darker parallel fibers. Occasionally this mineral becomes dark green along the edge, and then passes into hornblende which everywhere encloses it. The surrounding hornblende sometines looks like an individual srystal, and makes hence no distinct line of separation from the diallage. Since this line appears distinct only in polarized light, it is then plainly seen to run out and in irregularly. Apatite appears in all parts, in slender and also in thick crystals.

Chemical composition of the augite-quartz-dioryte (a) No. 16, from Watab.

SiO_2	65.27
Al_2O_3	15.76
Fe_2O_3	1.36
FeO	3.44
CaO	3.70
MgO	2.14
K_2O	3.97
Na_2O	4.57
H_2O	0.42
	100.63
P_2O_5	0.26

From this it follows that the rock is still very fresh, inasmuch as it holds but little water, and no carbonic acid; further, that it must be placed with the acid rocks, that is to say, it accords in its composition with typical syenites, and especially in this respect comes near to the syenite-granite from Watab. The high percentage of silica is produced partly by its richness in orthoclase, and partly by its free quartz. The high content of soda of this rock, in connection with the low per cent. of potash, shows that the plagioclase will have to be one rich in soda and poor in lime, especially as a part of the lime is absorbed in the hornblende and the augite. But both these minerals can be present in comparatively small amounts, on account of the small per cent. not only of lime, but also of magnesia. The percentage of apatite reaches 0.59.

Notwithstanding this rock in its chemical composition is comparable with the syenite-granite from Sauk Rapids, yet its mineral composition shows a distinction from it. In the first place, it is the plainly visible presence of an amount of diallage in which the foregoing rock differs from syenite-granite. Further, its content of soda is greater than its potash, and the triclinic feldspar is paramount over the monoclinic. On the other hand, this rock differs from the augite-diorytes conspicuously in its content of free quartz, and from the quartz-diorytes by its containing orthoclase and diallage. It must, therefore, be separated from the above-named classes, as augite-quartz-dioryte. It could with equal reason be designated augite-quartz-syenite, so as to bring out its affinity to the syenites. But since a hornblendic rock with abundant plagioclase and a small amount of othoclase, is recognized as dioryte, and one with much orthoclase and little plagioclase, as syenite, it will be appropriate to designate the foregoing rock as an augite-quartz-dioryte.

The augite-quartz-dioryte (a) No. 16, from Watab, therefore, consists of a medium-grained assemblage of the following: plagioclase (oligoclase) orthoclase, quartz, hornblende, often furnished with a central nucleus of diallage, a little biotite, and a very little apatite, and magnetite or titanic iron.

17. *Augite-quartz-dioryte (b) from Watab.* This rock presents a somewhat different aspect from the last.

Macroscopically it seems to be a coarsed-grained collection of the following minerals: (1) red orthoclase; (2) white or reddish plagioclase, which is in greater amount than the last; (3) gray quartz in very irregularly shaped masses; (4) black hornblende which is present in large quantity. The crystals of this are gen-

erally fibrous and sometimes wholly filled with biotite. In it also are seen here and there little metallic grains in considerable amount. The crystals of the hornblende are rather strongly lustrous, but very frequently contain, within a lustrous border, a dull greenish-brown center with a cleavage that lies as the orthopinacoid of the hornblende, in which case it is possible to measure the angle which the prism-faces of the hornblende make with the cleavage of the central grain, amounting to 150–153 degrees. This center here also plainly consists of an augitic mineral with a very conspicuous cleavage, namely diallage. The fifth (5) ingredient is therefore diallage. (6) Biotite; this is found in scattered brown scales or in slightly lustrous aggregations, the latter when it encroaches on the hornblende: (7) Metallic grains, which appear sometimes in octahedrons, are magnetite; (8) Occasionally, even under the lens, long needles of apatite are distinguishable, both in the feldspar and in the hornblende.

By a microscopic examination the quartz is shown to be present in large amount. It contains many fluid inclusions, very often with movable bubbles. The feldspars are completely overstrewn and filled with grayish-white grains, so that they are often hardly transparent. As, therefore, the striation is obscured, it is impossible to determine whether orthoclase or plagioclase predominates. On the other hand, the twinning-striation frequently is indicated with the greatest distinctness; inasmuch as the included impurities, which consist either of fine grains, or of long, slender, slightly colored blades, that cut each other alternately like wedges, run in parallel lines, and by the regularity of this parallel arrangement give perfect expression to the twinning-striation. The hornblende crystals are greenish-brown or brown, and strongly dichroic, cut by parallel cleavage, and of irregular outlines. Sometimes they are penetrated by green viridite. The augitic mineral is generally in light-brown or dark-green crystals, but little dichroic, often very fibrous, and nearly always surrounded by hornblende. Between crossed Nicols, the fibrous structure becomes especially distinct as an irregular color-striation. This diallage is also often filled with viridite; and, further, it contains grayish-looking granular groups of elongated form and parallel structure, as well as dark-brown elongated entirely rod-like crystals, which likewise lie parallel. The hornblende border is sometimes very thin, and sometimes so wide that the diallage-nucleus occupies but a very small space. Sometimes this border is very regular, in so far as it pertains to a single individual. Often no distinct separation between

the two minerals can be seen; it only appears in polarized light. Magnetite (or titanic iron) is in scattered grains or in irregular clusters, generally in connection with the hornblende. Biotite forms dark-green to brown, translucent or opaque plates. Apatite is evident in numerous large needles; and, finally, epidote and pyrite are very rarely seen.

The augite-dioryte (b) from Watab, No. 17, forms, therefore, a coarse-grained collection of plagioclase, orthoclase, quartz, hornblende, diallage; and connected with this, *biotite, magnetite (or titanic iron) and apatite, and very rarely epidote and pyrite.*

VI. SYENITE-GRANITE (HORNBLENDE-GRANITE).

This rock occurs at Sauk Rapids, St. Cloud, Watab, and Rockville on the Sauk river.

18. *Syenite-granite (a) from Sauk Rapids.* This rock consists, macroscopically, of a medium to coarse-grained collection of, (1) red and sometimes nearly colorless orthoclase, in which the cleavage surfaces are rather bright; (2) white, brightly-shining, triclinic feldspar; both these feldspars are very abundant; (3) quartz in the form of frequent gray grains; (4) scattered scales or clusters of brownish-black biotite; not frequent; (5) common hornblende, of a black color, in separate crystals, of irregular outlines, or in groups, often mixed with biotite. This hornblende, besides, plays only a subordinate role.

Microscopically one observes:—

(1) Orthoclase. This is very impure, often completely filled with very fine powder which consists of irregular brown and gray grains, but is not uniformly disseminated.

(2) Plagioclase. This is very often crossed by right lines of a black granular substance parallel to the twinning striation. This feldspar, besides, is everywhere filled with brown and gray grains.

(3) Quartz is present in large amount, in smaller and larger masses, sometimes only filling the interstices between the feldspar grains, and sometimes in apparently independent forms. It contains many fluid inclusions, with movable bubbles, more rarely long needles or short thick crystals of apatite, black specks, brown or greenish scales, and larger colorless crystallites with quadratic or rectangular cross-section.

(4) Dark brown to greenish-brown very dichroic hornblende, not very abundant. Sometimes this is completely opaque, and then appears black but with no metallic luster, and therefore filled with an opaque non-metallic substance.

(5) The plates of biotite are very seldom seen. They are mostly confined to the vicinity of the hornblende, and are concealed by the opaque masses.

(6) Magnetite in scattered grains (apparently octahedrons) is not abundant, and also adheres mostly to the hornblende.

(7) Apatite occures in nearly all the minerals in the form of long and short, thick and slender, crystals, which often show the planes oP, ∞P and P; also hexagonal cross sections are visible; these crystals are always very pure.

(8) Small, greenish-brown, pyramidal crystals, which were not more exactly determinable, come very rarely into view.

The chemical composition of the syenite-granite (*a*) from Sauk Rapids, No. 18, is as follows: —

SiO_2	67.70
Al_2O_3	16.11
Fe_2O_3	2.47
FeO	2.29
CaO	2.89
MgO	1.11
K_2O	4.47
Na_2O	3.64
H_2O	0.83
CO_2	trace
	101.44
P_2O_5	0.13

The high percentage of silica answers to the presence of a large amount of free quartz as well as of orthoclase (23.43 p. c.) which is indicated by the 4.47 of potash. Further, again, the tolerably high content of soda which is referable to an amount of triclinic albite, presupposes an equally high content of silica. This triclinic feldspar will come much nearer albite than auorthite, because in comparison with 3.64 p. c. of soda only 2.89 p. c. of lime is found in the whole rock, and a small part of this lime is needed for the hornblende. It would be entirely right therefore to consider the plagioclase as oligoclase. How little the hornblende is, is evident from the small percentage of magnesia and iron oxides, while the latter besides, take part in the forming of the magnetite. Apatite amounts to 0.32.

The syenite-granite (a) from Sauk Rapids, No. 18, consists therefore of a medium to coarse-grained collection of orthoclase, oligoclase and quartz; with which are added, in subordinate amounts,

hornblende, biotite, magnetite, apatite, and, very sparingly, scattered grains which are small pyramidal crystals of a greenish-brown color, not determinable.

19. *Syenite-granite (b) from Sauk Rapids* is a rock of somewhat different appearance, coming from the same quarry. Macroscopically this rock differs from No. 18, only in the greater amount of change suffered by the larger masses of hornblende. These are tolerably soft, and have a light greenish-gray streak. Microscopically, the quartz is noticeable for the great numbers of fluid-inclusions with movable bubbles. At one spot could be seen a bright four-angled grain alongside of a movable bubble, which was tossed about by the bubble. It probably is chloride of sodium. The hornblende is converted partly into a green, viriditic mass, but is sometimes unchanged. In the midst of the dichroic brown hornblende is occasionally seen a nucleus not dichroic, greenish in color and filled with granular substance, which perhaps may be referred to some augitic mineral. A similar appearance is repeated in the same rock from another place.

20. *Syenite-granite from St. Cloud* consists macroscopically of a medium-grained mixture of orthoclase, plagioclase and quartz, as predominating ingredients, among which are seen scattered crystals of brownish-black hornblende in somewhat greater proportions than in the rocks from Sauk Rapids. In addition to these there are also little scales of biotite and occasionally a little pyrite. The larger hornblendes, which afford the identification of the six-sided outline of this mineral ($\infty P \cdot \infty \breve{P} \infty$) and the angle of 125 degrees which the columnar sides make with each other, contain a center consisting of a green chloritic mass surrounded by a thin band of biotite. Between them still is seen hornblendic substance.

The microscopic conditions are like those of Nos. 18 and 19, though here were a few scattered hornblendes in which was a non-dichroic center which perhaps is derived from an augitic mineral.

21. *Syenite-granite between Sauk Rapids and St. Cloud.* This is also very similar to the above named; it contains, as can be seen by the unaided eye, in the greenish-black hornblende, a much decayed mineral of a yellowish-green to brown color, which can be recognized as augite. Very rarely a black mineral whose hardness is 6, can be seen, whose fracture is conchoidal and exhibits a strongly waxy or glassy luster, and which perhaps should be considered allanite or orthite.

22. *Porphyritic syenite-granite from Watab.* This rock has a

medium to a fine grained groundmass, with rather large crystals of red orthoclase which are surrounded sometimes by a band of plagioclase, The granular groundmass consists of quartz, red orthoclase and plagioclase, and greenish-black hornblende in subordinate amount.

Under the microscope the quartz contains numerous very fine fluid cavities, with and without bubbles, more rarely apatite, and green grains of hornblende. The orthoclase is for the most part, but especially in the large crystals, completely filled with brown or gray granular masses, and also embraces kernels and scales of hornblende. Plagioclase is but scatteringly seen. It is also very impure, filled with granular substance. The hornblende exhibits irregular outlines, has a brown or green color, is dichroic, fibrous, and appears mostly in small secretions, indeed principally in grains and scales in the quartz and feldspar. Black opaque grains are probably magnetite or titanic iron. Apatite is in slender needles in all portions.

The following is the chemical composition of the porphyritic syenite-granite from Watab, No. 22 ;

SiO_2	70.05
Al_2O_3	15.04
Fe_2O_3	1.70
FeO	1.09
CaO	1.97
MgO	0.82
K_2O	5.09
Na_2O	4.77
H_2O	0.81
	101.34
P_2O_5	0.07

From which it appears that this rock belongs to the most acidic of this class, and that it is therefore rich in quartz. The orthoclase, reckoned from the content of potash, reaches 30.1 per cent. But the plagioclase is also found plentiful, as seems from the amount of soda present. As, furthermore, the rock contains but little lime this must come nearer albite than anorthite, and hence it is nearest to oligoclase. The low percentage of magnesia and iron-oxides is in accordance with the very small amount of hornblende.

All these rocks, therefore, having the composition of syenite-granite, consist of quartz, orthoclase, oligoclase, with a little hornblende, bio-

tite, apatite, and some magnetite or titanic iron. In the hornblende is sometimes a central mass which might be taken for augite. Sometimes these rocks are porphyritic.

These rocks are placed as syenite-granite or hornblendic-granite, and not syenite, for the reason that hornblende in them is very sparse, while the ingredients of granite are very abundant.

From this examination of the hornblende-bearing rocks of Minnesota it appears, as a common and important result, that there a whole class of basic and acid rocks is found, which, along with hornblende as an essential ingredient, contain also an augitic mineral, which, while subsisting, it is true, sometimes as an independent ingredient, is for the most part intimately connected with hornblende, indeed is entirely conformable to it in its mineralogical developement. This augitic mineral is present not only in the basic rocks, but also in the acidic which contain orthoclase and quartz; in the most acidic, it is true, it is only indicated, its presence here not being proved with certainty. This augitic mineral is found to consist everywhere of diallage, in which the most evident cleavage plane truncates the obtuse columnar edge of the hornblende that envelopes it. The association of these two minerals is one so irregular, the hornblende encroaches in so thin partings into the augitic substance, that one cannot resist the idea that here the hornblende is derived from the augite. The final proof of this view, however, will be produced when it has been pointed out that the outer envelop of the whole crystal takes upon itself the form of augite. Should this proof be attained, then it will be necessary to conclude that other hornblendes which no longer have an augitic center, have resulted from augite, and that in them the change has become completed — that is to say that the rocks under consideration were once still richer in augitic mineral than they now appear.

These rocks with diallage belong consequently to a group of the old rocks recently made known for the first time, in which augite and hornblende exist at the same time. Without mentioning the gabbro-rocks, in which the co-existence of these two minerals has been known for a long time, here belong the syenites from Scharfenstein described by Kalkowsky[1], also the augite-syenite from Monzoni which according to G. von Rath[2] has the hornblende

1 Jahrb. 1876, p. 140. 2 Zeitschr, d.d. geol. Ges. XXVIII. p. 35.

as an accessory ingredient, but according to Doelter[3] in greater quantity than the augite. Von Rath[4] has stated also that at Laurvig a rock appears similar to augite-syenite, and the same investigator reports[5] that at LePrese the dioryte changes into gabbro by acquiring diallage. Here therefore the changed rock would correspond to augite-dioryte. The co-existence of augite and hornblende in the older rocks was also noted by Kürenz[6] in a dioryte at Trier, by Schmid[7] in a labradorite-dioryte from Ehrenberg, by Wiik in a dioryte-porphyry from Nokkala in Finnland, and in a dioryte-diabase[9] from Helsingfors; by Mattesdorf[10] in a monzonyte from the Agnelloberg; by Gümbel[11] in a rock of the Fichtelgebirg, by Tschermak[12] in a diabase from the Caucasus and in the melaphyrs[31] of the Fassathal[14].

VII. HORNBLENDE-LESS GRANITE.

This rock occurs at Watab, and at Coldspring, above Rockville, on the Sauk river.

The granite from Watab, which forms low hills at the entrance to the place, consists of a medium grained collection of quartz, grayish-white orthoclase which for the most part is in large crystals, grayish-white plagioclase and numerous scales of biotite.

The granite from Coldspring is porphyritic. Here lie coarse crystals of reddish orthoclase, white plagioclase and coarse grains of gray quartz, in a medium to fine grained groundmass which consists of quartz, much orthoclase, a little plagioclase and some biotite.

GIESSEN and HANNOVER, August, 1876.

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3 Jahrb. d. k. k. geol. Reichs-Anstalt, 1875, XXV. p. 217. Verh. d. k. k. geol. Reichs-Anstalt, 1875, No 14, p. 247; No. 15, p. 289; No. 16. p 304.
4 Zeitschr d. d g. Ges. p. 353. 5 Pog. Ann. 114, p. 248, Anmerk.
6 This Jahrb. 1876, p. 176 7 Der Ehrenberg, p. 19.
8 This Jahrb. 1876, p. 209. 9 This Jahrbuch, 1876, p. 208.
10 Verh. d. k. k. geol. R-A., 1876, No. 2, p. 33. 11 Dieses Jahrb. 1876, p. 436.
12 Min. Mitth. 1876, p. 132.
13 Porphyr-Gestine Œsterreichs, p. 124. See also Dœtler in Min. Mitth. 1875. p. 179, and Jahrb d. k k. g. R-A. 1875, p. 224.
14 During the correction of the proofsheets I received a very interesting work from Rosenbusch, in which the evidence is given that in the variety of granite described by him as granityte, augite is not very rare, and sometimes is associated with hornblende to a remarkable extent in the granite-porphyries. Z. d. d. g. G. 1876, p. 369.

III.

NOTES OF ROCK-OUTCROPS IN CENTRAL MINNESOTA.

BY WARREN UPHAM.

The following pages record observations of the localities, extent, and most noticeable lithological characters of the crystalline rocks in the central part of the state, mostly in Morrison, Stearns and Benton counties; and of their few outcrops farther northwest in Todd county and the southwest corner of Cass county, and on the east in the northwest corner of Sherburne county and in Mille Lacs and Kanabec counties; with a description, also, of the sandstones and the copper-bearing trappean rocks, which lie next eastward in Kanabec, Pine and Chisago counties. This district is almost entirely drift-covered and heavily timbered. A map of it, showing the rock-outcrops here described, is presented on plate I. The detailed descriptions of the several counties are given in the following order: Cass, Todd, Morrison, Stearns, Sherburne, Benton, Mille Lacs, Kanabec, Pine and Chisago.

A large area in Stearns, Sherburne and Benton counties, including the valuable quarries of Saint Cloud, Haven, Sauk Rapids and Watab, consists of syenite and exhibits no laminated or gneissic structure. It has considerable variety in texture, as to its coarseness of grain and readiness to be quarried and wrought to any required form. Mostly its color is light gray, but upon some extensive tracts it has a red tint, similar to that of the celebrated granite of Aberdeen in Scotland. In other portions of this district, granite, gneiss and mica schist are the common rocks, sometimes associated with syenite. Their strike is usually to the northeast or east-northeast.

At Little Falls and Pike rapids, and for several miles to the south, west and north, as also at the mouth of Fish Trap brook in northern Todd county, is a group of rocks quite different from the

foregoing, its range of variation being from a highly cleavable clay slate, and from a mica schist enclosing many crystals of staurolite and sometimes garnets and iron pyrites, to a very compact and tough, massive dioryte.

CASS COUNTY.

The only rock-outcrops known in Cass county are at Pokegama falls on the Mississippi river, described on page 195 of the ninth annual report; and those of T. 134, R. 32, the most southwest township of this county, about eighty miles southwest from Pokegama falls, and five miles northwest from Motley. The latter were first described by Professor Winchell on page 46 of the sixth annual report. The area of frequently outcropping rock at this locality reaches about a half-mile from south to north, and has a width of twenty to forty rods. It is mostly in the E.½ of the N.E.¼ of section 28, and extends north into the southeast part of the S. E. ¼ of section 21, and perhaps also beyond the lines of these into the adjoining sections 22 and 27 on the east. These outcrops in their southern part have a hight one to three feet, and in their middle and northern part five to eight feet, above the general surface of moderately undulating drift, being 20 to 40 feet above the Crow Wing river, which lies about three-fourths of a mile to the southwest. The only considerable elevation in this vicinity is a hill of glacial drift, extending a quarter of a mile from north to south, situated a short distance east of these ledges, in the west edge of the N. W. ¼ of section 27. This rises 40 to 50 feet above the rock exposures, and about 75 feet above the extensive marsh at its east side. Mainly the surface of this hill, as of the surrounding region, is sand and fine gravel, but boulders of granite up to five feet in diameter are found sparingly at its top and on its sides.

The greater part of the rock exposed here is gray syenite, rather fine-grained, containing both white and flesh-colored feldspar, and a greenish mineral, which last is sometimes most abundant in streaks or veins, up to two inches in width. Rarely two or three of these veins are seen within a foot, giving the rock a somewhat schistose structure. In the middle part of this area some of its ledges are granite, having principally a white feldspar, and including evident lumps of mica and also the green mineral of the syenite.

Two wide dikes of dark, tough, massive, trappean rock were noted. One of these, near the south end of this area, is visible

for an extent of twelve or fifteen rods being fifty to sixty feet wide. The line of contact with the syenite on the northeast side of this dike is very distinct and sharply defined along its exposure two or three rods in extent, bearing S. 50° E. At the second dike, near the north end of these exposures, both lines of contact with the enclosing syenite are visible at many places along a distance of fully two hundred feet, bearing S. 70° E., which is the course of a conspicuous system of joints in the syenite. The width of this dike is thirty feet. From its northern side a branch of irregular course and varying from two feet to three inches in width reaches forty feet northerly, as shown in fig. 2, plate I. At one point seven or eight feet from the main dike, an offshoot from this branch is seen extending several feet with a width from one inch to only an eighth of an inch. The aspect of this dark eruptive rock is nearly the same in all portions; its line of contact, wherever exposed, is very sharply defined; and the syenite adjoining shows no notable difference from that at a greater distance. Some portions of the syenite and granite here may be found valuable for quarrying, which, though several times contemplated, has not yet been undertaken.

TODD COUNTY.

Only two localities of rock in place are known in this county. These are in the townships of Moran and Ward.

Moran. In the channel of the Long Prairie river at the mouth of Fish Trap brook and for a third of a mile along this brook next above its mouth, being in the west part of section 34, T. 133, R. 32, five miles southwest from Motley, are extensive outcrops of dark and tough, nearly black dioryte, resembling that found at "the point," about a half mile south of Little Falls. It is a very compact, coarsely crystalline rock, with no lamination or apparent tendency to split more readily in one direction than another. Some of the large blocks of this stone, lying in the bed of the Fish Trap brook near E. P. Jones' mill, which is an eighth of a mile above its mouth, ring sonorously like an iron kettle when struck by a hammer. This rock forms ledges one to four rods long, rising one to five feet above the water, in the channel of Long Prairie river and in both its banks at the mouth of this tributary, and at a few places for six or eight rods distance both above and below. Its outcrops along Fish Trap brook are seen at many places to Jones' mill, but above this for about a quarter of

a mile are mostly covered by the mill-pond. Farther above, it has no exposure along this brook, which flows over glacial drift with many boulders and frequent rapids. In the vicinity of the mill its ledges occupy a width from two to four rods, and rise about twenty feet above the brook. It is mostly divided by joints from two to ten feet apart; but when Mr. Jones built his dam, he reports that he uncovered an extent of thirty feet of it without a seam. This rock is wholly worthless for quarrying because of its toughness to drill, and more especially because of the difficulty to bring it into any desired dimension. It is very hard to fracture and is evidently very durable.

Frequent outcrops of this rock, of small extent and hight, are reported within the next two miles eastward, in sections 34 and 35 and in the S. E. ¼ of section 36, also probably reaching across the township line, into the edge of the sections next south. Mr. Jones, who has explored this district, thinks that the only exception from the character of the rock as described, is a small belt seen at the the east side of Fish Trap brook, extending from the lumbermen's dam at its mouth a distance of about ten rods along the east shore of the pond. Here a nearly black slate is exposed, having its cleavage vertical or differing from this within a limit of five degrees upon each side. Its strike is N. 55° W., being parallel with the brook. The width of this slate visible is only from five to fifteen feet, and its contact with the neighboring dioryte is not seen.

Ward. The other rock-outcrop in Todd county is ten and a half miles farther southwest, lying nearly at the center of the N. E. ¼ of section 15, T. 131, R. 33, the west township of Ward. It is on land of Joseph Woell, a third of a mile west of Long Prairie river, and an eighth of a mile east of the road from Motley to Long Prairie, which here runs on the west edge of the valley-plain of modified drift. The extent of this ledge is some twenty rods from northwest to southeast, with a width of three or four rods, including several exposures, the longest of which reaches about a hundred feet. Their hight is from four to eight feet above the plain, which is about fifteen feet above the river. This rock, mostly quite uniform in composition, color, and texture throughout this area, is a bright-colored, medium-grained, gray syenite; containing about equal amounts of quartz, whitish feldspar, and dark, nearly black, hornblende; with a somewhat smaller proportion of a light-green mineral (probably epidote), in rather smaller grains

than the foregoing. This seems to be the same mineral with that mentioned in the rock of Cass county, five miles northwest of Motley, and it is present as a principal ingredient of the rock in Ashley, Stearns county; but it has not been noted in other outcrops of these crystalline rocks. The whole ledge here has this mineral in nearly equal amount, the only exceptions being very rare concretions, one to two inches long and thin, composed of a dark-greenish micaceous mineral, and very rare seams or veins, a sixteenth to an eighth of an inch wide and a few feet long, composed of the light-green mineral which is generally disseminated through this rock. The only other vein or variety noted was a mass of coarsely crystalline, flesh-colored feldspar, exposed upon a patch of only about one foot, but probably forming part of a long vein, adjoining which the rock was more jointed and coarse-grained than ordinary. This ledge is generally intersected by nearly vertical joints, from two or three to eight feet apart. It has never been quarried, but will probably be found valuable for common masonry; and dimension stone, six to eight feet long, could be readily obtained. Though nowhere obviously schistose, the grains of this rock are all slightly prolonged in parallelism with each other.

MORRISON COUNTY.

This large and diversified county has many outcrops of the bed-rocks. Their prevailing types through the part of the county east of the Mississippi are granite, syenite, and gneiss. Along this river and farther west they are slate, staurolite-bearing mica schist, and dioryte. The former belong to a group which has its characteristic development in the syenites of Benton and Stearns counties, and in the granites and gneisses of the upper Minnesota valley. Though the geographical continuation of the second group of slate and associated rocks cannot be traced because of overlying drift, their lithological character shows them to be probably connected and of the same age with the slates of the lower part of the St. Louis river and its vicinity. The hydromica schists found in Carlton county near Moose Lake station may also belong to this seeond group.

It seems probable that the slate, staurolitic schist and dioryte of Morrison county, and of northern Todd county at and east from the mouth of Fish Trap brook, form a synclinal axis or basin bounded both east and west by formations of granite, syenite and gneiss.

In describing the ledges observed in Morrison county, these groups are treated of separately, the eastern, mostly granitic and gneissic rocks, which are believed to be the older, being first considered.

Buckman. This is T. 39, R. 30. Its only rock-outcrop, so far as learned of, is on land of A. B. Skinner, in the S. W. ¼ of the N. W. ¼ of section 18, a short distance east of the road which runs on the west line of the township, aud north of a small creek. It is a coarse-grained, reddish syenite, nearly like that which occurs at many places in Sauk Rapids and Watab, Benton county. Several exposures of the rock are seen upon a space of about one acre, the largest being four rods long from north to south, and rising three or four feet above the general surface. Many blocks, four to fifteen feet in diameter, are scattered near.

Rich Prairie and vicinity. Proceeding northward toward the village of Rich Prairie, in Pierz township, the next exposure of rock is found about one and a fourth miles south of this village. It is at the east side of Skunk river, in the S. W. ¼ of section 17, on land of John Stumpf. Its area is equal to about forty feet square, and its hight is ten feet above the river. This rock is a gray granite, containing considerable black mica.

One and a half miles west from the last, and about a third of a mile south of Fish lake, upon the S. E. ¼ of section 13, T. 40, R. 31, is an outcrop of rock extending about fifteen rods from east to west and twelve rods from north to south, rising four or five feet above the general surface. Its eastern part is owned by Nicholas Meyer, and its west part by Anton Rauch. This is a fine-grained, light gray granite, very uniform in texture, with no veins or masses of other rock visible. It is divided by joints into beds one to two feet thick, dipping about 20° S., but it is not cut by vertical joints. It has been only slightly quarried, by Mr. Meyer for cellar walls. This stone has a pleasing color for building and monumental work, and a good degree of strength and durability. It is readily quarried in any dimensions that are ordinarily called for, and is easily cut or hammered. The ledge is valuable for quarrying, and a large excavation may be made without trouble from water, as the surrounding land is the porous sand and gravel of the modified drift; which also affords a nearly level and dry road for hauling the stone away.

About three miles southeast from Rich Prairie, exposures of the bed rock, probably granite, are reported to cover three or four acres, on land of Matthias Neuman, in the S. ½ of the N. E. ¼ of section 22. It has been slightly quarried.

One mile east of Rich Prairie or Pierz, the east bank of Skunk river between forty and eighty rods north of the mouth of Hillman brook, has frequent outcrops of gneiss, rising one to three feet above the general surface and ten to twenty feet above the stream, next to which they occupy a belt about six rods wide. This gneiss contains black mica and flesh-colored feldspar, the latter being sometimes gathered in layers or veins one to three inches wide. All these outcrops are more or less laminated, this structure being nearly vertical. They are all somewhat contorted and jointed. The strike is N. E. or N. 50° E., bearing in the direction of "Granite City," four miles distant, where similar gneiss has extensive exposures.

Along Hillman brook. In ascending this brook, my first observation of rock in place was at its lowest "roll dam," situated about three and a half miles above its mouth, in the north part of the N. W. ¼ of section 18, T. 40, R. 29. This outcrop is at the north end of the dam, and occupies an area about four rods long from north to south, by twenty to forty feet wide. Its southeastern two-thirds are gneiss, nearly like that last described, rather obscurely and contortedly foliated but indicating a N. E. to S. W. strike. This gneiss has much black mica and flesh-colored feldspar, and it is traversed by veins of this feldspar from an eighth of an inch to six inches wide. One of these veins, varying from three to six inches in width, nearly vertical, is visible for an extent of twenty feet in a straight east-to-west course. The joints of the gneiss are from two to ten feet apart.

The northwestern third of this ledge, extending within sight twenty feet from north to south and ten feet wide, is a fine-grained granite, containing much feldspar, which is partly gray and partly flesh-colored. This portion of the ledge is probably part of a dike or mass of erupted rock; it is rhomboidally divided by intersecting systems of joints, which are from two to twelve inches apart.

Ledges occur frequently in the vicinity of the second and third "roll dams," situated respectively about forty rods below and twenty rods above the mouth of the Little Hillman brook, tributary to the main stream from the south. About a mile above the mouth of the Little Hillman brook and a short distance, perhaps a quarter of a mile, above its dam, this stream is reported to flow some twenty rods in a gorge with walls of rock at each side, five to twenty feet high. Also, frequent outcrops of rock are found between these streams from their junction east and northeast to the "big dam" of Hillman brook.

This "big dam" is on the S. E. ¼ of section 35, T. 41, R. 29, about sixty rods west of its east line, and twenty rods south of its north line. Rock-outcrops of considerable extent occur at several places upon each side of the Hillman brook for a fourth or a third of a mile below and along an equal distance above the "big dam." These are gneiss and granite with the same characters as at "Granite City" and in the vicinity of Rich Prairie. Farther east the region drained by this brook and its tributaries has no known exposures of rock.

At the south end of this dam, about 400 feet south of the sluiceways, the gneiss is typical, including much black mica. Its coarse foliation is nearly vertical, with strike varying from N. 25°E. to N. 40° E. At the north end of the dam, 100 feet north of its sluices, the rock is a fine-grained gray granite, with black mica, nearly like that on land of Meyer and Rauch, south of Fish lake and a few miles southwest of Rich Prairie. This granite is here exposed upon an area which extends at least twenty rods east and ten rods west from the dam, and is from three to six rods wide. Mostly it is divided into rhomboidal masses from a few inches to four or five feet in dimension by joints, and no portion seen was sufficiently free from joints to yield large quarried blocks; yet it is quite likely that good quarry-stone would be obtained by excavating a few feet in depth. The texture and rift are nearly the same as south of Fish lake, to which this formation is probably continuous; the rock is equally compact and uniform in quality; and the color, though on the surface here weathered to a dull brownish tint, would probably be the same handsome gray as at Fish lake in deep quarrying.

"*Granite City.*" In the west part of section 21, T. 41, R. 29, on the northwest side of Skunk river, is the site where a steam saw-mill and a considerable town existed during several years next preceding the Indian outbreak of 1862. Its buildings remained empty from that time and were gradually removed or burned, the last continuing till 1873. The nearest farming immigrants are found about a half mile down the river, and from them northeastward the region drained by the upper part of the Skunk river and extending thence to Mille Lacs is an unbroken forest.

The rock outcropping at "Granite City," from which the name arose, is coarse, gray gneiss, containing much black mica. Its strike is from northeast to southwest, and its dip is vertical, or within a few degrees of it, being in some places 85° or 80° to the northwest, and elsewhere the same to the southeast. This rock

forms numerous bare hillocks and ridges, ten to thirty feet above the Skunk river, for a fourth of a mile along its northwest side, and occurring in less amount on its southeast side. It is also seen on the southeast side in an exposure of a few acres, rising ten to twenty feet above the river at a fourth of a mile farther east. All these outcrops, so far as seen, are gneiss, everywhere more or less contorted, often quite twisted and bent in lamination for short spaces, but having throughout a prevailing N. E. to S. W. strike and nearly vertical dip. The Skunk river is here ten to twenty feet wide, and flows in a meandering course among these ledges.

About six miles above "Granite City," on the northwest side of Skunk river, a little beyond where this stream is crossed by the road used for carrying the supplies distributed yearly to the Mille Lacs Indians, rock exposures are reported to cover as large an area as at "Granite City," but to have less hight above the adjoining surface of the drift. This is in or near the northwest corner of T. 41, R. 28.

Near the Platte river. Numerous outcrops of rocks occur within one to two miles west of the Platte river through the six miles next north of Gravelville, which is an enterprising new village, with mills, situated on this river in the N. E. ¼ of the N. E. ¼ of section 35, T. 41, R. 31. The first of these ledges are one to two miles north of Gravelville, in the N. E. ¼ of section 26, the east edge of section 23, and the west part of section 24, T. 41, R. 31. The longest extent of this tract is from northeast to southwest, reaching a mile and probably including sixty to eighty acres of rock. In the N. E. ¼ of section 26 it is granite, sometimes pink and sometimes gray, rising eight or ten feet above the general surface, which is nearly level. In the W. ½ of the N. W. ¼ of section 24, these ledges rise ten to twenty feet above the adjoining swamps. The rock here is a dark gray gneiss, mostly obscure in its lamination. The strike, at least in part, is S. 70° W., but generally, because of the contorted and indistinct lamination, it is not clearly exhibited.

In the north part of section 18, on land of John F. Whitney, and in the adjoining south part of section 7, T. 41, R. 30, one and a half miles northeast from the last locality, are extensive exposures of the same dark gray gneiss last described. It contains considerable black mica. It is for the main part obscurely laminated, and, though nowhere a true granite, it is rarely so definite in its foliation as to show strike and dip. In some portions

the strike is seen to be from north to south ; and the dip appears to be nearly vertical. Beginning near Mr. Whitney's house close to the center of section 18, frequent outcrops of this rock, rising one to five feet above the general surface, continue north to the north side of this section and into section 7. This section line crosses the most extensive of these tracts of rock, which covers some thirty acres, and here rises 25 or 30 feet above the adjoining swampy tracts. This gneiss has a nearly uniform character throughout the half mile here seen. Another outcrop of rock, probably the same, is reported one and a half miles farther north, near the center of section 6, covering about ten acres, and rising five to ten feet above the general surface. Three miles west from this a small ledge, covering five or six rods square, and one to three feet high, was found by surveyors near the middle of the north side of section 3, T. 41, R. 31, five miles east-northeast from Belle Prairie. Other ledges, which have not yet been observed, will probably be found in this district when its woods are cleared away. Thence northward to Brainerd and northeast to Mille Lacs, and beyond, no exposures of the bed-rock are known.

Slates, staurolite-bearing mica schist, and dioryte. The rocks which remain to be described in Morrison county, found along the Mississippi river and west of it, belong, as already stated, to a group lithologically different from the foregoing, and probably newer in age. The first exposure is on the Little Elk river near its mouth, about two and a half miles north of Little Falls. The most extensive outcrop here, about six rods square and ten feet in hight, is on the northeast side of the Little Elk river, opposite to Henry S. Hill's mill, about thirty rods above the mouth of this stream. This rock is dark, nearly black slate (argillyte), like that of Little Falls. It continues upon this northeast shore about ten rods down stream, southeastward, and for a few rods northwest above the dam; and is also visible in low exposures at the bridge, twenty rods above the mill. Opposite to the mill the course of the cleavage is N. 40° E. (referred, as are all the bearings stated in this paper, to the true meridian), and its dip is nearly vertical, varying to 80° S. E. This slate contains occasional veins of white quartz, from a quarter of an inch to two or three inches in width and one to twenty feet or more in length. These coincide closely with the cleavage in their strike and verticality. These slates throughout are rather soft and easily broken; and they are much divided, usually into rhomboidal masses from two or three inches

to one foot in dimension, by joints. In one system of these joints, dipping about 60° S. E., they are mostly six to twelve inches apart in parallel planes. Other joints, dipping 20° to 45° to the north-northwest and from that to north, and a system dipping 15° W., are about half as numerous as those first mentioned. Another system of joints, cutting these, is vertical, or between vertical and dips of 60° to each side, with their strike between west-northwest and north-northwest. No macroscopic staurolite, garnet, nor pyrite crystals were noticed here, but distinct laminæ, made by aggregation of minute crystals of staurolite or mica, not fissile and extending transversely across the cleavage, are found in much of this rock, nearly as at Little Falls. These probably mark the original lines of stratification, but unfortunately their dip and strike here were not noted. The Mississippi river between this locality and Little Falls has numerous alluvial islands.

At the ferry, a half-mile above Little Falls, this slate has low outcrops two to six or rarely eight feet above the river. On the west side these are seen at several places for twenty rods below the ferry. On the east side they are best exhibited at the ferry-landing and for eight or ten rods farther north. The cleavage here bears N. 35° to 40° E., and is nearly vertical. Some four rods north of the landing a very compact layer occurs, ten feet thick, showing scarcely any slaty cleavage. About two rods farther north a quartz vein a foot wide was noted, conformable with the cleavage.

At the rapids, or Little Falls of the Mississippi, beside the town of this name, this dark slate, varying from mica schist to argillyte, has extensive outcrops in each shore, and forms the north end of Mill island, on the west side of which it makes a perpendicular cliff twenty feet high. The principal rapid extends a fifth of a mile from about 600 feet above this island to 500 feet below its north end, the descent being five feet. Here the slate has mainly a firm and strong texture, having been only slightly decomposed or softened by weathering; but it is too variable in its cleavage, and is too frequently contorted and intersected by veins and joints, to promise well for quarrying for roofing-slate. It has been slightly quarried on the east shore, nearly opposite to the north end of Mill island, for use in foundations, but no massive blocks nor any of regular form are obtainable. Its cleavage is usually quite perfect, into sheets a fourth or an eighth of an inch in thickness; it is nearly vertical, not varying from this more than five degrees to either side, so far as seen in my examination; and its strike is N. 25 ° to 35 ° E. A lamination transverse to the cleavage,

and supposed to indicate the original planes of sedimentation, but not showing any tendency to split, was found well exhibited in a section twenty feet long and five feet high, at the outmost point beside the river on the east shore. The laminæ or layers referred to are from a twentieth to an eighth of an inch thick, and differ from the remainder of the macroscopically homogeneous slate in containing many minute crystals of staurolite and perhaps mica. These layers, which are very distinct, show many small undulations; but, in respect to their entire extent, run nearly in a straight line. Their dip is about 15 ° N.W. White quartz veins occur somewhat frequently in this slate, varying from an eighth of an inch to three inches in width, and extending from ten to fifty or seventy-five feet. Their strike and dip are conformable with the slaty cleavage. The thickest of these veins, situated in the channel of the river, is said to be one foot wide. In the east part of Little Falls this slate is encountered at the depth of about ten feet in digging wells; but it is not found thus in the west part, between this and its exposure at the river.

In some small portions of these outcrops the slaty cleavage is absent or scarcely noticeable, and the rock, massive, compact and hard, with sharp jointage angles, is apparently a dark quartzyte. Professor Winchell adds*: "Besides these variations there are nearly continuous layers of more or less lenticular and concretionary lumps or nodules, sometimes six or eight inches thick, of a rock very firm and dark-colored, but which on weathering becomes superficially lighter-colored, and shows needles and spangles of dark-green amphibole. The matrix in which these crystals lie is not well characterized, but is quartzitic and perhaps also feldspathic, so that on a fresh fracture the amphibole crystals are hardly observable. They appear on the weathering of the rock. . . . . A system of joints gives the rock, viewed across the river, the appearance of being conspicuously stratified, with a dip up the river of about 45 deg. from the horizon. The slatiness, which is nearly perpendicular, is somewhat injured, at least superficially, by the frequency of joints, of which there are at least two systems intersecting each other at a small angle, thus cutting the slates into rhomboidal masses, as they weather to pieces. . . . . Opposite the village of Little Falls a trap dyke of basic doleryte, apparently about 10 feet wide, appears in the slate, going diagonally across the slate; and on the south side of the dyke, in the lee of

*Sixth annual report of this survey, p. 50.

its protection against the current of the river, as well as against, possibly, the ice of the ice-period, the slate (or schist) is decomposed to the depth of four or five feet at least, making a greenish-blue clay, or incipient kaolin."

At Campbell's point, on the east shore of the Mississippi, about a half mile south of the middle of Little Falls village, and about a fifth of a mile south from the south end of Mill island, rock is exposed along a distance of five or six rods, rising eight or ten feet above the river. In describing this rock and its probable origin, professor Winchell states that it "consists, in general, of a hard, dark-colored dioryte, containing mainly amphibole in coarse crystals, and a little feldspar (labradorite?). The outward characters of this rock are the same as the concretionary lumps that exist in the slate already described. It is here simply in larger area and bulk. It is parted by joints that cause it to fall to pieces in slabs and cuboidal masses. This *may be* here in the form of a dyke, but its relation to the slate cannot be seen. The point which is formed by it is considerably higher than the bottomland on either side, but falls away somewhat on receding from the river, the rock itself becoming lost to view in the swampy bottoms, or involved with the drift of the river-bluffs. On long-weathered surfaces, under the action of the water, there is a ridged and furrowed form that shows the same direction and trend as the slatiness of the slate, i.e. N. 18 deg. E. [magnetic]. The ridges are about ¼ inch apart, and about ⅛ or ¼ inch high, separated by intervening furrows. This surface configuration is apparently due to the alternate arrangement of the mineral contents, and perhaps has its origin in a metamorphosed condition of the slate itself, or of the sedimentary rocks from which they both may have been derived. Thus this could not be of the nature of an igneous dyke, but a metamorphic variation due to the complex nature of the original sediments. This view is strengthened by the occurrence of a similar dioryte rock, in concretionary masses, in the slate itself, running in more or less regular layers or lines. This alternation of mineral contents does not pervade the whole of the rock exposed on 'the point'; but it is a conspicuous feature in some places. The ridges are composed of the lighter-colored minerals, and the furrows of the amphibole."

At Pike rapids, which are three and a half miles south of Little Falls and about a quarter of a mile south of the mouth of Swan river, numerous low outcrops of schist occur in the banks and channel of the Mississippi along a distance of about an eighth of

a mile, from the head to the foot of these rapids, which descend four or five feet. The rock here is a mica schist, containing many large crystals of staurolite and often small garnets. No veins or masses of quartz were noticed. On the west shore, which is only six to ten feet high, its exposures are numerous, but rise only one to five feet above the water. It rises in the channel of the river above its bed of boulders and sometimes above the water at frequent intervals across its whole width, the most conspicuous of these ledges being an island eight or ten feet high near the east side of the river. Small and low outcrops are also seen in the east shore, which is a steep bank of glacial drift, till capped with gravel, about 40 feet high. This rock has a laminated structure, which corresponds in strike with the cleavage of the slate at Little Falls and on the Little Elk river. Therefore, it should not, probably, be regarded as representative of the original layers of sediment, from which this rock has been derived by metamorphism. This lamination or foliation in the outcrops along the west shore of the river at Pike rapids has a strike N. 20° E., with a dip 70° to 75° N. 70° W.*

At Cash's rapids, about two and a half miles below Pike rapids, schist nearly like the foregoing occurs in low outcrops in the channel and on the west shore, rising two or three feet above low water.

About a quarter of a mile below the last, and probably in the north edge of section 17, Bellevue, rock almost exactly the same as at Pike rapids is seen in the east shore of the river along a distance of about fifteen rods, rising at the highest place, near its south end, fifteen feet above low water. Its lamination has a strike N. 25° to 30° E., and dips about 45° N. 65° W. Some twenty-five or thirty rods farther south, it again has a small exposure in the east bank, and forms an island which rises about eight feet above low water, and extends eight or ten rods from northeast to southwest, situated about a third of the way across the river from its east side.

Half a mile farther south, at the middle of Muncy's rapids, which are a quarter of a mile long, mica schist, filled with many large

* The site of the fort or stockade in which Lieut. Z. M. Pike and his men spent the winter of 1805-6, from which the rapids received their name, has been found by Mr. Nathan Richardson, of Little Falls, at a point on the west side of the Mississippi about fifty rods below these rapids, on nearly level land some fifteen feet above the river, and not over sixty feet from its shore at low water. This stockade was about thirty-eight feet square. At its northwest corner is a large pile of stones, doubtless used for a fireplace. The first settlers, twenty-five years ago, saw two of the bottom logs still remaining.

staurolite crystals, and sometimes also including small garnets, as at Pike rapids, extends about twenty-five rods along the east shore of the Mississippi, rising some eight feet above low water. This is on land of Isaac P. Lambert, in the north part of the S.W. ¼ of section 17, Bellevue. Its strike, nearly the same as at the last place, is N. 25° to 30 ° E., and its dip is about 60° N. 65° W. It has been slightly quarried for cellar walls, etc., and lies in layers from three inches to one foot thick. This rock also juts up at many places in the adjoining channel of the river along a distance of fifty rods or more, rising two or three feet above low water.

About a half mile below the last, the same staurolitic mica schist outcrops at the west side of the river, having an extent of only a few rods, but rising steeply to a hight of fifteen feet or more above the river. This is on the land of Charles Gillpatrick, in the N. E. ¼ of the N. W. ¼ of section 32, Swan River. Its strike is N. 20° E., and its dip is about 70° N. 70° W. It contains occasional masses or bunches of white quartz; one noted being a foot in length. This is the most southerly exposure of the staurolitic schist, which thus has frequent outcrops for four miles along the Mississippi, at Pike rapids and southward. Its lithological characters are nearly uniform throughout this extent; and its lamination has a nearly constant strike and dip. Proceeding northward, we find this strike and dip continued in the cleavage of the slate at Little Falls and on the Little Elk river, but with a slight deviation of the strike to a more northeasterly course. Beyond these outcrops northeastward, the nearest exposure of similar rocks is the district of slate ledges at the Northern Pacific Junction and on the St. Louis river, a hundred miles to the east-northeast. There the cleavage strikes nearly due east.

The only remaining outcrops of these crystalline rocks beside the Mississippi in Morrison county are about a half mile south from the last, being at Blanchard's rapids, best exposed upon the west side of the river, on land of Allen Blanchard, in the S. E. ¼ of section 32, Swan River. Here ledges are seen at numerous places upon an area of twenty or twenty-five acres, but nowhere rising more than two to four feet above the general surface. The largest exposure beside the river is fully a hundred feet long and averages forty feet in width. This is uniformly a very hard, compact, dark dioryte. It has no staurolite crystals. It shows no lamination, but is very much divided by joints, which are from one or two inches to a foot apart and nearly vertical. Their two principal sets bear N. 75° W. and due N. Lumps of white quartz, up to six

inches in diameter, occur in this rock; and a vein of it a foot wide was reported, but at the time of my observation was covered by high water. This rock reaches in occasional outcrops one or two feet above low water some three-fourths of the way across the river, which is here an eighth of a mile wide; but it has no exposures on the east shore. About ten rods west from the large outcrop beside the river, nearly the same rock, but much less divided by joints and somewhat finer-grained, is exposed upon a space about a hundred feet square, from which the covering of drift, with a thick growth of timber, was swept away about ten years ago by the sudden flood from a broken ice-gorge.

A stratum of rock, apparently belonging in the same group with the preceding, was encountered by the well of Mr. Calvin A. Tuttle, two and a half miles south from the last and close north of the mouth of the "main Two rivers." This well is about 23 feet above the Mississippi, which flows close at the east. Its depth of 50 feet was as follows: soil, 1½ feet; gravel, with pebbles up to six inches in diameter, 4 feet; "white stony clay," probably a marly till, 4½ feet; bluish till, 7 feet; apparently decomposed rock, of various colors and in irregular masses, with considerable kaolin in oblique layers, up to about six inches in thickness, 8 feet; and thence to the bottom, apparently a decomposed hydromica schist, dug into 25 feet and bored into 4 feet deeper. At the time of excavation, which was done with pick and shovel, this rock was thrown out in pieces up to ten pounds in weight; but all these, within a few weeks, by exposure to air and rain, were crumbled to a powder. It had no staurolite crystals, but occasional quartz lumps, from three to ten pounds in weight, and one of fifty pounds, were found in it.

On the Swan river. Swan river, in the southwest corner of section 1, of Swan River township, about one and a half miles above its mouth, as reported by Mr. Samuel Lee, has a fall of nine feet in six rods, over a bed of rock closely like that of Pike rapids, one and a half miles east. He thinks this has no exposure in the banks, of which that on the northeast is low, while that on the southwest is about 40 feet high, being composed of gravel and sand.

At the Ledoux bridge on Swan river, in the S. E. ¼ of the S. E. ¼ of section 4, Swan River township, a dark, compact rock, in part slaty and in part resembling quartzyte, is exposed in the bed of the stream and forms the foundation of the bridge abutments. Specimens were obtained; but observations of jointing, cleavage, or lamination, were prevented by the high stage of

the water. Several exposures of this rock are reported in the channel of the river within a quarter of a mile above and below this bridge.

West of Little Falls. In the S. E. ¼ of the N. E. ¼ of section 13, T. 129, R. 30, about one and one half miles northwest of Little Falls, numerous outcrops of rock, rising one to five feet above the general surface, occur upon an area some thirty rods long from north-northwest to south-southeast, and ten to twenty rods wide. This rock is all massively crystalline, with no apparent lamination or cleavage. It is all quite dark, probably including much hornblende. In part it is fine-grained; but mostly it is about medium-grained, and in part is quite coarse. The last of these varieties is sometimes decayed and friable, but mainly this rock is very compact and hard, not readily splitting in any particular direction. No staurolite, garnet, nor pyrite crystals were observed. Nearly all the varieties of this rock, when long exposed to the weather, tend to exhibit crystals of a greenish mineral, a sixteenth to a fourth of an inch long; and by further weathering these are dissolved, leaving small cavities. Mica is rarely present; it was noted only in narrow veins, a half to one inch wide and of small extent. These ledges are on the east border of an area of till, which thence extends indefinitely westward. They are ten to fifteen feet above a grass-marsh, a half mile wide, which lies on the east and southeast, but are scarcely higher than the plain of modified drift which occupies the Mississippi valley eastward.

Near the fork of Little Elk river. The only other outcrops of the crystalline rocks known in Morrison county are in the N. E. ¼ of section 7, T. 130, R. 30, being between the north and south forks of the Little Elk river, about a quarter of a mile northwest of their junction. One of these ledges is crossed by the road some thirty rods west from the ford of the north fork. Thence the rock reaches about fifteen rods south, with a width of one to two rods; but northward its exposures extend fully an eighth of a mile, occurring frequently upon a width of five to ten rods. It is said to have no outcrops upon any of the streams of this vicinity. As this whole region is woods, other outcrops may have escaped notice. The rock here rises in ragged knolls and small north-to-south ridges, three to eight feet above the general surface, which is 10 to 25 feet above the north fork. It is nowhere massively crystalline, like the diorvte at "the point" near Little Falls; but is a dark schist, having always a more or less distinct lamination, often irregular and contorted. Its strike is uniformly from northeast to

southwest, or within five degrees of this; and its dip varies from vertical to 75° N. W. It has no slaty cleavage, and is all very compact and hard, with few joints. In color and texture it is nearly like some portions of the Little Falls ledges. So far as examined, it has no staurolite nor garnet crystals. In one place a specimen was obtained, holding numerous large pyrite crystals, but these are not generally noticeable. This dark rock sometimes becomes by weathering spotted with brown particles; and by further weathering these are dissolved, leaving a minutely pitted surface. Often the rock includes gray, apparently quartzose, lenticular masses, a half to one inch thick and four to twelve inches long, coinciding with the nearly vertical northeast-to-southwest lamination. It has been slightly quarried by Gilbert T. Smith for his mill, situated a half mile to the east.

STEARNS COUNTY.

Ashley. The most northwestern rock-outcrops of this county are found in Ashley township, eight miles west of Sauk Center. They lie close south and southwest of a school-house at the south side of Ashley creek, partly in the S. W. ¼ of the N. W. ¼ of section 17, owned by George H. Pendergast, and more in the S. E. ¼ of the N. E. ¼ of section 18, on land of Lucas Kells. This rock has numerous exposures, the largest being about a hundred feet long, upon an area which reaches thirty rods from east-southeast to west-northwest, their hight being from one to five feet above the general level. It resembles syenite, but contains much of a light-green mineral (probably epidote), like that mentioned in the ledges thirty and thirty-five miles farther north, in Todd and Cass counties. This takes the place of hornblende and mica, neither of which can be detected. Joints occur from one to five or ten feet apart. No schistose or laminated structure was observed. Vein-like masses of coarsely crystalline orthoclase, enclosing small amounts of white quartz and of the green mineral, occur in this rock at many places, often extending ten feet or more, and varying from one to several feet in width. These ledges may be quarried for coarse masonry. Their surface is smoothed by glacial erosion, but retains no striæ.

Sauk Center. Exposures of rock are found at the southwest side of the railroad from an eighth to a fourth of a mile southeast from Sauk Center depot. They are partly upon the land of the railroad, but mostly for their western portion upon land owned by Tobias

Carl. The largest outcrop is about fifty rods from the depot, and a hundred feet southwest of the railroad, covering an area about six rods long from northwest to southeast by two to three rods wide, and rising only one to two and a half feet above the general surface. This ledge has several distinct varieties of rock. The greater part is a reddish feldspathic gneiss, laminated from northeast to southwest, or a similar syenite where this lamination is absent. Masses a few feet in extent, not definitely separated from the foregoing, are very coarsely crystalline, flesh-colored feldspar and quartz ; the latter constitutes about one-fourth part; and both occur in crystalline masses one to two inches long. Portions of this gneiss and syenite are porphyritic with feldspar crystals up to a half inch, or rarely an inch, in diameter.

The most southern part of this ledge, extending thirty feet from east to west, and ten feet wide, divided from the last by a width of about two rods which is covered with drift, is a very hard and compact, dark, granular rock, perhaps to be called syenite, in which the most abundant mineral is apparently hornblende. A small space of this, about eight feet long and four feet wide, shows a vertically laminated structure, curving from a south to a southeast course.*

Eight rods west from the last is another exposure of the same hard, dark rock, about two rods in extent, not rising above the general level. About fifteen rods west-northwest from the large outcrop first described, another of similar rock is found, being mainly gneiss, laminated from northeast to southwest. This ledge is about fifty feet long from west-northwest to east-southeast, and rises from one to one and a half feet above the general surface. Again, some twenty-five rods southeast from the first described exposure, excavations at each side of the railroad, five to fifteen feet below the track, show the dark, tough hornblendic rock, like its two exposures farther west, except that here it is more intersected by joints, which are from one to six feet apart. On the southwest side of the railroad this rock is uncovered for a length of a hundred feet; but on the northeast side only two or three small knobs are visible. None of the outcrops are suitable for quarrying.

Melrose. The next exposure of the bed-rock is eight miles east-southeast from the last, at Clark's mill, in Melrose. This mill, situated on the south side of Sauk river about ten rods west of the bridge, is founded on a ledge of very hard, coarse, red syenite,

* Glacial striæ, clearly seen on the west part of this southern outcrop, bear S. 40° E , being at right angles with the striæ noted in Sauk Rapids, about forty miles farther east.

which also extends some twenty-five feet from the mill, half-way across the waste-way of the dam.

In the west part of Melrose village, a third or half of a mile west from this mill, and on the level plain of valley drift, rock has been encountered in attempts to dig wells at W. H. Rothaermel's house. Its depth below the surface is about six feet, and it has an extent of a hundred feet or more. A well blasted into this rock supplied the stone for the foundation of the Methodist church near by. It is a dark, unlaminated, rather coarsely crystalline, hornblendic rock, different from any other found in this district.

Wakefield. Several outcrops of very hard, dark dioryte, and of coarse syenite occur within a radius of a fourth of a mile about the corner of sections 19, 20, 29 and 30, Wakefield. This is on the north side of the Sauk river, two miles east of Richmond, and about twenty miles southeast from Melrose. One of these knobs rises forty feet above the general level. The abutments of the Richmond bridge were quarried at this locality.

About one and a half miles farther east, near the center of section 21, a small outcrop of coarse syenite occurs in and close south of the road, its length being four rods and its hight three or four feet. It is intersected by joints at intervals of two to six feet.

At Cold Spring, one and three-fourths miles farther east, a fine-grained, reddish, much jointed syenite has abundant outcrops, underlying the mill and dam, and covering an area on both sides of the Sauk river equal to a quarter of a mile square, with its highest points 20 to 25 feet above the river. It has been somewhat quarried for local use in foundations, walls, etc.

Rockville. Four miles farther east, massive outcrops of coarse-grained, gray granite, containing black mica, which weathers to yellow, occur near Rockville. The most prominent mass of this rock is at the east side of Mill creek, a quarter of a mile south of Rockville mill, forming a knob forty or fifty rods in length and breadth and fifty feet high. This rock is very free from joints or seams, being sometimes unbroken for thirty or forty feet. Otherwise it appears to be well adapted for quarrying, to supply stone for heavy masonry, as bridge piers and abutments. Two other exposures of this rock are found a quarter of a mile northeast from this mill. The most southerly of these, situated east of the road, covers some thirty rods square, and rises about forty feet above the river; and the second, less than an eighth of a mile farther north, crossed by the road, and lying mostly between the road and the

river, covers an area 30 by 20 rods in extent, and rises 20 to 30 feet above the river. Both consist of massive, rounded ledges, with few seams or joints, which are often twenty to thirty feet apart.*

Saint Joseph. In the N. E. ¼ of section 26 of this township, nearly four miles northeast from Rockville, massive, coarse-grained, gray syenite or granite, closely like that of Rockville, is exposed on the land of Fred Schilplin, about an eighth of a mile southeast from his house. It forms a rounded outcrop some twenty rods broad, rising ten feet above the general level, its hight above the Sauk river, three-fourths of a mile to the northwest, being about 35 feet. This ledge has few joints, one space fifty feet square being without a seam.

One and a half miles west-southwest from the last, an exposure of rock is reported in section 27, on land of I. S. Staples, at the east side of Sauk river, above which it is said to rise five to ten feet, covering an acre or more.

Saint Augusta. Granite, containing flesh-colored feldspar and black mica, is exposed near the middle of section 19, Saint Augusta, about a fourth of a mile west of Luxemburg post-office and St. Wendel's church. This is four miles east-southeast from Rockville and eight miles south-southwest from Saint Cloud. It lies on the west side of a slough, above which it rises 15 to 20 feet, its extent being about twenty rods. It is divided by joints three to fifteen feet apart; the course of their principal system, nearly vertical, is from northwest to southeast.

Saint Cloud. This township has many exposures of these rocks, principally syenite.

In the N. E. ¼ of section 32 a reddish gray syenite or granite, and in the N. W. ¼ of section 33 a very dark syenite, containing a large proportion of hornblende, form quite extensive outcrops, in each case covering an area equal to a quarter of a mile square. An eighth of a mile west of the road, these rounded hillocks of rock rise 20 to 25 feet above the general level; and close east of the road and for an eighth of a mile or more from it, their hight is five to ten feet. About forty rods farther north, the road goes by ledges of syenite nearly like that of the quarry at Sauk Rapids. These are probably in the southeast corner of section 29; they lie

*These and nearly all the ledges of eastern Stearns county are planed and worn to a smooth surface by the ice-sheet; but none of them, so far as seen in this survey, retain glacial striæ, because of the slight disintegration wrought upon their surface by rains and frosts.

close west of the road, above which they rise 15 to 20 feet. The next two miles to the north and northwest have abundant outcrops of gray and reddish syenite, of which the following is a list in part.

On land of Jacob Streitz, in the N.W. ¼ of the N. E. ¼ of section 28, considerable quarrying has been done, forty cords or more of the stone having been sold for masonry in Saint Paul. This is an excellent gray syenite, rising about ten feet above the general surface, well adapted for supplying dimension stone. It is near the eastern side of this tract of abundant ledges; and the hills one to one and a half miles east and northeast, rising 50 to 75 feet higher and 125 to 150 feet above the Mississippi river, are morainic drift.

A quarter of a mile west of the last, on land of Louis Hohmann, in the N. ½ of the N. W. ¼ of section 28, ledges of the same rock as the last cover two or three acres, rising about five feet above the general level of the surrounding modified drift. Some quarrying has also been done here.

On land of Ferdinand Hartmann, in the north edge of the N. E. ¼ of section 29, he has quarried during several years, in two low outcrops of syenite, selling the stone for $3 per cord at Saint Cloud. The southwestern outcrop, six rods square, is a somewhat coarse-grained, reddish syenite, divided by joints from one to eight feet apart. The other ledge, fifteen rods north-northeast from the last, is about ten rods long from west to east by six rods wide. This is mainly red syenite like the former, but includes a large mass, occupying an area about four rods square, of finer-grained, bright gray syenite, containing occasional scales of black mica. At its border a gradual change of color takes place from the gray to the red.

An area of several acres of reddish syenite, like that of the last localities, begins thirty or forty rods northwesterly from the last, and reaches a sixth of a mile or more northward. This is on land of Matthias Leim, in the S. ½ of the S.W. ¼ of section 20, and of Nicholas Scheuer in the north half of the same quarter-section. It rises in rounded hills and knolls 30 to 50 feet above the lowland eastward.

About forty rods northwest from the last, in the N. W. ¼ of the S. W. ¼ of this section 20, owned by Nicholas Scheuer, gray syenite, closely like that of Streitz and Hohmann, and of Hartmann's northern quarry, forms a hill which covers six or eight acres and rises 50 feet above the general surface. It is smoothly glaciated, but retains no clear striæ. This rock has few joints, sometimes

none for an extent of thirty feet. Here and upon many of the ledges of this region a scale of rock a fourth to a half of an inch thick, has become separated or is easily separable from the surface by weathering. In some places this might be attributed to forest or prairie fires, which seem often to have produced such scaling; but here it is notably exhibited on bare ledges six rods or more in extent.

Within a mile westerly are many lower outcrops of this syenite, rising 10 to 20 feet above the average of the vicinity. Good locations for quarrying are reported on the land of William Besinius, in the S. E. ¼ of section 19, and of Jacob Hiltimes in the west half of this section.

The red syenite continues from the ledges owned by Hartmann and Leim northerly to the land of the Saint Cloud Granite Manufacturing Co., L. A. Evans, agent. This is the N. W. ¼ of the S. W. ¼ of section 17, where excellent quarrying stone is found. A few years ago a block of this red syenite was obtained for a monument pedestal, which had been sought but could not be supplied (so reported) from the famous quarries of similar stone at Aberdeen, Scotland. The size of this block was 7 feet square by 2½ feet high, its weight being ten tons. It was cut and polished in Saint Cloud, and was sold in Chicago for about $800. This quarry has not been worked for the past two or three years.

Excellent localities for quarrying the same red syenite also occur within a half mile west and southwest from the last, in the S. E. ¼ of section 18, owned by H. C. Waite, and in the N. W. ¼ of section 19. Some of these localities also yield gray syenite, and that which is gray, tinted reddish.

Syenite outcrops in the N. W. ¼ of section 17, at the northwest side of the road about a half mile west of John Becker's. Its extent is about fifteen by ten rods, and its hight is some twenty feet above the adjoining lowland and river, an eighth of a mile west, and eight feet above the road. This ledge exhibits some marks of water-wearing. A system of nearly vertical joints crosses it from north to south, varying from six inches to four feet apart; and others, less conspicuous and less numerous, extend from east to west.

The only exposure of rock beside the Mississippi river in this county below the Saint Cloud bridge, is about a half mile south of the state normal school, at C. Bridgeman's steam saw-mill and for twenty rods to the south. It is coarse gray syenite, with joints

ten to twenty feet apart, and forms small ledges five to ten feet above the river.

Fifteen to twenty rods south from the west end of the Sauk Rapids bridge, is a ledge of porphyritic, gray syenite, consisting mostly of feldspar, with about a fourth part of quartz, and including some hornblende and rare grains of mica. It rises some five feet above the river, and is traversed by nearly vertical joints one to eight feet apart. It has been slightly quarried.

Le Sauk. In this township, situated next north of Saint Cloud, these crystalline rocks are exposed upon the lowest mile of Watab river, and at several places within three miles thence north-northwest. The grist-mill and its dam, owned by J. B. Sartell & Sons, on the Watab river, about a third of a mile above its mouth, are founded on gray syenite. This is exposed to view only on the south side of the river, under the foundation of the north side of the mill, rising a few feet above the water of the flume below the dam. It was quarried for this mill, and is a desirable building stone.

Mr. Sartell owns another quarry a half mile northwest from this mill, covering several acres and rising twenty feet above the general level. It is in or near the S.E. ¼ of section 17. This has a more reddish tint. Quarrying has been done here more or less during the past ten years, perhaps yielding quarried stone to the value of $1000 in all, only for use in this vicinity.

A third of a mile east of the last, in the south part of section 16, is another outcrop of rock, similar to that at the grist mill. This covers about two acres. It has a low smoothed surface, not much above the general level.

Another ledge of similar syenite or granite is seen at the west side of the road, east of the north part of Clark lake, in the south half of section 8. This also covers two acres or more, its hight being about ten feet.

On or near the east line of section 9, a rock-outcrop, said to be coarse-grained and of iron-rusty color, covers several acres and rises some fifty feet above the Mississippi river, which is ten or twenty rods farther east.

Reddish fine-grained syenite has been somewhat quarried for local use, in or near the N. E. ¼ of the N. E. ¼ of section 7, on land of D. B. Searle. Farther northwest, near the center of section 6, similar rock has outcrops at many places along a distance of about half a mile from east to west, not extending into Saint Wendel township.

Brockway. A medium-grained, gray granite or syenite, containing garnets a fourth of an inch in diameter, is exposed on the N. W. ¼ of section 33, in the southeast part of Brockway, on land of William Gordon, about a quarter of a mile west from the road and from his house. It shows only a smooth flat surface, ten by fifteen feet in extent, not rising above the general level.

Rock is also reported to occur in the west shore of the Mississippi river, about fifteen rods south from the northeast corner of this section 33. The rock is exposed also in the east bank and in the channel of the river, but its outcrops rise only two or three feet above extreme low water. This is about a mile north of the high hills of rock at the east side of the river in Watab.

SHERBURNE COUNTY.

The principal quarries of the district here reported are near Saint Cloud, but are situated on the opposite side of the Mississippi, in Sherburne and Benton counties. In their order from south to north, these quarries are in Haven, the northwest township of Sherburne county, and in Sauk Rapids and Watab, the townships which succeed next to the north, lying in Benton county, all bounded by the Mississippi river on the west.

Haven. The most southern rock-outcrop is in the S. ½ of the S. W. ¼ of section 17, four miles southeast of Saint Cloud, and about two-thirds of a mile west of the Saint Paul, Minneapolis & Manitoba railway. It is owned by Robbers & Barthelemy, and was by them leased in May, 1881, for two years, with privilege to extend the lease three years more, to the firm of Saulpaugh & Co., of Rock Island, Illinois, who are contractors for building the bridge for the Northern Pacific railroad across the Missouri river at Bismarck. They have also leased quarries in Watab for this bridge, which in its abutments and four piers requires 7000 cubic yards of cut stone. The outcrop has an area of four or five acres, being about thirty rods across, and rises with a rounded, smooth surface of bare rock ten to fifteen feet above the surrounding prairie of nearly level modified drift. Hence it is often called the "rocky island" or "rocky point." About ten rods west of the main outcrop is another of small extent.

This rock is a coarse-grained syenite, of whitish gray color, with dark blotches of hornblende. It is evidently a stone of great strength and durability. The first quarrying at this point was by Daniel Burns, of Sauk Rapids, in 1879, supplying stone, some 600

cubic yards, at price of about $9,000, for the Mississippi river bridge of the Chicago, Milwaukee & Saint Paul railway on the short line between Saint Paul and Minneapolis.*

Two miles north from the foregoing and the same distance southeast from Saint Cloud, are the quarries of Breen & Young, situated close west of the railroad, nearly on the line between the S. E. ¼ of section 6, and the N. E. ¼ of section 7, Haven. The rock here has frequent exposures along a distance of nearly a half mile from the quarry, to the southeast and northwest, rising five to twenty feet above the adjoining marshy lowland. On the south and southwest side it is covered by morainic drift, which forms a ridge 40 to 50 feet high and of irregular contour, reaching from the railroad westward through section 7. Most of these ledges are a gray syenite of fine grain and uniform texture, well suited for building purposes. It is used in the corners, steps and trimmings of the United States custom house and post office, in Saint Paul. Breen & Young employ about twenty-five men here in quarrying. The greater part of their stone-cutting, especially for ornamental work, is done in their shops at Saint Paul. Their quarry of this syenite, commonly called granite, has been wrought since 1868; the extent of the principal excavation is about 250 by 200 feet, and its depth is mostly from four to six feet. About thirty rods west of this opening is an area of reddish syenite, which has been slightly quarried. The same color is also seen in small outcrops a sixth of a mile farther north beside the railroad.

In Haven and generally through Benton and Stearns counties, this belt of crystalline rocks consists mainly of syenite, which differs from true granite in containing the mineral hornblende instead of mica, both being otherwise alike composed of quartz and feldspar. The three ingredients of each occur in crystalline grains; and no schistose or laminated structure, and consequently neither dip nor strike, are observable. The common species of feldspar present in these granites, syenites, gneisses and schists, is orthoclase.

NOTE. These are the only exposures of rock in place in Sherburne county. Principally the surface of this county is the stratified sand and gravel of the modified drift, bearing a thin forest growth in which black and bur oaks are the most abundant species. Comparatively small areas or belts are composed of till, or intermixed clay, sand, gravel and boulders, unstratified. The boulders are mostly syenites, granites, and crystalline schists, with occasional pieces of limestone In size they are mostly less than five feet in diameter, and boulders more than ten feet in diameter are very rare in nearly all parts of

*No boulders are seen on the surface of this ledge; and though it is wholly moutonned, or smoothly planed and rounded by glacial erosion, no distinct striæ were found.

Minnesota. One of the largest found in this state is the "big rock," situated on land of Peter E. Clarity, in the N. W. ¼ of the S. W ¼ of section 7, Palmer, six miles east from Breen & Young's quarry. The dimension of this mass is about 20 by 35 feet, and its hight is 20 or 25 feet It probably also reaches several feet below the surface, from which it rises perpendicularly on all sides. This boulder is dark mica schist, varying to gneiss, coarsely laminated, with much black mica and many minute garnets, and containing in some portions whitish feldspathic layers from a quarter of an inch to two or three inches in thickness From it numerous fragments, three to ten or twelve feet long, have been riven off by frost, especially on its northwest side. It lies on a southwesterly sloping swell of till which forms part of a morainic belt, 20 to 50 feet above the general level, extending from section 9, Palmer, west to section 7, Haven.

BENTON COUNTY.*

Sauk Rapids. This township has many outcrops of rock. The quarry which has been longest worked and yields the best stone, a fine-grained gray syenite, especially adapted for ornamental use and for cemetery monuments, is situated nearly in the center of the village of Sauk Rapids. It was first opened by Mr. F. A. Fogg, in May, 1867, and was worked by him four years. It is now owned by Collins, Mitchell & Searle, of Saint Cloud, and within the past three years has been leased and worked by Messrs. Burns, Reeder and Robinson, who cut and polish the stone near the quarry. The excavation is about 150 by 100 feet in extent, and five to seven feet deep. The sales are about $2,000 annually, and have varied from $500 to $10,000 a year. In Minneapolis the towers of the suspension bridge and the city hall are trimmed from this quarry, the rest being Trenton limestone. In Saint Paul the wholesale hardware store of Nicols & Dean is built from this quarry, except the columns and buttresses, which are from Watab. In Milwaukee this quarry supplied the polished front of the Mitchell Bank building, some of the slabs used being 11 feet by 3 by 1 foot in dimension. The Iowa state capitol at Des Moines, recently built, took part of its stone for trimmings from here, some of the pieces measuring 10 by 2½ by 2 feet. This syenite is closely like that of Breen & Young's quarry in Haven.

A coarser syenite is exposed about a quarter of a mile farther west, at the east end of the Sauk Rapids bridge and dam, which are founded in part upon this rock. Its outcrop, coarsely porphyritic, a few rods south of the west end of this bridge, is described on a

* The drift in this county is generally till, having a moderately undulating or rolling contour, with no conspicuous elevations, but rising in gentle swells 40 to 60 feet above the streams. It is mainly covered with heavy timber, all of deciduous species, excepting in the north and east portions of Alberta, which have a good growth of white pine. Upon the greater part of the county the bed-rocks are wholly covered by the drift.

preceding page, with the other rock exposures of Saint Cloud, Stearns county.

The fall in the Mississippi here in about one mile, from the mouth of the Sauk river to Maple island, is 22 feet, from 992 to 970 feet above the sea. Its channel is strown with boulders, but has no extensive exposures of solid rock.

About a mile east from Sauk Rapids, in the N. W. ¼ of section 24 of this township, an outcrop of reddish, rather fine-grained syenite occurs in a swampy depression, some twenty-five rods south of the Gilmanton road. Its area reaches about twenty rods from north to south and is about ten rods wide, with a hight of two to five feet. This rock is traversed by joints from one to ten or fifteen feet apart. Its surface is smoothly glaciated but retains no striæ.

An exposure of gray syenite occurs in the S. W. ¼ of section 13 of this township, on land of Robert W. Leyerly. Its extent is about 50 by 30 feet, with hight of three feet above the adjoining marshes. It is crossed by joints two to eight feet apart.

In the N. W. ¼ of section 13, on land of the E. D. Learned estate, a coarse-grained reddish syenite, with large proportion of feldspar, covers an area thirty rods or more in length toward the west-northwest, averaging eight rods in width. Its higher portions are four to seven feet above the marsh which mainly surrounds it. This rock is very massive, extending in some places thirty to forty feet without a joint. It is cut by a trap dike, the ordinary dark and tough doleryte, one to one and a half feet wide, and reaching within view about fifty feet from east to west.

Extensive outcrops, partly of coarse-grained reddish syenite, and partly of finer-grained gray syenite, of which the latter has been considerably quarried, occur on the N. E. ¼ of section 14, on land of Joseph Moody; covering some thirty acres and rising 25 feet above the adjoining swamps, or 75 to 100 feet above the Mississippi. This rock is mostly divided by joints from six inches to five feet apart.*

Syenite nearly like the coarse reddish portion of the last or that described in the N. W. ¼ of section 13, occurs also at several places in the S. E. ¼ of section 11, on land of William Kouts. Its most northerly exposures are about sixty rods north of the south line of the section, and do not rise above the general level of the surrounding marshy land. A smooth surface of this rock, about fifty feet

* In several places on this quarter-section distinct glacial striæ were observed, bearing S. 45° to 50° W., by the true meridian. At another point, a few rods from these, their course is S. 15° W. On the other ledges of this township before described, these marks have been effaced by weathering.

across, being the largest patch seen here, has no joint or seam. An outcrop of this rock about a hundred feet square, lying some forty rods south-southwest from this, upon the same quarter-section and three to ten rods north of its south line, rises five feet above the general level and is divided by joints three to eight feet apart, mostly running north and south, with others less numerous from east to west.

In the N. E. ¼ of the N. W. ¼ of section 11, owned by Collins, Mitchell & Searle, and in the adjoining N. ½ of the N. E. ¼ of the same section, owned by E. E. Beal, are large exposures of red syenite, which has been quarried somewhat. It covers about ten acres, and rises ten to twenty feet above neighboring depressions. At the quarry it is distinctly red near the surface, but gradually changes to gray at a depth of three or four feet. It is rather coarse in grain. Feldspar, quartz and hornblende are all present in considerable amount, the feldspar being about half of the whole. This rock is very massive, sometimes extending a hundred feet without a joint. The distance to the railroad is one and a half miles, and to Sauk Rapids, two and a half miles.*

Watab. The southern two miles of this township, to a distance of three miles from the Mississippi, have many outcrops of these crystalline rocks, mainly of syenite, which presents varieties similar to those described in Sauk Rapids.

In the N. W. ¼ of section 35, about one-third of a mile east of Watab station, is the quarry of Talcott, Castle & Co., which was worked by them in 1871 with forty men, drawing the stone six miles to Sauk Rapids, then the end of the railroad. This stone was mostly used for buildings in Chicago, which were destroyed in the great fire of October, 1871. It has been much used for cemetery work, as monuments and bases.†

About a half mile farther east, in the N. E. ¼ of this section 35, is the quarry owned by H. D. Gurney, of Saint Paul, which was opened and considerably worked in 1874 and 1875. From that time it remained idle till 1881, when it was leased to Saulpaugh & Co., by whom it was operated with from fifty to a hundred men, including quarrymen and cutters, the stone being used with that quarried by them in Haven, as before stated, for the Northern Pacific bridge at Bismarck. This exposure includes three distinct varieties of syenite: gray, coarse-grained, which makes up the

* Glacial striæ, seen at a dozen places upon this outcrop, bear quite uniformly S. 50° W., referred to the true meridian, varying rarely to S 45° W. and S. 55° W.

† Glacial striæ were observed here, bearing S. 15° W.

greater part of the stone quarried; gray, finer-grained; and reddish, with grains of intermediate size. These kinds of rock lie in contact, showing, at least in some portions of the quarry, no gradual transition but an abrupt change at a definite line. A branch track, a mile in length, was laid from the railroad to this quarry in May, 1881.

Extensive ledges of similar rock lie in the S. E. ¼ of section 36.

In the north part of section 34, on land of Joseph Campbell, are also large exposures of syenite of excellent quality, but not yet quarried, except to supply a block, 3 by 1½ by 1 foot in size, polished on one side, which was sent to the Centennial Exposition.

The highest points of the foregoing ledges rise 10 to 20 feet above the average of the adjoining land, or 75 to 100 feet above the Mississippi river, which here is 1,000 feet above the ocean.

Prominent knobs of syenite, mostly reddish and somewhat porphyritic, and often darker and finer-grained than the preceding, sometimes in appearance approaching trap, dikes of which are also present, occur in section 27, between the railroad and the river, a half to one mile north from Watab station. At each side of the river road its elevations are 40 feet above the road and 75 to 90 feet above the river. One of these hills of rough, bald rock (called by Schoolcraft the *Peace rock*) rises in moderate slopes directly from the river's edge about a half mile south from the mouth of Little Rock creek, which was so named because of these ledges.

Prospecting for gold was undertaken here, some fifteen years ago, by Major T. N. Newson, sinking a shaft about ten feet. This is close southeast of the river road, near the center of section 27. It is some 40 feet above the river, with a depression on the east, separating it from a hill about 75 feet high a sixth of a mile east. The vein explored is quartz, one to eight inches thick, dipping 80° S. E. The east wall of this vein is dark and tough trap; and its west wall is a porphyritic, reddish syenite.

A small outcrop, twenty-five or thirty feet across and some 15 feet high, lies in the N. W. ¼ of section 26, a short distance east from the railroad and highway. Beyond this northward the only other rock-exposure known in this county near the Mississippi river is a small and low outcrop in its bank, of a tough, close-grained, hornblendic rock, occurring about a mile farther north, opposite to the northeast corner of section 33, Brockway, Stearns county.

Gilmanton. The only ledges that remain to be described in

Benton county are in its central and northeastern portions, within Gilmanton and Alberta townships.

In the S. E. ¼ of the S. W. ¼ of section 18, Gilmanton, on land of Clement Tellier, about twelve rods west of the road, reddish syenite, mostly in large fractured blocks, is exposed at the south side of a small brook, upon an area two or three rods in extent.

About three-fourths of a mile west from this, similar rock is said to outcrop on the east side of the Elk river and in its channel, rising about ten feet above the river and extending six or eight rods.

Alberta. At the end of the portion of the old state road which had its timber cleared off, this being at the middle of the north side of section 20, in the east township of Alberta, the most northeastern of the county, this road crosses an exposure of rock which has an extent of about twenty-five rods from north to south, and is some fifteen rods wide. The quarter-section stake is about five rods east from the north part of this ledge, which extends into the edge of section 17, but lies mainly in the N.E. ¼ of the N.W. ¼ of section 20, on land of Charles A. Gilman, of Saint Cloud. The northeast part of this outcrop contains a dike of trap, dark with whitish spots, seen along a distance of thirty or forty feet and varying from eight to eighteen inches in width. Its course in the east part of its visible extent is S. 60° W.; but it is changed beyond to about due west. South of this dike the rock is a coarse-grained, reddish syenite, composed mostly of feldspar, with perhaps one-fourth part quartz. On the north side of the dike the texture of the rock is very different, though its mineral composition may be nearly the same. Here it is very fine-grained, and is much more traversed by joints, which are usually only one to two feet apart, dividing the rock into rhomboidal masses. These diverse rocks, definitely divided at this dike, appear to form respectively the south and north parts of this outcrop. Other ledges of syenite are reported within a mile northward, in section 17 and the N. E. ¼ of section 18.

About four miles east from the last, in the N.W. ¼ of section 24 of the same township, several exposures of coarse-grained reddish syenite occur in the banks and bed of the West branch of Rum river. In proceeding eastward and down the stream, the first of these outcrops is about twenty-five rods above the new "roll dam," which was rebuilt in 1879. At this upper ledge wings of logs are built on each side to turn the floating logs into the middle of the stream, which here falls three feet, the open space between

the wings being thirty feet. The channel here and both banks to a hight one or two feet above the water, along a distance of twenty or thirty feet at each side, are this syenite, but it has no exposures upon the general surface, which is elevated only about five feet above the stream. The crystals of this rock are an eighth to a half of an inch long; about two-thirds of the whole consist of flesh-colored feldspar; about one-sixth is quartz, varying from whitish to smoky and transparent; and the remainder consists of dark particles, mostly hornblende, with rare grains of black mica.

At the "roll dam," twenty-five rods northeast from the last, the same rock is exposed in the south or right bank, and the south half of the dam for about seventy-five feet is founded on it. Its width visible is from ten to twenty-five feet, and its hight above the water below the dam is one to two feet. The fall here is also about three feet. Both these outcrops are massive, often showing no joint for twenty or thirty feet.

At a bend in the river about thirty rods below, being northeast and within sight from the "roll dam," the northern or left bank has an exposure of this coarse syenite, about twenty-five feet long and five to fifteen feet wide, rising one foot above the water; succeeded in the next twenty-five feet east by a very fine-grained, compact, but considerably jointed rock, of deep dull red color, apparently made up mainly of feldspar. Its extent seen was about twenty-five feet long by five to ten feet wide, reaching one foot above the water, which at the time of this examination was probably two feet above its lowest stage.

Within sight from the last and about a dozen rods down the stream, which here flows to the southeast, the coarse-grained massive syenite is again exposed in the northeast or left bank of the river. Its extent is about 50 by 10 to 20 feet, and its hight was two feet above the river, to which this ledge descends perpendicularly, with deep water at its side.

These are the first ledges found by lumbermen in descending this West branch of Rum river.

MILLE LACS COUNTY.

The only remaining exposures of rock on this stream are within three miles southeast from those last described, being in sections 19 and 29, of T. 38, R. 27, in Mille Lacs county.

T. 38, R. 27. At Stony Brook dam, situated on the West branch near the center of section 19, fifteen and a half miles in a

straight line northwest from Princeton, and about three-fourths of a mile east-southeast from Brown's lumber camp and the mouth of Stony brook, the excavation at the north end of the dam shows a small exposure, about twenty-five feet across, of the same coarse, reddish syenite as occurs at and near the "roll dam." This has a smooth surface, nearly free from joints. Its hight is only one or two feet above the river.

In section 29, this rock occurs at many places in the banks and channel of the river along a distance of more than a half mile. These ledges begin about a mile southeast from the Stony Brook dam. The following notes describe them in the order that they were found in following down the river.

The first outcrop noted, perhaps below some which were not seen by me, occurs on the west or right side of the stream; and is about fifty feet square, reaching from the bank nearly across the river, which through this section varies from two to four rods in width, and is from three to six feet deep. It here has a fall of one foot, and the rock rises one to two feet above it. This is a massive syenite, coarse-grained and reddish, indistinguishable from that at the "roll dam."

At about twenty-five rods and again at thirty-five rods from the preceding, down the stream, which here flows south, ledges of the same rock are exposed in the left bank of the river, at each place having a length of about twenty-five feet and a hight of three or four feet.

Some twenty rods south from the last, where the river turns east, its right bank just below the bend has an outcrop of the same rock, extending four rods and rising five or six feet above the water. A part of this ledge is divided by east-to-west joints, one to two or three feet apart; but the higher southern part, like most of these outcrops, is massive, rarely intersected by joints.

About forty rods below the last, southeasterly, the river flows, falling about one and a half feet, over ledges of the same rock, in part divided by east-to-west joints. In the east or left bank these outcrops rise six feet above the water. Low exposures of this rock continue in the left bank about eight rods south, and after an interval of four or five rods again appear in the left bank for about fifty feet, rising seven feet above the river.

Twenty rods down stream, south-southwest from the last, ledges of the same rock re-appear in the left bank, and reach ten or twelve rods west-southwest, down the stream, rising five to eight feet above it.

Some ten rods below, westerly from the last, it is again exposed in the left bank at a small island.

From twenty to forty rods farther down the stream, westerly to where it turns south, then flowing south and southeast, there are frequent outcrops of the same rock at each side of the stream, above which these ledges rise from one to five feet. No exposures of rock are known below this on the West branch of Rum river; and none were found elsewhere in this region, except as described in the banks and channel of this stream. The descent of the West branch in its course of about three and a half miles from the "roll dam" to the lowest of these ledges, is estimated to be about 25 feet.*

The numerous rock exposures seen along these three miles are remarkably alike in lithological character, being a coarse, flesh-colored or reddish syenite, with occasional particles of mica. It is well adapted to be quarried for ordinary masonry and building purposes; but it has not yet been worked because settlements have not extended into this district.

On the main Rum river, generally denominated the "East branch," the drift and topographic features are mainly like those described on the West branch. Its only exposures of the bed-rock are about thirty miles, in a direct line, north of Princeton, being six to ten miles south of Mille Lacs. Low outcrops of small area, seen in descending this stream at Rum river falls, in the S. E. $\frac{1}{4}$ of section 18, T. 41, R. 26, a half mile above the mouth of Bradbury brook, and at other points a few miles below these falls, are described by Norwood as syenite, hornblende rock, gneiss, granite, and greenstone. Another outcrop is reported at the "ledge dam", on the south fork of the Bradbury brook, three or four miles above its junction with the East branch.

KANABEC COUNTY.

The glacial drift and surface features of this county are much like those of Benton and Mille Lacs counties. The ledges of crystalline rocks examined in Kanabec county are on Ann river in the vicinity of the Ann Lake dam; and on Snake river at and near its Upper and Lower falls, which are situated in T. 42, R. 23, respectively one and a half and two and a half miles south from the north line of the county.

* The adjoining land is moderately undulating till, varying from a few feet to thirty or forty feet above the river, well wooded, but with little pine. Its soil promises well for agriculture. The pineries which still remain upon the head-waters of the West branch begin several miles farther northwest, beyond the west line of Mille Lacs county.

The Ann Lake dam, having eight feet head, and raising the level of Ann lake about five feet as a reservoir for log-driving, is situated two miles below the mouth of this lake in the east edge of the S.E. ¼ of section 30, T. 40, R. 24. About ten rods south from the gate of this dam is a rock exposure six or eight rods in length and width; but the rock does not appear here in the channel or bank of the river. Its next outcrop is some fifty rods down stream, southeast, being in the S.W. ¼ of section 29, at the southwest end of the "roll dam," extending ten or twelve rods beside the river, and about six rods in width. These outcrops rise five to ten feet above the river. Again, about thirty rods down stream, south from the last, and in the same quarter-section, or in the north edge of section 32, at a "breakwater," a ledge two or three rods in extent is found a few rods southwest from the stream, and six or eight feet above it, but not rising above the general surface. All these outcrops are on the southwest side of the river. They are all alike, being a light gray, rather fine-grained granite, somewhat decomposed next to the surface, so that it breaks with a crumbling fracture. In excavation by quarrying it would probably be found adapted for building purposes, with fair durability. Throughout these exposures it has a very uniform texture, with no noteworthy variation and no included veins. It is cut by joints from two to ten or fifteen feet apart.

Similar rock-outcrops are reported on the Little Ann river two to four miles west and northwest from the foregoing, in section 26, T. 40, R. 25, and probably in the S.E. ¼ of section 14, occurring at several places in the channel and banks of the stream; but not at its dam, which is in or near the S.W. ¼ of section 11.

Vicinity of the Upper and Lower falls of Snake river. The trip to these falls was from Kettle River station southwesterly by the north side of Pine lakes to McClure's lumber camp, situated on the west side of Cowan's brook, in the N.W. ¼ of the N.W. ¼ of section 35, T. 43, R. 23. The logging-road which follows down Cowan's brook, at about two-thirds of a mile south from this camp, in the S.E. ¼ of section 34 of this township, a little north of the line between Aitkin and Kanabec counties, goes over a spot which is strown with many blocks of a fine-grained, gray granite, containing black mica. This is doubtless the bed-rock here, at a little depth below the surface.

About a mile farther southwest, some forty rods below McClure's landing and a quarter of a mile above the mouth of Cowan's brook, probably in the N. W. ¼ of the S. E. ¼ of section 4, T. 42, R. 23, a

medium-grained gray granite, with a little black mica, outcrops in both banks of Snake river and forms a short rapid. These ledges on the left shore extend about forty feet, rising only one or two feet above the water; but on the right bank, a short distance below, they reach a hundred feet or more, having a hight six or eight feet above the river.

An eighth of a mile farther south, a finely-laminated, dark gray mica schist forms outcrops two or three rods long and six feet above the river, in each bank. This has a northerly dip, varying from 5° to 15°. It is traversed irregularly by veins, from one inch to one foot, and on the west bank from one to four feet in width, composed of coarsely crystalline light gray granite, which has crystals of white mica an inch long.

The head of the Upper falls of Snake river is about two-thirds of a mile south from the mouth of Cowan's brook, in the north part of section 9. The first noteworthy ledges beyond those last described are about twenty-five rods below, west-southwest from, the head of these rapids. Here the river flows ten rods westerly between walls of granite only thirty to forty feet apart, with a descent of two or three feet. This is called the "jaws of the Upper falls." The rock here is mainly gray granite, in part fine-grained, but more generally of medium or very coarse grain. It also encloses many veins and masses, from one to eight feet in width, of exceedingly coarsely crystalline granite, with flesh-colored feldspar, or of such feldspar alone; and these in some portions make up nearly half of the rock exposed. Veins of white quartz, up to one foot in diameter, are also present. In some parts this rock has a distinct but much contorted lamination, being thus changed to gneiss and mica schist. Joints, vertical and nearly horizontal or oblique, divide these ledges into blocks from one to five or ten feet in dimension. Because of this structure the channel eroded by the river is enclosed by zigzag, nearly vertical walls, which are 10 to 15 feet high. The same formation, with great lithological variety, reaches twenty to forty rods from the river on each side, and rises 25 to 40 feet above it; and extends with nearly continuous exposures a third of a mile or more along the river south and southwest to the foot of these falls, which is near the mouth of Hay creek, a tributary from the west. Similar rocks, including very coarse granite, occur also at the "roll dam" and at the "gate dam" on this creek, situated respectively three-fourths of a mile and one mile above its mouth. On the east side of Snake river, about thirty rods south of the "jaws of the Upper falls," the

rock for several rods is darkish gray gneiss, dipping 30° to 40° S. Some twenty-five rods farther south, it is a medium-grained, light gray granite, containing both black and white mica, the former most abundant; this is a little northeast from a small island in the river, and is about an eighth of a mile north from the foot of these rapids of the Upper falls. This granite by its color and texture promises to be a handsome and easily wrought building-stone. It has more extensive exposures one mile farther southeast along the Lower falls.

A quarter of a mile south from the last, an exposure of dark granite or gneiss extends about ten rods along the southwest bank of the river. It is divided by a conspicuous system of joints which dip about 45° southerly. No outcrop occurs here on the northeast or left bank.

About forty rods southerly from the last, an outcrop of medium-grained, flesh-colored granite forms a small rapid. It occurs in the channel and has small and low exposures on each shore.

The head of the Lower falls is about an eighth of a mile south from the last, being where the river bends eastward in the north part of section 16. Between the Upper and Lower falls, as also above and below them, the land is slightly or moderately undulating till, 5 to 25 feet above the river, which is from three to eight rods wide.

The Lower falls of Snake river lie in the E. ½ of the N. E. ¼ of section 16, T. 42, R. 23, and in the N. W. ¼ of section 15, reaching about three-fourths of a mile, in which the river flows east and east-northeast, falling some twenty feet in this distance by a succession of rapids, but having no great fall at any one place. Along this distance the river is bordered by abundant granitic ledges, roughly ragged, jointed and broken, but rarely vertical, varying from 10 to 30 feet in hight. These rock-outcrops reach twenty to forty rods or more from the river upon each side, and form several east-to-west ridges, an eighth to a fourth of a mile long, rising 25 to 40 feet above the river. They rise most steeply in the south or right bank of the river, owing to a general system of joints which dips about 60° southerly. Throughout this area the principal rock is a medium-grained, light gray granite, desirable for quarrying, like that found fifty or sixty rods south from the "jaws" of the Upper falls. This rock is usually divided by joints at intervals of five to ten feet; and it includes veins and masses of gneiss, mica schist, very coarse flesh-colored

granite, and of feldspar; but these are far less frequent than at the Upper falls.

The place of the river's channel across this formation may have been determined by a stratum of dark, partly crumbling mica schist, which seems to be included in the granite. It is seen in each bank of the river along the central and east part of the Lower falls for a distance of a quarter of a mile; its best exposure is in the east part of this distance, where its strike is E. or N. 80° E., coinciding with the course of the river. The dip of this bed is about 75° S., and its thickness appears to be about one hundred feet. This schist encloses occasional seams of white quartz up to three and sometimes six inches in thickness, coinciding with the foliation.

Potsdam sandstone. Below these falls, the only remaining outcrops of rock on the Snake river in Kanabec county are sandstones, in part conglomeritic, which are believed to belong to the Potsdam period. No fossils were found in them. Their first exposure is about one and a half miles southeast from the Lower falls, being at O'Brien's camp, in the north part of section 23, T. 42, R. 23, where the river turns from a west to a south course. Here a dark red sandstone, divided throughout in layers from a quarter of an inch to two inches thick, is exposed in the river's west or right bank for twenty-five rods at and south from its sharp bend, seen at several places to a hight two to six feet above the water. Its best exposure is just below this, reaching twenty rods south-southeast, in the east bank of the river, forming a wall three to eight feet high. The general surface eastward is only about ten feet above the river, but it has no rock-outcrops. All this sandstone is divided in thin layers, which in many places show oblique bedding, varying five to ten degrees from the planes of stratification, which throughout dip 10° to 20° E. N. E. It is further divided by irregular vertical joints, into pieces only six to eighteen inches long. At several places this rock includes many gravel stones, up to a half or two-thirds of an inch in diameter; these are mostly quartzose; and one of soft, red pipestone was found.

In the south part of the next township (41 of range 23), Shumard reports an exposure, twenty-five feet in thickness, of red sandstone and alternating ash-colored clays.

At Knife River bridge, which crosses Snake river in the N.E.¼ of section 3, T. 39, R. 23, about three miles east-southeast from the

exposures of granite near Ann Lake dam, this sandstone is exposed for a length of about 300 feet and a width of 75 feet, on the southwest or right shore of the river. It has mainly a sloping surface, rising from the water's edge to about five feet above it; but at its east end for nearly 100 feet it has a vertical outcrop, rising in its highest part seven to ten feet above the river. This rock is a coarse-grained sandstone, of gray and iron-rusted color, divided by weathering into layers from a quarter of an inch to one and a half inches thick. Mainly it has an eastward dip, which appears to be slightly variable in amount and direction. At one place, the steepest noticed, the dip is 15° E. S. E. In some layers this rock has a deep dull red color for three or four inches vertically through a length of six to ten feet. This entire outcrop encloses pebbles here and there, mostly quartz or quartzose, of all sizes up to three and a half inches in diameter, but they are nowhere so plentiful as to give the rock the character of an ordinary conglomerate.

The foregoing comprise all the exposures of rock known in Kanabec county.

PINE COUNTY.

Crystalline schists. The most northern outcrops of rock learned of in this county, are in the east part of its northwestern township (T. 45, R. 21), where schist, conspicuously veined with white quartz, is reported as forming knobs 40 to 75 feet high and extending two miles or more in a course from southwest to northeast. Toward the southwest this formation appears in Kanabec county at the Upper and Lower falls of Snake river, and in Aitkin county at the dam on this river, situated in the S. W. ¼ of section 21, T. 43, R. 23, a few miles above these falls, and again in the north part of the same township, a few miles above this dam and a half to one mile below the fork of Snake river. Northward, it is exposed in Carlton county at the mouth of Split Rock river, tributary to the Kettle river from the west in section 32, T. 46, R. 20, and six miles farther east in the vicinity of Moose Lake station, which is two and a half miles north of Pine county line.

The last of these localities is the only one which I have examined. The southern limit of the rock exposures here is near Fox & Wisdom's steam saw-mill, a mile south of the depot. Thence northward the rock lies for two thirds of a mile partly on each side of the railroad. From the village its area reaches west a half mile, and continues about a mile farther north at some distance

west of the railroad, rising in moderate slopes 25 to 40 feet above the railroad and lake. It is mainly a darkish gray hydromica schist, considerably contorted, with variable dip, its lamination being sometimes horizontal, but usually dipping 15° to 25° S. or S. 15° E. Quartz veins, mostly from an eighth of an inch to three inches, and rarely from one to four feet, in thickness, are frequent. A vein, or dike, only about an inch in thickness, of dark, columnar trap, was found half a mile west of the station. Part of this rock, especially northward, is very fine-grained and compact, resembling quartzyte, and having a dark slate color. This usually shows no distinct lamination and has no slaty cleavage, but it is much divided by joints into rhombic masses one to two feet long. Other portions of this outcrop are traversed by joints from one to ten feet apart; their principal system is nearly vertical and runs from north to south or S. 10° E.; fewer joints cross these, bearing southwest or nearly from east to west. Through all the extent of this rock, it is very much broken upon the surface into a multitude of angular blocks from one to ten feet in dimension, so that on a large part of its area considerable search is needed to find it in undisturbed position.

Sandstone. An area of sandstone, shown on the map as belonging to the Potsdam period, but which upon further consideration seems to be more probably referable to the lower part of the St. Croix formation, is found on the Kettle river in Pine county from about three miles north of Kettle River station southward along a distance of nearly twenty-five miles. The most northern outcrop of this sandstone is reported in a bluff at the west side of Kettle river, near the southwest corner of section 10, T. 44, R. 20. Its next exposure is some two miles south of Kettle River station, in the S. E. ¼ of section 3, T. 43, R. 20, where it rises about ten feet in the northeast bank of Kettle river. Here and frequently onward to the mouth of the Grindstone river, this rock forms the river-bed and produces rapids. Where the old Government road crossed the Kettle river, a mile below this reef, the sandstone rises 10 to 15 feet in its right bank. Through the next fifteen miles, to about a mile below the Grindstone river, a deep channel has been eroded by the Kettle river in this formation, which is seen almost uninterruptedly along both sides, often making a wall 5 to 20 feet high at the water's edge, and ascending within a distance of an eighth to a third of a mile from the stream in bluffs 75 to 100 feet high, their upper half being usually vertical cliffs. Occasionally tower-like masses are left isolated beyond

the line of the bluff, the edge of which, also, is in many places broken into immense blocks, some of which have been already dislodged, while others are separated by yawning chasms, from one to six feet or more across and ten to twenty-five feet deep, ending in cavernous clefts and recesses below. This whole gorge fifteen miles long, like that of the Mississippi eight miles long from Fort Snelling to Minneapolis, has probably been cut by the river since the ice age. The drift in the vicinity of Kettle river is thin, and the sandstone reaches from the base to the top of its bluffs, which rise to the general level of the adjoining country. On tributary ravines and creeks this rock often forms picturesque cliffs to a distance of a half mile or one mile above their mouths; but farther back the water-courses are usually of small depth, not cutting through the moderately undulating drift-sheet, and only few exposures of the underlying sandstone are known. This sandstone is mostly fine but partly coarse in grain, rarely conglomeritic, seldom very hard and sometimes easily crumbling, usually gray or buff in color, and in stratification nearly level or inclined only a few degrees.

At the Upper falls (or Dalles) of the Kettle river, situated four miles east of Miller station, in the south edge of T. 43, R. 20, the river flows southwest in rapids about a half mile long, closely bordered upon each side by ragged cliffs of this rock, 50 to 100 feet high. About a sixth of a mile below the foot of this rapid, a little stream joins the river from the west, having a pretty waterfall, 13 feet high, a dozen rods above its mouth. Here the sandstone rises in successive steps of ten to twenty feet each, often overhanging, to a hight about 75 feet above the river. It is fine-grained, slightly reddish or yellowish brown, and bedded in layers from six inches to three feet thick. These layers are nearly level, but resemble many modern sand deposits in being often obliquely laminated, their dips varying from 10° to 45°, mostly southward. On the small tributary mentioned, this sandstone forms a picturesque ravine extending about a mile northwestward from the river. At a basin near the head of this gorge, it dips about three feet in a hundred feet, or approximately two degrees, to the southeast.

The Lower falls of Kettle river are in the south part of section 15, T. 42, R. 20, being a short distance below a very large chalybeate spring which issues at the foot of the eastern bluff, and about a mile south of a tributary whose loudly dashing descent down this bluff is hidden from view by its heavy woods. In the three miles between these falls of Kettle river, it flows with a gentle current.

At the Lower falls the sandstone forms both shores and the river's channel, in the middle of which it rises in an island with vertical walls and nearly level top, about a hundred feet across, and 10 or 12 feet above the water at the head of this fall. West of the island is a perpendicular descent of four or five feet, with rapids which fall two feet within a few rods above, and as much more within twenty rods below, making a total of about eight feet. East and south of the island the descent is a nearly continuous rapid, broken by vertical falls of only about one foot. The sandstone here is fine-grained and somewhat friable ; its color is yellowish gray ; and its stratification, in beds from six inches to three feet thick, has a slight dip to the south, varying from one to four feet in a hundred feet.

In sections 16 and 17 of this township, one and two miles west from the Lower falls, exposures of this sandstone occur on the south side of a small brook, 10 to 20 feet above it, and at the general level of the surrounding drift-covered country. In the west part of section 17, it is hard and fine-grained, and was quarried several years ago to test its value as a grindstone.

At Hinckley, on the Grindstone river four miles above its mouth, this sandstone has been quarried by the Saint Paul & Duluth railroad company. The section thus exposed is six to nine feet high and about 250 feet long from north to south, lying close north of the river and east of the railroad. The top of this ledge is twelve feet above the river, and is overlain by three to eight feet of very coarse gravel, nearly like till. This rock is a hard and compact, medium-grained sandstone of light buff color, nearly level in stratification. Its beds vary from one inch to two feet in thickness, and in some portions they show oblique lamination, which is inclined 10° to 15° northward. Quarrying was begun here in 1878, since which time this stone has been largely used for bridge-masonry.*

This rock is reported to occur frequently in large blocks, and perhaps has low outcrops in place, along the north branch of Grindstone river, and about Grindstone lake. Below Hinckley this river has cut its channel about fifty feet deep in drift deposits, and no exposures of rock in place were found. From its mouth north along Kettle river, the sandstone occurs in the bluffs, has extensive exposures where the old Government road crosses Deer creek, and forms Pine Island rapids, about four miles south of the Lower falls. A half mile to one mile below the mouth of Grindstone river, ledges of sandstone, nearly level in bedding, light

* Glacial striæ, seen here at several places, run S. and S. 5° W., by the true meridian.

gray in color, and often containing fine gravel up to an eighth or a fourth of an inch in diameter, occur a short distance west of Kettle river, having a hight 20 to 40 feet above it. On the east side of Kettle river here and probably at many places through several miles farther southeast, to the head of the rapids which reach thence to its mouth, a line of broken sandstone bluffs, declining southward from 50 to 25 feet in hight, is found a fourth to a third of a mile from the river.

The next observation of sandstone southeastward is by Owen, who reports it on the southeast side of the St. Croix river a little below the head of the Kettle River rapids. It is red, much shattered, and is underlain by a conglomerate. Near by are numerous outcrops of cupriferous eruptive rock.*

Copper-bearing trap. My examination of the trappean rocks and their beds of tufaceous conglomerate, includes the three miles of Kettle river next to its mouth, and also two ledges seen in its west bank about a mile below the mouth of Grindstone river; outcrops of these rocks on the St. Croix below Kettle river ; and their belt crossed by the Snake river in the three miles next east from Chengwatana. Numerous other outcrops of these rocks are reported by Owen and Shumard along the upper three miles of the Kettle River rapids of St. Croix river, and on Kettle river in the distance of about ten miles between its portions here described.

In northern Michigan this trappean formation is rich in copper, which is there extensively and profitably mined. Its continuation westward in northern Wisconsin, on the north shore of lake Superior, and in Pine and Chisago counties, contains generally traces of copper ores, often green in color, most abundant in seams and veins and in decomposing portions of the rock, and rarely particles or even considerable masses of native copper are found in it; but no profitable mining has been yet found upon its areas in Minnesota.

The most northern exposures of trap on the Kettle river are in T. 41, R. 20. The ledges seen by me in this township are situated about twelve rods apart, in the southwest bank, a mile below Grindstone river, being near the northeast corner of section 27. The southern of these outcrops is about seventy-five feet long and

*East and northeast from the Kettle River rapids on the St. Croix, no outcrops of the bed-rock have been learned of in Pine county, by much inquiry addressed to surveyors and lumbermen who are familiar with this part of the St. Croix and with its tributaries, Bear, Sand, Crooked and Tamarack creeks. The region consists chiefly of till, rising by gentle slopes to hights 25 to 50 feet above the streams, and is well-timbered with hard wood and much red and white pine.

rises three to five feet above the river; and the northern has about half this length and hight. Both are trap, somewhat decomposed, of dull red or dark rusty color, partly amygdaloidal, and much divided by irregular joints and cracks into fragments from one to twelve inches long.

Kettle river from the east line of T. 40, R. 20, to its mouth, a distance of about six miles, consists of a succession of rapids, alternating with portions that have a gentle current. My notes cover the lower half of this extent, beginning at the elbow where the river bends from a south to an east course, in the southern part of section 32, T. 40, R. 19. At this bend and eastward an outcrop of trap extends about twenty-five rods in the southwest bank, rising perpendicularly at each end about ten feet above the water, but in its middle portion having a hight of only two or three feet. Much of this rock is the usual dark and tough trap; it is minutely pitted upon weathered surfaces; and is often divided by joints into rhombic masses from three inches to two feet long. Some portions are amygdaloidal, holding green bunches of chlorite and epidote, apparently because of decomposition and metamorphism. Veins of calcite in the form of satin spar, from a sixteenth of an inch to one inch in thickness, and sometimes ten feet or more in length, occur in many of the joints, vertical, oblique and horizontal, in the decomposing parts of these ledges.

About a half mile farther east, near the center of the S. W. $\frac{1}{4}$ of the S. W. $\frac{1}{4}$ of section 33, trap is exposed in the northeast bank of the river, having an extent of a few rods and rising about five feet above low water. This is known as the "copper claim," from prospecting shafts sunk here by Mr. N. C. D. Taylor, in 1865.

Here the river turns south and holds this course to its mouth. A little below the "copper claim," in the north part of the N.W. $\frac{1}{4}$ of section 4, T. 39, R. 19, its east shore is trap, declining in hight from ten to two feet along its extent of about forty rods from north to south, overlain by a bluff of red till, 25 to 30 feet high.

Next this rock outcrops at many places on the west shore of the river along a distance of nearly a quarter of a mile, at the middle part of the west side of this section 4. It rises one to five feet above the river. Generally it is somewhat decomposed, being often oölitic and nodular, with frequent green stains. Small portions of it are tufaceous conglomerate. It is much divided by joints from two to eighteen inches apart, varying in inclination from 45° to vertical. Their most conspicuous system of parallel planes has an

east-northeast strike. All this lower part of Kettle river has low shores or bluffs only 25 to 40 feet high, and the adjoining country is moderately undulating drift.

The mouth of Kettle river is divided by two small islands into three channels. Opposite to its mouth and for three miles above and one mile below, the St. Croix river is turned in two channels, by three long islands, which together are called the "Big island." The eastern, large channel is the state boundary; and the western is commonly called the "slough." In both the river has a strong current, with numerous rapids, the largest fall being two or three feet in a few rods at a reef of trap which crosses both channels near the middle of the upper island. This extent of about four miles on the St. Croix river is named Kettle River rapids. The highest outcrops of trap in this distance rise only 10 to 20 feet above the water.

Descending the St. Croix from the mouth of Kettle river, the first rock was found at the south end of the "Big island." Here very compact and hard, dark trap has an extent of about twelve rods from east to west and a hight of five feet.

About a mile farther south, near the south line of section 20, trappean rock, nearly like the last, divided by joints one to four feet apart, forms the west shore of the river for ten or twelve rods, reaching five to ten feet above the water. It again has an exposure of similar extent in the same bank some fifty rods farther southwest, being in the N. W. $\frac{1}{4}$ of section 29, T. 39, R. 19, about twenty-five rods below the north end of the "Thousand islands," where another ledge of this rock occurs.

The most southern outcrop of trap on this part of the St. Croix is found on the Wisconsin side about a half mile south from the last. Its visible length is only about ten feet, and its hight six feet. Forty rods farther south, opposite to the last of the "Thousand islands," is the most northern point on the St. Croix river at which I observed the St. Croix sandstone, which thence is frequently exposed along a distance of nearly twenty miles to the south.

The southwestward continuation of this area of copper-bearing trap is found on the Snake river at Chengwatana and for three miles east. Farther southwest the bed-rocks are universally concealed by the drift, as also along this river above to its sandstone outcrops in Kanabec county. Chengwatana dam, in Snake river at the mouth of Cross lake, is built on ledges of trap and conglomerate, which here and in their other outcrops, seen at several places within the next mile, and two and three miles below, rise five to

fifteen feet above the river. Their exposures are restricted to its channel and banks, and the adjoining region is gently undulating or nearly level drift, 20 to 50 feet higher. The greater part of this belt consists of dark, hard and compact, fine-grained, tough trap. Other portions show various stages of decomposion and metamorphism, and bear amygdaloidal masses of chlorite, epidote, and other minerals, and veins of calcite.

Search for copper in these rocks was made several years ago by Mr. Adolph Munch, about three-fourths of a mile below Chengwatana, by several shafts of little depth, upon each side of the river and in its channel. During 1880 and 1881, further prospecting for copper was entered upon by the Chengwatana Mining Company, represented by Mr. J. Bennett Smith, who has sunk shafts at three points on the north side of the river, three-fourths of a mile, one mile, and one and a half miles east from Chengwatana. The first of these is in a dark red, ochery conglomerate, which contains many water-worn pebbles, mostly from a half inch to two inches in diameter, apparently derived from the trap, but altered and decomposed. Mr. Smith states that this bed of conglomerate is thirty feet thick, with strike N. 15° E. and dip 70° S. 75° E.. He reports another bed of conglomerate, very coarse, fifty feet thick, a half mile east of Chengwatana, and a third, about twenty-five feet thick, at the mouth of Cross lake, close above the dam.

At the time of my observation here, October 17, 1881, Mr. Smith was at work at the shaft a mile east of Chengwatana, in an amygdaloidal bed, fifty feet in width, dipping 70° S. 75° E. This had been excavated to a depth of 45 feet, below which farther exploration has been since made with a diamond drill. The hanging wall is very hard, fine grained black trap; next to this the first five or six feet are soft, decomposed amygdaloid, holding many chloritic bunches, from a quarter of an inch to two inches in diameter; the central and lower portions are somewhat harder, and contain much calcareous spar in crystalline masses and in banded veins, besides a large variety of other minerals; the foot wall is compact and hard, somewhat amygdaloidal trap. All these beds of conglomerate and amygdaloid have approximately the same strike and dip. Prof. T. C. Chamberlin reports the strike of these strata on the Snake river to be N. 10° to 15° E., and their dip 50° to 60° south of east. The formation was made up by successive overflows of molten rock, which cooled to form hard, finely crystalline trap beneath, but often in the upper part became

scoriaceous and amygdaloidal; and between these eruptions, during intervals of repose, layers of tufaceous conglomerate sometimes were accumulated.

St. Croix sandstone. East of this trappean belt, the next exposures of rock on the Snake river are near its mouth. Its northeast bluff in the S. ½ of the N. E. ¼ of section 36, T. 39, R. 20, about a mile above its junction with the St. Croix, has an outcrop of gray and white sandstone, which extends about twenty rods, rising ten to fifteen feet above the river. This is a levelly stratified, somewhat friable rock, in layers from three inches to one and a half feet thick, mostly intersected by nearly vertical joints two to five feet apart. It was quarried a few years ago by Mr. T. R. Rice and others for the foundation of the court house at Grantsburgh, seven miles east in Burnett county, Wisconsin. Two or three feet above the line of low water, this sandstone includes a layer of conglomerate, one foot thick, composed of gravel and pebbles up to an inch in diameter, mostly white quartz, all much water-worn.

Half a mile farther east, where the river turns from a north to an east course, about a hundred rods above its mouth, another outcrop of this formation was seen along an extent of about fifty feet and to a hight of six feet. The lowest beds here, about four feet in hight, are whitish and yellowish, somewhat pebbly sandstone, in layers from a quarter of an inch to six inches thick; in part rhomboidally divided by many joints; levelly stratified at the east, but at the middle of the exposure dipping 1° to 10° southwesterly and disappearing. The overlying beds are soft, finely laminated shales, red, green and yellow. Their red layers are from an inch to one and a half feet thick, rarely enclosing yellow laminæ; and the green vary from one to four inches in thickness, including yellow layers up to three-fourths of an inch thick.

On the St. Croix river similar beds were noted in its southeast bank, opposite to the most southern of the "Thousand islands," a mile above the mouth of Snake river. Here whitish and slightly yellowish, soft sandstone was exposed along a distance of forty feet, and to a hight of ten feet above the water, in the base of a high bluff. It is bedded in horizontal layers, which are obliquely laminated, and vary from three to twelve inches in thickness, sometimes divided by layers a quarter of an inch to one inch thick of greenish sand. Under this sandstone, the three feet next to the water consisted of soft shales, the upper one and a half to two feet being dark red, finely laminated, with occasional thin streaks of green or yellow; then, about a foot of light green color, with lit-

tle yellow and red, underlain at the water's edge by a second red stratum. An eighth of a mile farther south, this eastern bluff, about 90 feet high, exposes a vertical thickness of fifteen feet of nearly white, level sandstone, 35 to 50 feet above the river.

A quarter of a mile below the mouth of Snake river, this sandstone occurs, thinly covered with alluvium, a few rods north of Mr. T. R. Rice's house, on the Wisconsin side, being eight or ten feet above the St. Croix.

The Horse-race rapids, not broken by boulders, are a half mile long, lying mostly in the N. E. ¼ of section 7, T. 38, R. 19. The next half mile of the St. Croix, two to two and a half miles below Snake river, is bordered on the Wisconsin side by perpendicular cliffs of white, coarse-grained, soft and crumbling, horizontally bedded sandstone, about 50 feet high.

CHISAGO COUNTY.

St. Croix sandstone. At Baltimore rapids, on the St. Croix river a little below the northeast corner of Chisago county, in the N. E. ¼ of section 4, T. 37, R. 20, this St. Croix sandstone forms a bluff on the Minnesota side, 50 feet high and a quarter of a mile long.

In the southwest quarter of this section, about a half mile below the last, ledges of sandstone, light gray in color, coarse-grained and rarely including white quartz pebbles up to three-fourths of an inch in diameter, friable, and level in stratification, occur at two or three points within an eighth of a mile on the Wisconsin side, rising 10 to 15 feet above the river.

An eighth of a mile farther southwest, the same stone rises on the Minnesota side in a vertical and overhanging cliff twenty feet high and about fifteen rods long, known as the "big rock." It is the last prominent ledge seen in descending the St. Croix before coming to the high outcrops of trap in the southeast part of this county.

Only two localities of rock-exposures are known in the intervening distance of twenty-five miles, both being sandstone with the characters already described. These are at a fall of about ten feet on Rush creek a half mile above its mouth, and at Yellow Pine rapids in the St. Croix, on the east side of section 18, T. 36, R. 20, where low ledges of this stone are seen in its channel and banks along a distance of nearly a mile.

This sandstone and its included shales are exposed at many places in the bluffs of the St. Croix river at St. Croix Falls and Taylor's Falls, and through Franconia, the southeastern township of this county. In stratification all these beds are nearly horizontal and show no indications of any disturbance or metamorphism since their deposition. They reach from the level of the river to hights 50 to 100 feet above it, and are overlain by the glacial drift. Where they lie in contact with the steep, vertical, or overhanging sides of the trap rocks which here form the Dalles of the St. Croix, they are often changed to conglomerate, containing many fragments that fell from these cliffs, which had already been deeply eroded before the St. Croix sandstone and shales were deposited. These sediments contain multitudes of shells of *Lingula* and *Orbicula* species, and trilobites occur rarely; but no fossils have been found in any of the strata which lie farther north, described in the foregoing pages.

At St. Croix Falls, in Wisconsin, fossiliferous shales, mostly gray, but in some beds green, often bearing films of iron rust in their crevices and joints, and including thin layers of sandstone, are seen from the river's shore to a hight of 50 feet. These shales also form the Minnesota bank of the river, about 30 feet high, between twenty and forty rods north of the Taylor's Falls bridge.

In the two miles between the Upper and Lower Dalles, the formation is a whitish or yellowish gray, soft, often friable, sandstone, exposed in the bluffs west of the St. Croix to the hight of about 100 feet. Near Taylor's Falls it has been somewhat quarried for use as a building stone.

At Franconia, close below the Lower Dalles, it reaches in the bluff of Lawrence creek at Paul Munch's mill to a hight of about 70 feet above the creek or 90 feet above the St. Croix. Its upper 40 feet are a gray, thick-bedded sandstone, which is rather friable, but hardens after quarrying; it supplied the stone of which this mill was built, fifteen years ago. The next 12 feet are finely laminated, slightly sandy shale, soft, but hardening by exposure, green and iron-rusted, superficially ash-colored; and the 20 feet at the base are dark-greenish sandstone, soft and incoherent at the weathered surface.

The ravine of Lawrence creek for a half mile above this mill is enclosed by cliffs of this sandstone, mostly like the upper part of the foregoing section, rising 50 to 75 feet above the creek, and in their highest portion about 125 feet above the St. Croix. Myriads of *Lingulæ*, difficult for preservation, excepting as fragments, because of

the crumbling character of the stone, occur in these beds on each side of the creek, an eighth to a fourth of a mile north from the mill, at about the hight of the flume. The dip here is one to one and a half feet in a hundred, or about three-fourths of a degree, southward.

Travertine, a limestone deposited from the water of springs, occurs in large deposits on the face of the bluffs of this sandstone, and has been extensively burned for lime, a quarter to a half of a mile south of Munch's mill in Franconia, and near Osceola, a few miles farther south on the Wisconsin side. At the latter place, nearly opposite to the southeast corner of Chisago county, the St. Croix sandstone is thinly capped by the Lower Magnesian limestone, which thence southward overlies this formation along the St. Croix and Mississippi rivers.

Copper-bearing trap. The remarkable outcrops of trappean rocks forming the picturesque and grand Dalles of the St. Croix, are more than thirty miles south of the areas of these rocks in Pine county. About a mile above Taylor's Falls and close above St. Croix Falls, trap occurs in the channel and on both sides of the river, its highest portions having an elevation of 50 feet. At Taylor's Falls the St. Croix enters its Upper Dalles, where for three-fourths of a mile it is walled on both sides by bold, often vertical, ragged cliffs, 75 to 150 feet high, of tough, nearly black, massive trap. This gorge and the similar one of the Lower Dalles, about a quarter of a mile long, close above Franconia, have been cut in this rock by the river, the excavation being aided by nearly vertical joints. At Taylor's Falls landing these bear N .60° E. and N. 45° W.

East of the road to this landing, the ledges of very hard trap, 25 to 60 feet above the river, are surprisingly water-worn, with many pot-holes of all sizes from those only one and a half feet in diameter and six feet or more in depth, almost perfectly cylindrical, to the caldron, situated six rods northeast of the landing, twenty feet in diameter, circular, and ten feet deep with perpendicular sides to the surface of the water which partly fills it. Into one of these wells, eight feet in diameter, a pole has been thrust down thirty feet.

The origin of this formation, as in Pine county and in the lake Superior region, appears to have been by overflows of molten rock poured out from fissures of the earth's crust; but only inconsiderable portions of the beds exposed here are amygdaloidal, and this structure is rarely seen to be characteristic of distinct layers. A general system of jointage planes, which is quite noticeable in

these outcrops, dipping about 15° W. by S. is regarded by Professor Chamberlin as parallel with the planes of bedding of the trappean overflows, at first nearly level, but subsequently disturbed and tilted. He further remarks that these rocks and those of Pine county are bent in a synclinal, like their broader continuation northward, which forms the depression of lake Superior; and that this continuously synclinal belt is slightly curved upward, saddle-like, between the lake and its southern extremity in the St. Croix basin.

A band of conglomerate, the only one observed in the exposures of trap in this region of the Dalles, is reported by Mr. D. A. Caneday, in a ravine on the Minnesota side, nearly a mile southwest from the bridge; being a layer eight feet thick, dipping 15° westerly, overlain and underlain by trap, which is dark above and reddish beneath.

Exploration for copper and silver has been made in the trap formation at Taylor's Falls by three shafts. A short distance east of the Lutheran church on the road to Franconia, Mr. N. C. D. Taylor went to a depth of 43 feet, finding films and small masses of native copper. This is near the highest part of these trappean ledges, about 200 feet above the river, and 50 below the average hight of the rolling drift which universally covers the bed-rocks from the top of this river-bluff westward. The two other shafts were sunk by the Taylor's Falls Mining Company, one being near the river, and the other about 75 feet above it, on Ravine street. The last was worked in 1874 and 1875, and reached a depth of 120 feet, following a vein eight to ten feet wide, which dipped to the west about 85°, or ten feet away from a plumb-line. This vein contained ores of both copper and silver. An apparently metalliferous vein, four feet wide, with strike nearly from north to south, is seen on the surface about half-way between this and Mr. Taylor's shaft. Another, eighteen inches in thickness, dipping 12° W. S. W., is described by Mr. Caneday, near the foot of the Upper Dalles, at a little hight above the river; the four inches next to the hanging wall being bornite, a sulphuret of copper and iron, with about a foot of white quartz and a thin earthy layer below.

IV.

LAKE AGASSIZ: A CHAPTER IN GLACIAL GEOLOGY.

[Read before the Minnesota Academy of Natural Sciences, Jan. 6th, 1882.]

BY WARREN UPHAM.

In the last of the geologic ages a very cold climate covered the north part of our continent with ice. Every year the snowfall was greater than could be melted away in summer; and its depth gradually increased till its lower portion was changed to compact ice by the pressure of its weight. This pressure also caused the vast sheet of ice to move slowly outward from the region of its greatest thickness toward its margin. Our reasons for believing that there has been such a wonderful glacial period, are abundant and must convince anyone who gives attention to them.

The surface of the bed-rock at the quarries in this city [Minneapolis], on Nicollet island and beside the Mississippi farther east, bears fine scratches and markings, called *striæ*, like those which are found beneath the glaciers of the Alps. Only one cause is known which can produce markings like these, and this is the rasping of stones and boulders frozen in the bottom of a moving mass of ice, accumulated upon the land in a solid sheet of great extent and depth. As these striæ are found upon the rocky surface of British America and of the northern United States to a southern limit that coincides approximately with the course of the Ohio and Missouri rivers, we must conclude that an ice-sheet has covered these regions.

The superficial material that overlies the bed-rock within this northern glaciated area has everywhere been ploughed up and worked over by the slowly moving ice-sheet, and at its disappearance was left in a deposit of clay, sand, gravel and boulders, mixed in one confused mass, which is called *till*. Except in the valleys, as of the Mississippi at Minneapolis, where streams have assorted these materials and spread them in layers, the till forms the surface of nearly all of Minnesota, its thickness being from 50 to 250 feet. It is the stony and gravelly clay, in which cellars and well are dug; and it forms a sheet of such great extent and thickness that about half of the counties of western Minnesota contain no exposures of the underlying older rocks.

The thickness of the ice-sheet was so great that its striæ and transported drift are found on the top of mount Katahdin, of the White mountains, and the Adirondacks; and over northern Minnesota it was probably of equal depth, or about a mile thick. By the direction in which the boulders have been carried from their original ledges, and by the courses of the glacial markings, we know that the ice moved in general from north to south. In New England its current was southeastward, and the border of the ice-sheet was pushed into the Atlantic to the fishing banks south of Newfoundland and east of cape Cod. Over Canada and the region of the great lakes, the ice-flow was southwestward. A glacial current moving in this direction has spread upon eastern Minnesota a red till, thus colored by the hematite, or anhydrous sesquioxide of iron, contained in the red quartzyte, sandstone and shales of lake Superior, which were eroded by this ice-sheet. In western Minnesota the ice flowed southward from lake Winnipeg to Big Stone lake and thence southeast into northern Iowa, spreading a blue till, with many boulders of limestone.

Terminal moraines, or hills, knolls and ridges of drift heaped at the border of the ice-sheet, are found stretching in a remarkably curved and looped course across Wisconsin, Minnesota, Iowa and Dakota. The line of this formation in Minnesota reaches from Stillwater and Saint Paul northwest to the vicinity of Saint Cloud and to the Leaf hills, this part being at the limit of the ice-current which came from lake Superior; then from the Leaf hills south by Glenwood, lake Minnetonka, and Albert Lea, into Iowa to the vicinity of Des Moines, this part being pushed out at the east side of an extensive lobe of the ice-sheet, whose central current went south and southeast; then, on the west side of the same glacial lobe, its terminal moraine has been traced from cen-

tral Iowa northward by Spirit lake and lake Benton to the Head of the Coteau des Prairies, twenty miles west of lake Traverse. This moraine was formed at the margin of the areas that were overspread by the ice of our last severely cold epoch.

At some earlier time of the same great glacial period, the ice-covered area extended much farther south, to northeastern Kansas, into Missouri to Saint Louis, and to southern Illinois, Indiana and Ohio. Within this area and entirely surrounded by the ice-sheet, a district about 150 miles long from north to south and 100 miles wide, lying in southwestern Wisconsin and adjoining parts of Illinois, Iowa and southeastern Minnesota, was singularly exempted from glaciation. The picturesque bluffs of rock along the Mississippi from lake Pepin to La Crosse and southward, often standing out isolated and alone like the ruins of turreted castles, are in the region which has no till and has not been planed and smoothed by the ice-sheet.

The end of the glacial period was brought by the genial influence of a milder climate when the surface of the ice-sheet was melted faster than it was replenished by the snowfall. Its depth and extent could no longer increase, but were thenceforth gradually diminished. While the ice had been growing deeper and much of the snow that fell each year remained unmelted, its surface was probably as smooth and nearly level as our most uniform and monotonous tracts of prairie ; and its vast area was one white expanse, unflecked by pebbles, earth or even dust, excepting close to the border where its progress was stayed by melting and the drift which had been gathered into the ice-mass became exposed on its surface and was carried forward and heaped at its margin.

At the departure of the ice, the scene was changed. Its surface upon large areas, reaching probably two or three hundred miles from its edge, was hollowed into basins of drainage and channeled by streams which flowed between walls of ice. The boulders, gravel, sand and clay mingled in the ice, mostly in its lower portion, were exposed by this melting, so that at length, when only a small thickness of the ice was left, its surface must have been covered by the drift which it had contained.

The portion of North America which was overspread by the ice-sheet, and from which it disappeared in this way, was of great extent, reaching from the north part of the United States to the Arctic ocean, and from New England to Dakota and westward in British America to the Pacific. The melting and recession of this ice began at its southern border and slowly proceeded northward.

Wherever there was free drainage away from the ice-sheet, a large part of the materials of the drift which had been gathered up into it fell in a comparatively loose, unstratified mass, forming the upper part of the till with its moderately undulating surface, and covering the land upon which the ice had lain, whether this was bed-rock, a ground-moraine, or till formed in an earlier glacial epoch.

Other parts of the drift held in the ice were washed away by its streams and deposited as *modified drift*, forming layers of gravel, sand, and fine silt, in the valleys along which the flood supplied by its melting descended toward the ocean. The high water of the rivers, like that which now occurs for a few days in the freshets of spring, was then maintained through the entire summer, and this was repeated yearly till the glacial sheet had retreated beyond their lines of watershed. The abundant supply of sediment through this time gradually lifted these floods upon the surface of thick and wide plains, sloping with the valleys.

After the departure of the ice, the supply of both water and sediment was so diminished that the streams could no longer overspread these flood-plains, and add to their depth, but were thenceforth occupied mainly in slow excavation and removal of these deposits, leaving remnants of them as plains or terraces, sometimes 100 to 200 feet, or more, above their present channel. The conspicuous bluffs of loess bordering the Missouri river were formed in this way. Along the Mississippi the flood-plain of modified drift at Brainerd and Saint Cloud has a hight about 60 feet above the river ; at Clearwater and Monticello, 70 to 80 feet ; at Dayton, 45 feet; and at Minneapolis, 25 to 30 feet above the river at the head of St. Anthony's falls.

This review of the condition of Minnesota during the glacial period prepares us to understand how the glacial *Lake Agassiz* was formed in the basin of the Red river of the North and of lake Winnipeg during the final melting and gradual recession of the ice-sheet. It thus belongs to the closing epoch of the ice age, when the continental glacier, subdued by a more temperate climate, was yielding its ground between northwestern Minnesota and Hudson bay. During this retreat free drainage from the melting ice could not take place, because the descent of the land is northward. As soon as the border of the ice had receded beyond the watershed dividing the basin of the Minnesota from that of the Red river, it is evident that a lake, fed by the glacial melting, stood at the foot

of the ice-fields, and extended northward as they withdrew along the valley of the Red river to lake Winnipeg, filling this valley and its branches to the hight of the lowest point over which an outlet could be found. Until the ice-barrier was melted upon the area now crossed by the Nelson river, thereby draining this glacial lake, its outlet was along the present course of the Minnesota river. At first its overflow was upon the nearly level, gently undulating surface of the drift, about 1100 feet above the sea, at the west side of Traverse and Big Stone counties; but in process of time this cut a channel here 125 to 150 feet deep, and from one to two miles wide, in which lie Traverse and Big Stone lakes, respectively 970 and 962 feet above the sea. From this outlet the Red river valley, 30 to 50 miles wide, stretches 315 miles north to lake Winnipeg, which is 710 feet above the sea. Along this entire distance there is a very uniform continuous descent of a little less than one foot per mile. The drift contained in the ice-sheet upon this area, and the silt gathered by its glacial rivers, were here deposited in a lake, shallow near its mouth, but becoming gradually deeper northward. Beyond our national boundary this lake covered a large area, varying from 100 to 200 miles in breadth at and west of lake Winnipeg; and its total length appears to have been at least 600 miles. Because of its relation to the retreating continental ice-sheet, this lake has been named in memory of professor Louis Agassiz, the first prominent advocate of the theory that the drift was produced by land-ice.

Under the direction of professor Winchell, the state geologist, it was a part of my work last summer to trace the course, and determine the hight, of the shore-line of this ancient lake. This was done in July and August, the only months of the past season which had sufficiently dry weather for entirely satisfactory progress in such exploration. Horace V. Winchell was my efficient assistant as rod-man in the work of leveling, by which the hight of the upper beach was ascertained along its whole extent examined. This was about 175 miles, following the course of the old shore, extending from lake Traverse to the north side of Maple lake, twenty miles east of Crookston. The distance that it includes from north to south is 142 miles.

BEACHES OF LAKE AGASSIZ.

[For a map of these, see fig. 3, plate 1.]

The upper or Herman beach. Along nearly the whole of this distance there exists a remarkable deposit of beach gravel and sand,

forming a continuous, smoothly rounded ridge, such as is found along any part of the shores of the ocean or of our great lakes where the land sinks in a gently descending slope beneath the water-level. Usually the beach of lake Agassiz is a ridge three to ten feet above the land next to it on the side that was away from the lake, and ten to twenty feet above the land adjoining it on the side where the lake lay. In breadth this beach-ridge varies from ten to twenty-five or thirty rods. It is thus a broad wave-like swell, with a smooth, gracefully rounded surface.

Such being a section across the beach, remember that this ridge extends along the whole distance that we have explored, with only here and there gaps where it has been cut through by streams and rare intervals of a quarter or a half mile or at the longest two or three miles where the outline of the lake shore, or the direction of the shore-currents, prevented such accumulation. We find similar interruptions in the beaches of present lakes and on the sea-coast; and like these modern deposits the beach of lake Agassiz varies considerably in its size, having in any distance of five miles some portions five or ten feet higher than others, due to the unequal power of waves and currents at these parts of the shore. The moderate slope of the land toward lake Agassiz was favorable for the formation of a beach-ridge, and it has been clearly traced as one continuous formation along this distance of 175 miles. In calling it continuous, we mean that whenever it is interrupted it is found a little distance farther along, beginning again at very closely the same hight.

The gaps where the beach is not a distinctly traceable ridge-like deposit of gravel and sand, cannot exceed one-twentieth of its whole course. In a few places the lake has undermined its shore, forming a terrace in the till, with no definite beach-deposit, the work of the waves having been to erode and carry away rather than to accumulate. In other places, sometimes two or three miles in length, the area where this ancient lake had its margin is a marsh or shaking bog, full of spring water, and rough with hummocks of grass, which grows luxuriantly, but is safe from the hay-makers because teams cannot be driven upon these tracts.

Nearly everywhere along the course of this beach of lake Agassiz the land upon each side is till, or unstratified clay, containing some intermixture of sand and gravel and occasional stones and boulders. The material of the beach-ridge is remarkably in contrast with this adjoining and underlying till, for it includes no

clay but consists of stratified sand and gravel, the largest pebbles being usually from two or three to six inches in diameter.

When lake Agassiz stood at its greatest hight and formed the upper beach, its outlet was about 85 feet above the present surface of lake Traverse, or 1055 feet above the sea. The channel which at this time had been excavated in the drift by its outflow was 30 to 40 feet deep along the distance of about fifty miles where now are lake Traverse, Brown's valley, and Big Stone lake. This beach is crossed by the Breckenridge line of the Saint Paul, Minneapolis & Manitoba railway at a point about one and a half miles northwest from Herman.

The Norcross beach. Two lower beaches, of the same character as to form, size, and material, with the highest, were also noted; their course was traced through long distances; and their hight was determined by our leveling. At the next epoch, after that of the upper or Herman beach, when the lake-level was again nearly stationary long enough to form a ridge of gravel and sand upon its shore, the outlet had been eroded about 30 feet deeper than at the time of the upper beach, but was still 55 feet above the present lake Traverse and Brown's valley. The beach of lake Agassiz when it had this lower level is crossed by the Breckenridge railway line at Norcross, five miles northwest of Herman. This is accordingly named the *Norcross beach.* Its course and hight have been determined through an extent of a hundred and fifty miles from Norcross northward to a point twenty-five miles north of Maple lake and ten miles beyond Red Lake Falls.

The Campbell beach. A third series of beach-deposits of similar extent and conspicuous development with the foregoing, was formed when the outlet of lake Agassiz had been lowered some 50 feet more, completing the excavation of its channel to the present beds of Traverse and Big Stone lakes. The beach of this third stage of lake Agassiz crosses the township of Campbell in southern Wilkin county from southwest to northeast, and hence it is denominated the *Campbell beach.* The course of this formation through Wilkin and Clay counties has been noted at a few places, and is thus known approximately. Through its next one hundred miles, from the Wild Rice river to the Tamarack river, it has been traced continuously. For forty miles next beyond Red Lake river the old Pembina trail lies most of the way upon this beach. It has been explored to the north line of Marshall county, sixty miles beyond Maple lake.

Three distinct series of beach-ridges of gravel and sand were thus formed by lake Agassiz at successive stages of hight during its process of deepening the channel by which it outflowed southward.

THE RED RIVER VALLEY.

The central part of the basin of lake Agassiz, within the limits of Minnesota and Dakota, now drained by the Red river, has an exceedingly flat surface, sloping imperceptibly northward, as also from each side to its central line. The Red river has its course along the axial depression, where it has cut a channel 20 to 60 feet deep. It is bordered by only few and narrow areas of bottomland, instead of which its banks usually rise steeply on one side and by moderate slopes on the other, to the lacustrine plain which thence reaches nearly level ten to twenty-five miles from the river. Its tributaries cross the plain in similar channels, which, as also the Red river, have occasional gullies connected with them, dry through the most of the year, varying from a few hundred feet to a mile or more in length. Between the drainage lines, areas often five to fifteen miles wide remain unmarked by any water-courses. The highest portions of these tracts are commonly from two to five feet above the lowest.

This vast plain, twenty-five to fifty miles wide, lying half in Minnesota and half in Dakota, and stretching from lake Traverse and Breckenridge north to Winnipeg, is the widely famed *Red river valley*. The material of the lower part of this ancient lake-bed shown in the banks of the Red river and reaching several miles from it, is fine clayey silt, horizontally stratified; but at its south end, in Traverse county and the south half of Wilkin county, and upon large areas of each side of this plain, it is mainly unstratified boulder-clay, which differs from the rolling or undulating till of the adjoining region only in having its surface nearly flat. Both these formations are almost impervious to water, which therefore in the rainy season fills their shallow depressions, but none of these are so deep as to form permanent lakes. Even sloughs which continue marshy through the summer are infrequent, but, where they do occur, cover large areas, usually several miles in extent.

On all the area drained by the Red river in Minnesota the glacial drift is so thick that no exposures of the underlying rocks have been found. The depth of the drift here is nearly the same as its average throughout the western half of the state, or from 100 to 250 feet. The prominent topographic features of all this

region are doubtless due to the form of the underlying rock-surface, upon which the drift is spread in a sheet of somewhat uniform thickness.

Erosion, before the ice age, had sculptured the rocks which are everywhere buried and concealed under this universal drift-sheet, and had formed the broad nearly level depression of the Red river valley, which is 1000 to 800 feet, from south to north, above the sea. Slopes and terraces of these rocks beneath the drift cause the rise eastward from this valley to the lake-sprinkled plateau, 1300 to 1500 feet above the sea, which reaches from Glenwood, Alexandria and Fergus Falls, to the sources of the Mississippi. For example, though the traveler finds no ledge of rock in going from the Red river at Fargo and Moorhead seventy-five miles east-northeast to Itasca lake, we yet believe that the form of the surface, marked by two remarkable terraces, is due to that of the bed-rock. The flat of the Red river valley extends from Moorhead to about six miles east of Glyndon, with a slight ascent of about 50 feet in these fifteen miles. The next two or three miles rise 200 feet to the top of a terrace which reaches from south to north the whole length of the Red river valley in Minnesota, though it is not all the way so distinct nor so high as here. Beyond this ascent the surface is again nearly level, being a sheet of slightly undulating or rolling till, with a rise of perhaps four or five feet per mile, through twenty-five miles eastward. Next is a terrace, also reaching a long distance from north to south, which is ascended in three or four miles, rising about 300 feet, to the White Earth Agency, which thus commands a very extensive western prospect. Thence a more rolling plateau extends, with little change in the average hight, thirty miles eastward to Itasca lake.

In like manner the elevation of the Coteau des Prairies, in southwestern Minnesota, 1500 to 2000 feet above the sea, and the terrace-like ascent at the west side of the flat Red river valley in Dakota, lying at a distance of twenty to thirty miles west of the Red river, and stretching from the south bend of the Sheyenne river north to the British line where it is called Pembina mountain, are undoubtedly due to the contour of the bed-rock, rather than to differences in the thickness of the drift.

The till upon each side of lake Agassiz has a moderately undulating and rolling surface. Within the area that was covered by this lake it has a much smoother and more even contour, but has been only slightly stratified. The action of its waves gathered from this deposit of till, which was the lake-bed, the gravel and

sand of its beaches; and corresponding deposits of stratified clay, derived from the same erosion of the till, sank in the deeper part of the lake. But these sediments were evidently of small amount, and are not noticable upon the greater part of this lacustrine area, which consists of a smoothed sheet of till. The position of the thick beds of stratified fine silt and clay in the central depression of the Red river valley, shows that they were not deposited by the waters of lake Agassiz, which must have spread them more generally over its entire area; but instead appears to prove that they were brought by the rivers which flowed into this hollow and along it northward after the glacial lake Agassiz had been reduced to its present representative, lake Winnipeg.

Wells within this area show the character and depth of the drift, but none that we have learned of within the basin of lake Agassiz in Minnesota are certainly known to penetrate through this formation. The nearest point in our state at which the exact depth of the drift is known is Herman, about a mile outside the upper beach, where the till or stony clay, yellow near the surface but bluish below, reaches to the depth of 124 feet, beyond which a well was drilled 65 feet in rock, mostly mica schist. At Campbell a well 260 feet deep went all the way in till, excepting occasional layers of sand and gravel, mostly thin, but at one place eight feet thick, from 165 to 173 feet below the top. At Fargo, in Dakota, the first 95 feet were stratified clay; next was a layer of gravel, 10 feet; then till, 115 feet; below which the remaining 42 feet were probably Cretaceous strata, being soft, dark blue shale, 32 feet; coarse sand-rock, 6 feet; and a second shale, 4 feet, in which the well stopped at a total depth of 262 feet.*

Deep wells farther north in the Red river valley are at Ada, 217 feet; near Crookston, 190, 195, and 205 feet; at Grand Forks, in Dakota, 265 feet; at South Angus, eighteen miles north of Crookston, 253 feet; and at Saint Vincent, 165 feet. Perhaps none of these wells, excepting those at Herman and Fargo, reach through the drift; but the two mentioned at Grand Forks and Saint Vincent, which yield salty and alkaline water, may go below it, and if so, the stratified gravel and sand in which they stop are of Cretaceous age.

The fame of this valley for its large harvests of "No. 1 hard" wheat, averaging twenty bushels to the acre, is nearly equaled by the unenviable reputation of the water supplied by its wells. The drift upon this part of the state contains much of the carbonates and sulphates of lime and magnesia, derived from the Cretaceous strata which covered this area and were ploughed up by the ice-sheet, mixed with much drift from the region of granites, gneiss and crystalline schists on the northeast, and redeposited as till. These alkaline ingredients of the soil are often seen in the dry season forming a white or gray efflorescence, resembling frost, sometimes a quarter of an inch thick.

Wheat thrives better where the soil contains a considerable proportion of these alkaline salts, so that their presence throughout the Red river valley is one principal cause of its superiority in wheat-raising; and this, grown year

* Report of U. S. geological survey of the territories, 1872, p. 301.

after year, gradually takes away these ingredients and prepares the land for other crops. But their effect as dissolved everywhere in wells and streams partly offsets this benefit, and makes the water of all this region objectionably hard, and often in wells and springs noticeably bitter or salt, especially in the northern part of this valley both in Minnesota and Dakota.

These waters, too, more readily than pure water, decompose the wooden curbing, which, being the most convenient and cheapest material, is too commonly used in the wells of this region destitute of stone-quarries. Usually these wells after a few weeks or months become offensive to taste and smell; the water is discolored, gives off sulphureted hydrogen, and horses and cattle refuse to drink it or are made sick by it. Let such wells be pumped so as to fill them with new water every day, and these offensive qualities are principally removed. Instead of wood the material for lining wells ought to be stone, iron pipe or bricks, the last of which are manufactured at many places, and may be made almost anywhere, from the stratified clay along the Red river, of excellent quality and at moderate cost.

Artesian wells have been obtained at many places in this valley. Usually in its southern part, as far northward as Crookston, their water has less alkali in solution than the shallower surface wells. The largest flow yet found is on the Fountain Valley farm, owned by C. H. Brush & Co., situated four miles east of Campbell. This well went 56 feet in till to a layer of sand which is known to be 10 feet thick and was not penetrated at this depth, making a total of 66 feet. The diameter of the pipe is one foot, reduced below to seven inches. A large stream of very clear cold water is constantly flowing away from this well, its estimated volume being seven or eight barrels per minute, or about 250 gallons. It has been flowing at this rate more than a year. This water is of excellent quality for house and farm use, but is hard and slightly irony, and deposits a rusty sediment in the channel of the stream. Its temperature is 46 degrees Fahrenheit.

The Ada town-well, 217 feet deep, four inches in diameter, supplies a stream which partly fills a one-inch pipe. It was bored last spring, and has since been running at the rate of about a hundred barrels per day. This water is very transparent, and forms no irony sediment. Its cool temperature, 47 degrees Fahrenheit, and its purity, being called soft water, nearly equal to rain-water for washing, make this a very satisfactory investment for the town. Its cost was about $500.

Another well, nearly like the last in the amount of flow and character of the water, is at E. S. Corser's elevator at Carman, one mile south of Crookston. Its depth is 190 feet.

The deepest well learned of in the Red river valley is at Grand Forks, 265 feet deep. This has an artesian flow; but at the time of my visit in last August, its rate of flow, probably because the pipe had become choked with sand and clay, was very small, not amounting to more than two or three barrels in twenty-four hours. This water has a decidedly brackish taste, and is therefore worthless for any ordinary use. The well at Saint Vincent, 165 feet deep, is of the same alkaline character. Both were bored to supply water for locomotives but cannot be used because of their mineral residue.

It may be that these very deep wells derive their alkaline and salty water from Cretaceous strata; but some shallower artesian wells in this north part of the

Red river valley get quite brackish water from layers of gravel and sand contained in the drift. One of these is on the farm of E. N. Davis, in the south edge of Kittson county, about thirty miles south of the national boundary. This is 45 feet deep, and was bored in a quarter of a day with an ordinary two-inch auger. Its flow has continued nearly constant through more than a year, at the rate of three pailfuls a minute, or more than three hundred barrels daily. Its temperature is 42 degrees. Though salty to the taste, it was drank freely by farm-stock through all last winter with no apparent injury, and it has been used by people as the only water for drinking and cooking through several weeks of drouth. The hight to which it will rise is known to be more than 23 feet, at which hight the flow seemed to be undiminished.

The upward pressure and abundant supply of water in these wells show that the water-bearing layers of stratified drift enclosed in the till are continuous through long distances and descend from a higher level. The veins of soft water found at the depth of about 200 feet at Ada and Carman probably have their sources upon the high land twenty miles distant eastward.

THE OUTLET OF LAKE AGASSIZ.

The excavation of the remarkable valley occupied by the Minnesota river was first explained in 1868 by general G. K. Warren,* who attributed it to the outflow from this ancient lake that filled the basin of the Red river and lake Winnipeg. This valley or channel begins at the northern part of lake Traverse, and first extends southwest to the head of this lake, thence southeast to Mankato, and next north and northeast to the Mississippi at Fort Snelling, its length being about 250 miles. Its width varies from one to four miles, and its depth is from 100 to 225 feet. The country through which it lies, as far as to Carver, about twenty-five miles above its junction with the Mississippi, is a nearly level expanse of till, only moderately undulating, with no prominent hills or notable depressions, excepting this deep channel and those formed by its tributary streams. Below Carver it intersects a belt of terminal moraine, composed of hilly till. Its entire course is through a region of unmodified drift, which has no exposures of solid rock upon its surface.

Bluffs in slopes from twenty to forty degrees, and rising 100 to 200 feet to the general level of the country, form the sides of this trough-like valley. They have been produced by the washing away of their base, leaving the upper portion to fall down and thus take its steep slopes. The river in deepening its channel has been constantly changing its course, so that its current has been turned alternately against the opposite sides of its valley, at some time

* Since the above was written, the lamented death of this distinguished soldier and engineer, whose interest in science added much to our knowledge of the geography and geology of the Northwest, occurred Aug. 8, 1882.

undermining every portion of them. In a few places this process is still going forward, but mainly the course of the Minnesota river is in the bottomland. Comparatively little excavation has been done by the present river. As we approach its source, it dwindles to a small stream, flowing through long lakes, and we finally pass to lake Traverse, which empties northward ; yet along the upper Minnesota and at the divide between this and the Red river, this valley or channel and its enclosing bluffs are as remarkable as along the lower part of the Minnesota river. It is thus clearly shown to have been the outlet of lake Agassiz, excavated while the melting ice-sheet supplied extraordinary floods, much greater in volume than the combined waters of the Minnesota and Nelson rivers at the present time.

This valley in many places cuts through the sheet of dritt, and reaches the underlying rocks, which have frequent exposures along its entire course below Big Stone lake. This excavation shows that the thickness of the general drift-sheet upon this part of Minnesota averages about 150 feet.

Lakes Traverse and Big Stone are from one to one and a half miles wide, mainly occupying the entire area between the bases of the bluffs, which rise about 125 feet above them. Lake Traverse is fifteen miles long ; it is mostly less than ten feet deep and its greatest depth probably does not reach twenty feet. Big Stone lake is twenty-six miles long, and its greatest depth is reported to be from fifteen to thirty feet. The portion of the channel between these lakes is widely known as Brown's valley. As we stand upon the bluffs here, looking down on these long and narrow lakes in their trough-like valley, which extends across the five miles between them, where the basins of Hudson bay and the gulf of Mexico are now divided, we have nearly the picture which was presented when the melting ice-sheet of British America was pouring its floods along this hollow. Then the entire extent of the valley was doubtless filled every summer by a river which covered all the present areas of flood-plain, in many places occupying as great width as these lakes.

General Warren observes that lake Traverse is probably due to a partial silting up of the channel since the outflow from the Red river basin ceased, the Minnesota river at the south having brought in sufficient alluvium to form a dam ; while Big Stone lake is similarly referred to the sediment brought into the valley just below it by Whetstone river. Twenty-five miles from Big Stone lake, the river enters Lac qui Parle, which extends eight miles, with a width varying from one-half to three-fourths of a mile and

a maximum depth of twelve feet. This lake, as general Warren suggests, has been formed by a barrier of stratified sand and silt which the Lac qui Parle river has thrown across the valley.

THE NORTHERN BARRIER

by which the water of lake Agassiz was restrained from flowing in the direction of the present drainage, to Hudson bay, is supposed by general Warren to have been an elevation of the land much above its present hight northeast of lake Winnipeg. He thinks this elevation was shared by other northern portions of North America, and that these regions have recently been depressed at least several hundred feet. The depths of the great lakes, and many topographic features of the interior of the continent, besides this channel of lakes Traverse and Big Stone and the Minnesota river, appear to him to support this opinion. Instead of this, we believe that the surface of the continent had nearly the same form then as now, and that the continental ice-sheet, resting on the land in a solid mass of great depth, formed the northern shore of lake Agassiz and was the barrier that prevented its flowing into Hudson bay.

Before adducing the evidence, apparently amounting to positive proof, of this glacial origin of lake Agassiz, which is drawn from our exploration of its beaches and determination of their hight, we ought to mention that professor Dana's and general Warren's theory of an elevation of the northern part of the continent, during the ice age or since that time, followed by subsidence to its present hight, is opposed and disproved by the general occurrence of sea-beaches and marine shells above the present sea-level all along our northern shores. They show that the ocean in these recent epochs covered more of the land than now in northern latitudes; that is, that the elevation of the land, as compared with the sea-level, was less instead of greater than at present. More than this, the hight at which these recent marine deposits and sea-shells are found, increases from south to north. In New Hampshire and Maine it is from 50 to 300 feet above our present sea-level; in the St. Lawrence valley, about 600 feet; and on the coast of Labrador, about Hudson bay, and in Greenland, 600 to 1500 feet. Our proof that the ice-sheet was the northern barrier of lake Agassiz, also gives us an answer to the question why the sea-level thus rose higher than now toward the north.

The three series of beach deposits before described (mapped in fig. 3, plate I), which mark the shores of lake Agassiz at as many stages

of its hight, have each been traced, and their altitude determined, through an extent of about 150 miles from south to north; and each of them, like the old sea-level, is found to have a gradual ascent northward, as compared with the present level-line, or the surface which a body of water would have now, if confined in this valley. As before stated, these beaches were formed at epochs when the lake-level was nearly stationary for a considerable time during the excavation of its channel of outlet at lake Traverse and southward. The hight of the mouth of the lake and its outflowing river was at the time of the upper or Herman beach 85 feet above lake Traverse; at the time of the Norcross beach this outlet had been lowered 30 feet; and when the Campbell beach was formed, it was nearly at the present level of lake Traverse.

Our exploration and leveling along the upper beach extended from the north end of lake Traverse about 25 miles eastward to Herman and thence about 140 miles north to Maple lake. Through this distance it lies from fifteen to thirty miles east of the Red river. The ascent of this beach northward is at the rate of about four-tenths of a foot per mile in its southern portion for about 60 miles, lying in Traverse, Stevens, Grant, Otter Tail and Wilkin counties. Farther north, through its remaining 80 miles in Clay, Norman and Polk counties, its rate of ascent is considerably greater, varying from three-fourths of a foot to one and a half feet per mile. In all, the surface of lake Agassiz at this time of its greatest hight ascended northward, above a line now level, 125 feet in these 142 miles, from 1055 feet, very nearly, above sea in Traverse county, to 1180 feet, very nearly, at the north side of Maple lake, twenty miles east-southeast from Crookston. Through this distance the upper beach clearly marks one continuous shore-line; and the accuracy of our leveling is attested by close agreement with railroad surveys at five widely separated points.

Before lake Agassiz had fallen below the line of this upper beach in the south half of its explored extent, it had formed a slightly lower parallel beach, three-fourths to one and a half miles distant, through the northern third of Clay county; and this secondary beach, sometimes double or treble, was noted at several places along the next thirty miles northward. The continuation of this beach at the northwest side of Maple lake was accumulated when lake Agassiz had fallen at this latitude about fifteen feet below its highest line. Here it is the second of a series of four well-defined beach-ridges below the upper or first beach, which were formed when the lake had fallen successively about 8, 15, 30 and 40 feet from its highest level. Yet all these beaches were accumulated while the lake remained with only very slight depression of level.

not sufficient for the formation of any secondary beach-ridge, along its southern part for some 75 miles northward from lake Traverse and Herman.

The Norcross beach has been explored and its hight measured through a length of 150 miles. In this distance it ascends northward about 70 feet by a nearly uniform slope of a little less than a half foot per mile. The amount that the surface of lake Agassiz had fallen at this time from its highest level was 30 feet in Traverse and Grant counties, 50 feet in northern Clay county, and 90 feet northwest of Maple lake. Its fall in this extent of 150 miles had been thus 60 feet more at the north than at the south end. Double and multiple ridges occur along the northern half of this distance, and show that the lake-level at the time of formation of the Norcross beach fell five to ten feet northward while it remained without change or with less change than was required to form additional beach-ridges southward.

The hight of the Campbell beach, formed when the outlet had been excavated to the level of lake Traverse, is known along a distance of 135 miles, in which its northward ascent was at first 50 feet, and afterward only about 25 feet. This continued depression of the lake northward, while it remained with slight or no change southward, is indicated, similarly with the foregoing, by the occurrence of an additional ridge, along the northern part of the course of this shore-line. The fall of lake Agassiz from the upper or Herman beach to the Campbell beach was about 80 feet at the south near lake Traverse, and 165 feet at the north near Maple lake; and instead of the northward ascent of the upper beach 125 feet in 142 miles, we find the corresponding ascent of the Campbell beach in nearly the same distance at first 50 feet, but reduced later to half this amount.

If the barrier north of lake Agassiz had been land, its subsidence to give way for drainage northward in its present course would cause the beach deposits of the former lake-shores to have the opposite slope, or a descent, from south to north. These observations are therefore inconsistent with such explanation of the cause of this lake; but they appear to prove that its northern barrier was the receding continental glacier. All the differences of the once level lines of lake Agassiz from our present level-line would be produced by the gravitation of the water of the lake toward this ice-sheet. At first this attraction had a large effect upon the lake-level because of the nearness of a great depth of ice on the east, in northern Minnesota and northward in British America, but it was gradually diminished to a comparatively small influence when these ice-masses had been melted and the attracting

force proceeded from the region far north between lake Winnipeg and Hudson bay.

In the same way the ocean during the glacial period was drawn toward the ice-sheet, so that northward it stood higher than now, as shown by its recent deposits along our northern coasts, far above the present sea-shore. It appears that the form of the surface of the continent during the ice age was about the same as it is to-day; but that the sea-level was much changed by the great accumulations of ice, being drawn toward them by gravitation and thus raised higher than now toward the poles, while it was proportionately lowered about the equator.

AREA AND DEPTH OF LAKE AGASSIZ.

The upper beach of lake Agassiz, as here described from lake Traverse and Herman north to Maple lake, extends through a prairie region, very favorable for exploration and leveling. Its farther course turns to the east and northeast and lies in a trackless forest, much of which consists of almost impassable tamarack swamps. It is therefore quite impracticable to trace its course exactly through this wilderness; but from the known elevation of Red lake, 1140 or 1150 feet, very nearly, above the sea, of the lake of the Woods, 1042, and of Rainy lake, about 1175, the outline of lake Agassiz when it had its greatest hight can be mapped approximately.

From the north side of Maple lake it first extends east sixty miles, passing south of Red lake. Next this shore of lake Agassiz turns northward east of Red lake, beyond which it again runs eastward, crossing the Big fork of Rainy Lake river, and extends along the south side of Rainy lake, its hight above Red and Rainy lakes being probably between 50 and 100 feet. Thus lake Agassiz at this time of greatest hight reached along our northern boundary beyond the meridians of Minneapolis and Saint Paul. Its expanse included no islands, excepting rarely one of small area close to its shore.

When this glacial lake attained its greatest extent, just before it found an outlet into Hudson bay over the melting ice-sheet, its length from south to north was probably greater than the length of lake Superior; but its area was only half or two-thirds that of lake Superior, because of its less average width.

At the time of the formation of its highest beach, the depth of lake Agassiz above the lake of the Woods was some 200 feet; above the Red river valley at our northern boundary, 450 feet; and above lake Winnipeg, about 600 feet.

LETTER.

CHEMICAL LABORATORY, HAMILTON COLLEGE,
CLINTON, ONEIDA COUNTY, N. Y., July 11, 1883.

Prof. N. H. Winchell:

MY DEAR SIR, — I enclose herewith my long delayed paper on your Minnesota Iron Districts. The delay, however, has not been through any neglect of mine, but because I could not, until recently, persuade the owners to allow me to make the facts public. I now send you a complete statement, which I hope you will consider of some value to your work. Every analysis given was made here by myself, personally, and I will answer for the correctness of all the chemical work. The story might perhaps be made stronger for Vermilion, but it is strong enough as I put it.

Very sincerely yours,

ALBERT H. CHESTER, E. M., Ph. D.
Prof. of Chemistry and Mineralogy.

V.

THE IRON REGION OF NORTHERN MINNESOTA.

BY ALBERT H. CHESTER.

There are two extensive iron districts in northern Minnesota, known respectively as the Mesabi Iron Range, in Town 59, Range 14 W. and Town 60, Ranges 12 and 13 W., and the Vermilion Iron District, in Town 62, Range 15 W. These districts are about twenty miles apart. Within a few years both have been very carefully explored to ascertain the extent and value of the ore deposits. Before these explorations were undertaken all knowledge of this region, inhabitated only by Indians, was obtained from the explorers and timber hunters who had run over it in the pursuit of their calling, and from those who had visited Vermilion lake during the gold excitement of 1866. Little attention was paid to iron at that time however, though some samples of the hematite from T. 62, R. 15, were sent with the so-called gold ores to be exhibited with other ores from Minnesota at the Paris Exposition of 1867. The pieces sent were large and handsome samples of nearly pure, hard, specular iron, and it is strange that they did not attract more attention. In May, 1867, the Smithsonian Institution distributed boxes of mineral specimens to such academies as applied for them. No. 5021 of the list of minerals sent is labelled "Hematite, Vermilion lake, Minn." As these were fair sized cabinet specimens, and a hundred or more of the boxes were sent out, a considerable quantity of the ore must have been brought down in 1866, to furnish the material used. It was not however until 1875 that the Mesabi district was explored, and Vermilion received little attention as an iron district until the expedition of 1880. It is the object of this paper to give in detail the results of these expeditions.

THE MESABI IRON RANGE.

To reach this district the old government road to Vermilion lake was followed as far as the Embarras bridge. From this point a new road was cut out, striking T. 59, R. 14 in the southwest quarter of section 31. Before reaching this township evidences of what is to appear are seen in the decided disturbance of the compass needle, and the occasional pieces of magnetite in the drift. Some of these are of considerable size and cause so much variation of the needle as readily to lead an observer to suppose that ore bodies of magnitude were near at hand. No ore in place was found, however, until section twenty-eight was reached, where, in the southwest of the northwest quarter the ledge was exposed by sinking to a depth of eighteen feet, and the rock found to be magnetitic quartzyte similar to that described below, and too poor to be called ore or to deserve farther attention.

In the northwest of the northwest quarter of section fourteen considerable excavations were made to ascertain the nature of the deposit, there being a decided outcrop of magnetite. The rock strata throughout the district lie nearly horizontal, and the beds of ore are intercalated with the everywhere abundant quartzyte. The slight dip here is to the south, as is usual throughout the district. A perpendicular face of about fourteen feet was exposed and was found to consist of layers of mixed quartzyte and ore. A sample from the best layers, aggregating four and a half inches in thickness, was taken for analysis, and showed 48.47 per cent. of iron.

About a half mile east of this point, in the same quarter-section, ore shows on the surface for a length of thirty feet. Here a pit was sunk cutting the strata at right angles. At the top three feet of white quartzyte was found. Underneath this lie six feet of mixed magnetite and quartzyte. At this depth a layer of ore comes in a foot and a half thick, of which four inches at the middle is better than the rest and contains 53.45 per cent. of iron. For seven feet below this to the bottom of the pit the ore is very poor.

Near the center of section eleven there is a bold outcrop of jaspery hematite, at the foot of which a pit was sunk to considerable depth. At fifteen feet from the surface a layer of black sand was found containing boulders of quite pure hematite. An average sample from these boulders showed 62.17 per cent. of iron, almost

the richest ore discovered in the district. Careful search failed to find the ledge from which these boulders came, and they seemed a novelty in a district covered with horizontal layers of magnetite and quartzyte.

The next exposure of ore was found near the center of section 24, T. 60, R. 13. The best ore found here was a layer on the top about two and a half inches in thickness and containing about 60 per cent. of iron. A pit was sunk to a depth of thirteen feet but nothing was found as good as that on the surface.

In the northwest quarter of section 20, T. 60, R. 12 W., the most important of the workings of Mr. Peter Mitchell, the first explorer of the Range, was found. This was a pit six feet in depth, and from it was said to have been obtained the best ore he brought back. This old pit was cleaned out and sunk to a depth of 11.2 feet. The stratification on one side of the pit was as follows :

3 0	feet,	surface soil, sand and gravel.
0.4	"	ore, sampled.
0.7	"	poor ore,
0.5	"	ore, "
0 6	"	medium ore,
0.2	"	ore, "
0.6	"	" "
2.0	"	poor ore, "
0.2	"	ore,
0 6	"	poor ore and quartzyte,
1.3	"	ore, "
0.6	"	" "

As mentioned above, this represents only one side of the pit, the changes from magnetite to quartzyte being so abrupt that the layers of ore can seldom be followed for any distance. The total thickness of ore shown here is about three and a half feet and the sample made from all the best layers gave 44.10 per cent. of iron. Selected samples from this place previously brought out by Mr. Mitchell gave on analysis the following results:

	1	2	3	4	5
Metallic iron	52 67	57 95	53.51	56.76	56.88
Silica	22 22	11 37			
Alumina		2.84			
Lime	0 22	1 53			
Magnesia	1.61	3.33			
Manganese oxide		1.32			
Sulphur	trace.	0 06			
Phosphorus		trace.			
Oxygen with iron		22.08			
Total		100.48			

These analyses were made by the writer previous to the expedition, and from samples furnished by the owners of the property. The magnetic character of these samples was very noticeable, some very fine lodestones having been found among them. This is a prominent characteristic of all the best ore of the district.

Another of Mitchell's old workings was found on the line between sections 18 and 19, in the same town. This was continued until a total depth of fourteen feet was attained. About four and a half feet of good ore was found at this place, an average sample showing 52.82 per cent. of iron.

In the northeast quarter of section 17, T. 60, R. 12, a ledge was discovered which, after having the talus at the base cleared away, exposed the stratification for a hight of twenty-five feet as follows :

0.2	feet	best ore.
1.5	"	good ore.
2 5	"	ore mixed with quartzyte.
0.2	"	good ore.
10 6	"	poor ore and quartzyte.
10.0	"	quartzyte with some ore.

The whole amount of good ore here shown is less than two feet, the best being at the very top of the cliff and showing 62.37 per cent. of iron. Clearing off the moss on the level ground at the top, the whole surface for some distance is shown to be of this layer, smoothed and polished by glacial action, and as one walks over it he seems to be walking on solid iron. The deposit at this place is of sufficient extent to give color to the story of "a mountain of iron, larger and richer than the famous Iron mountain of Missouri." But when the surface is carefully examined it is seen to have a mottled or marbled appearance in consequence of the constant changes between the magnetite and quartzyte. No layer can here be followed any distance without showing this change. This lack of uniformity is one of the most noticeable features of these deposits.

In the northwest quarter of section 20, an outcrop of the ore is seen in the bed of a small brook. A layer of about six inches in thickness and of considerable permanence can here be followed for nearly a quarter of a mile. The dip of the stratum is to the south at the rate of about six feet in every one hundred. An average sample of this ore shows 57.12 per cent. of iron.

A sample was made from all the specimens brought back which showed by analysis 44.68 per cent. of metallic iron. It was extremely difficult to take fair samples of the ore on account of the continual changes in the character of the layers, but so large a

number of specimens were selected, covering so great an extent of territory, that this is believed to be a fair representation of the richness of the ore in the district, above the level of the swamp water. All the pits were sunk to this level, and work was stopped only when the water came in so rapidly that further work was impossible without pumping.

A ledge of quartz containing galena should be mentioned here, which was found in the southeast quarter of section 11, township 59, range 14. This vein of quartz dipping 78° to the southeast and cutting through the horizontal beds of quartzyte has a very interesting appearance, and from the galena it shows was at once called a silver mine by the miners. But careful assays of the ore obtained failed to reveal any trace of the precious metal, and the amount of galena is too trifling to make it of value as a lead ore.

The quartzyte so often mentioned here is a greyish colored quartz-schist often slaty and arenaceous, and generally more or less impregnated with magnetite, though sometimes free from it. Even the strata that are richest in iron show plainly this mode of formation. A sample of this magnetitic schist, which well illustrates the whole, examined under the microscope by polarized light, showed areas of nearly pure magnetite with some hornblende and quartz, in which were minute crystals of apatite.

These magnetitic schists are terminated on the north by a red or pink granite which constitutes the backbone of the Mesabi range. The nearly horizontal schists abut against this backbone, which rises abruptly in some places to a considerable hight.

The granite was not examined under the microscope but appeared to the eye to be much the same as the one described further on, and which forms the divide between the waters flowing north and those running south. It is probable that the Mesabi range originally formed this divide, but now the Embarras river has broken through it, and discharges into the Saint Louis river and thence into lake Superior.

The schists and slates of the Mesabi district dip in general toward the south, but never at an angle of more than two or three degrees from the horizontal, the dip changing a little from point to point so as to present the appearance of a slightly undulating surface. In all respects except this horizontal bedding the Mesabi district is precisely similar to the Penokee region of Wisconsin, and a person familiar with the latter cannot fail to notice the close resemblance. Here are the same magnetitic schists, hornblendic magnetitic schists, dark and light grey quartz schists, arenaceous

grey and white quartzytes, and other similar rocks; and especially, here is the same apparent substitution of quartzyte and magnetite for each other. The writer pointed out this resemblance in his report on the Mesabi district, presented in 1875, and is now clearly of the opinion that the iron-bearing rocks of this district bear the same relation to the Huronian series as do the rocks of the Penokee Iron range in Wisconsin.

On the north side of the Mesabi ridge the rock strata are much more inclined and consist of similar slates and quartzytes, but without the magnetite. The general trend is east and west following the line of the ridge. There is a second belt of red granite, the one alluded to above, exposed on the long portage between the Embarras and Pike rivers, in the southwestern part of T. 60, R. 15 W., which is identical in appearance with that of the Mesabi backbone. This is a medium grained, flesh red or pink hornblende-granite, in which the crystals of feldspar are sometimes porphyritically developed, and show twinning of the Carlsbad type. Under the microscope it presents the following characteristics. Microcline, oligoclase and orthoclase are the principal ingredients, named in order of abundance. Quartz is very plenty and also common green highly dichroic hornblende. Magnetite and ferrite occur as accessories.

In descending the Pike river but little rock was found in place, but at one of the rapids in the south part of T. 61, R. 16, there is a considerable exposure of a blackish schist, the beds being nearly perpendicular, dipping however slightly to the south. The trend of these beds is similar to that of the rocks found in connection with the iron further north. These are hornblendic biotite-schists, minutely crystalline, of dark grey color, schistose in structure, and pyritiferous. Under the microscope there is seen a quartz groundmass of very fine particles; biotite in minute scales; hornblende, next in abundance, and rather plentifully distributed through the rock in relatively good sized crystals. Porphyritic quartzes are also seen with quite distinct crystalline outlines; as accessories pyrite and ferrite are seen. This is at once recognized as a typical Huronian schist.

THE VERMILION LAKE IRON DISTRICT.

At the time of the explorations in the Mesabi Iron range in 1875, attention was called to the iron near Vermilion lake, and some preliminary exploration was made there. Although the full extent

of the deposit was not discovered, enough was seen to warrant a favorable report, and many samples were brought back and analyzed with results as follows:

	1.	2.	3.	4.
Metallic iron	64.25.	67.77.	65.19.	63.26.
Silica				7.57.
Alumina				1.89.
Phosphorus				trace.
Sulphur				0.05.
Oxygen with iron				27.11.
Total				99 88

These samples were obtained from what was afterwards ascertained to be T. 62, R. 15 W., No. 1 being from section 27, No. 2 from section 28, No. 3 from section 33, and No. 4, an average of all the samples obtained. On account of the depression in the iron market nothing further was done in the matter until 1880, when an exhaustive examination of the whole district was made.

The belt of iron ore is well defined where exposed, and numerous trenches were made to show it where it was covered up with the superficial layer. The ore is found as usual in connection with jasper and quartzyte, and in many cases presents well defined walls of slate. It is intimately bedded with the rocks of the country, and stands so nearly perpendicular that it was difficult to ascertain the true dip, but as the result of many observations it was thought to incline slightly to the south. The trend is generally east and west, though this varies from point to point. The rock strata are very much folded and contorted showing evidence of great geological disturbance. The topography of the country resembles in a marked degree other Huronian iron regions, the general characteristics being low hills, and short ridges without regularity, separated by swamps and small lakes. Often the rock ledges are exposed, sometimes forming perpendicular cliffs, and these have served to determine the general details of the surface; but there are masses of earth and gravel in many places, which modify and alter the topography to a considerable extent, some of the ridges being entirely composed of such material. The evidence of glacial action is also very marked, the rocks being worn and polished in many places, the grooves and striations having the general direction S. 10° W. The prevailing rocks are the slates and schists found in other Huronian areas in connection with iron ore beds.

As developed by the exploration there seem to be two principal deposits of ore, running nearly east and west, and about a mile apart. The more northern one, nearest the lake, and upon which are located the Stone, Tower, Stuntz and Ely mines of the Minnesota Iron Co., has a total length of nearly a mile, continuing from the eastern part of section 28, nearly across section 27. The outcrop was seen on the surface in many places, and by trenching the whole width of the bed was exposed wherever practicable, until the fact was demonstrated that the deposit is one of great magnitude, rivaling those of Marquette and Menominee. The following table shows the width of ore on the surface, the average per cent. of iron in samples taken all across the bed without any sorting, and the character of the ore at the various places.

Mark.	Width of bed.	Per cent. of iron.	Character.
1	30 feet.	59.98	Bright, hard, specular.
2	30 "	54.29	"
3	38 "	56.45	"
4	35 "	59.58	Soft hematite.
5	16 "		"
6	18 "		"
7	25 "	58 21	Bright, hard, specular.
8	16 "		"
9	17 "	60.47	"
10	44 "	61.84	"
11	10 "		"
12	10 "		"
13	15 "		"
14	58 "	59.87	"
15	10 "		"
16	10 "		"
17	30 "	50.27	"
18	11 "		"

At some of these points the ore is very pure and free from admixture of rock, and needs little sorting. At others there are several seams of slate and jasper included in the sample, which would be sorted out in actual mining operations.

A description of one of these exposures will show the great similarity of the deposits to those of northern Michigan. At the one marked 3, for instance, the cross section is as follows, beginning at the North side :

6 feet, ore.
10 feet, ferruginous slate.
7 feet, ore.
8 feet, slate.

6 feet, jaspery ore.
18 feet, ore
20 feet, lean ore.
13 feet, brownish talcose schist.
22 feet, banded jasper.
7 feet, ferruginous slate.

The swamp water prevented further exploration at either end.

At 9 the ridge is abruptly terminated by a cliff of the presnt, brightest and hardest, steely looking ore, making the finest display in the district. The walls of the ore deposit are here clearly marked, being slate on the south and jasper on the north side. The end of the ridge was found completely covered with huge blocks of pure ore for a distance of 100 feet, which had been broken off and thrown down by the elements.

An average sample made from all the specimens taken from this belt was analyzed with the following results :

Silica,	5.55	per cent.
Iron,	58.31	"
Alumina,	9.96	"
Lime,	0 55	"
Manganese oxide,	0.20	"
Sulphur,	0.14	"
Phosphorus,	0.065	"
Oxygen,	25.08	"
Total	99.855	"

This percentage of iron is very high when we consider that all seams of quartz, jasper and slate occuring in the beds were included in the sample. Analysis of a sample picked from the richer pieces, carefully excluding all that showed any rock, showed 69.17 per cent. of iron.

The other principal deposit of the district is in section 33, where the exposures can be followed for a distance of nearly half a mile. The general description given above will suffice for this deposit, though the widest surface exposure is found here. At one place the writer walked forty steps across the outcrop of the bed which stands as before nearly perpendicular. An average sample for a width of 120 feet, gave 57.04 per cent. of iron. The following table shows some of the measurements and percentages :

Mark.	Width of bed.	Per cent of iron.	Character.
19	26 "	54.88	Hard specular.
20	18 "		"
21	5 "	62.82	"
22	120 "	57.04	"
23	14 "	52 43	"
24	26 "	54.70	"
25	13 "		"

The ore of this deposit is more streaked with white quartz than that of the other belt, and consequently does not show so high a percentage of iron. A partial analysis of an average from all the samples obtained from here gave the following results.

Silica	11.63
Iron	55 86
Sulphur	trace
Phosphorus	0.034

The percentage of phosphorus is, however, very small, making it a true Bessemer ore, and it can easily be sorted to high grade. A sample of sorted ore was made from each deposit and analyzed with results as follows:

	1	2
Silica	3.39	3.89
Iron	66 93	66.43
Alumina	0.74	0.85
Lime	0.08	trace
Phosphorus	0.011	0.006
Sulphur	0.01	none
Oxygen	28.695	28.477
Total	99.856	99.653

No. 1 is from the northern belt, and No. 2 from the southern.

It seemed desirable to ascertain the geological relations of the rocks of this district, and rock samples were carefully taken, many of which were subjected to examination in thin section under the microscope by polarized light. The most common rock of the region, and the ore in which the quartz veins formerly worked for gold are found, is a sericitic quartz-schist. It is aphanitic, dark-gray in color, not very hard, and with a sharp-edged fracture. Not thinly schistose, and effervesces in acids. Under the microscope it is an excessively fine-grained rock, with a ground-mass of minute quartz particles. There is a felt-like mass of sericite fibres all through the ground-mass, which are very close together and run in a common direction, but are more or less interwoven. Numerous particles of calcite are seen, and some magnetite.

A series of samples from the south of the ore, represents a highly altered mica schist, with sericite prevailing in the ground-mass. Porphyritic quartzes and fine quartz crystals are often seen in the ground-mass. Some of the sections show an abundance of chlorite. Hematite, limonite and magnetite are present as accessories, some specimens being red-stained by the iron. There are also some peculiar aggregations of brownish and blackish particles which may represent some original constituent, possibly andalusite or staurolite.

The samples of slates intercalated with the ore were found to be the same sericite schists, but more completely replaced by iron oxide, which reddens and permeates the rocks. In some cases this replacement is so complete as to constitute beds of soft hematite.

The rocks north of the ore, between it and the lake, are mostly these same schists but not so much altered. Some of the specimens are still dark colored, and not much altered. Others are a mere clay. Banded jasper is also found in abundance, and also something closely resembling novaculite. A very siliceous limestone is found in many places exactly similar to one common in the Huronian of Michigan and Wisconsin. Its best development at Vermilion is at Ely island.

At one point in the eastern part of section 27, there is a break in the continuity of the ore deposit where a small stream runs south into the swampy ground south of the ore. On the east side of the small ravine caused by the stream, the ore is in place, showing a width of 30 feet, but on the west side it was not found. Every change in the rocks was carefully noted and samples were taken throughout the length of the ravine, crossing the line of the ore and continuing several hundred feet south of it, and north of it to the lake. The rocks were found to be largely the same sericite schists, showing under the microscope folia of sericite, and quartz, in the ground-mass; porphyritic quartzes with crystalline outlines; brown opaque particles as before; and chlorite. Some are magnetitic quartz-schists exactly similar to those of Mesabi. One section in particular shows a ground-mass of minute closely fitting angular quartz particles composing most of the rock. Magnetite is abundant in this specimen, in many square and rhombic sections. The red color of some of them is due to the presence of red oxide of iron. Particles of specular hematite are also seen. As at Mesabi there is a small quantity of hornblende. Besides these sericitic and magnetitic schists, and the banded jasper and specular iron, very fine granular quartzytes were found. In one specimen of this kind there was seen quartz in very close-fitting angular particles, composing most of the rock; magnetite in minute particles, often distinctly outlined, and films of real oxide of iron among the particles of quartz. Some altered quartziferous porphyries were also found near the lake. These are of a grayish color and much weathered. They are aphanitic, non-schistose and with porphyritic glassy quartz crystals. Under the microscope they show the char-

acteristics of altered porphyries, the ground mass being largely kaolinized, though the original felsitic character can still be clearly made out. Another quartzyte found in section 22 in considerable masses is white and granular. Under the microscope it exhibits large quartz and feldspar particles, buried in a matrix of the same materials, and may be of fragmental origin.

The above describes all the varieties of rock collected in the town where the iron is found. The next town east, T. 62, R. 14 W., was carefully looked over for the continuation of the ore deposit, but it was not found. This town is very much cut up with small lakes and swamps, but many rock exposures were found and samples taken, particularly from sections 9, 11, 15, 16, 17 and 19. Those brought back consisted of light colored granite, aphanitic dark grey slate, black aphanitic quartz-magnetite schists, the amount of magnetite varying in different specimens, sericitic quartz-schists, jaspery rocks, and fine-grained quartzytes. One of the latter appears as follows under the microscope. Quartz in fine particles which are angular and interlocked; magnetite and red oxide of iron in patches, and pyrite, while veins filled with chlorite and epidote intersect the specimen.

In section 2 of the same town about three miles north of the line of the ore beds, rocks of a very different character are found. They are more chloritic, of a decidedly greenish color, and schistose in character. There are also greenish aphanitic slates and banded magnetitic cherts, resembling in every particular the Laurentian rocks found in connection with the iron-bearing Huronian rocks of the south shore. In T. 63, R. 13, similar rocks were found which bear a very close resemblance to the Laurentian rocks just mentioned, one being a greenish aphanitic schist, and another a medium grained, dark greenish semi-schistose and highly crystalline rock. Another is seen under the microscope to be a dioryte, consisting of hornblende and oligoclase as the only important constituents, and in nearly equal proportions. The hornblende is in large ragged-edged green sections, while some of the feldspars are much altered. There is some epidote as an alteration result, in clusters of round grains, with apatite and magnetite in minute quantity.

Besides a careful examination of the iron-bearing rocks, the so-called gold deposits were looked over. Specimens were collected from many quartz veins, on some of which mines were formerly located, and all were carefully assayed. It is hardly necessary to say that not a trace of gold was discovered. No true iron pyrites

was found, but all was of that form known as pyrohotine, or magnetic pyrites. Among the many samples of pyrites, from all parts of the country, assayed for gold at the laboratory of Hamilton College, not one containing magnetic pyrites has shown any gold, and so-called gold mines have been condemned at once when the character of the pyrites was recognized, subsequent assay always corroborating the opinion. It was therefore not a matter of surprise that these "gold ores" did not contain any gold.

A careful study of the region above described, and of the rocks and ores brought out, forces on the writer the conviction that this deposit of iron is the representative on the north shore, of the Michigan and Wisconsin iron deposits. There can be no doubt that the regions described belong to the Huronian. The rocks are many of them typical Huronian rocks, and the whole Mesabi district presents such a strong likeness to the Penokee in all particulars as to make its identity indisputable. That the Vermilion deposits are simply a continuation of the same formation seems also to be a fact. The intricate foldings of the strata account for their vertical position, and the rocks are so nearly like those of Mesabi and bear such similar relations to the Laurentian granites and slates, as to convince one of their identity. The peculiar replacement of the schists by red oxide of iron, forming beds of soft hematite entirely similar to certain deposits found at Marquette, and the very siliceous limestone common in this region, and similar in character as well as in mode of occurrence to beds found in Marquette, Penokee and Menominee, are facts with a plain signification.

The geological similarity of the Vermilion iron deposits to those of Marquette, is the impressive fact to be noticed by the people of Minnesota, and it is safe to predict the development there of an iron district of immense value and importance.

This paper should not be closed without an expression of thanks to professor Roland D. Irving, of Madison, Wis., to whom all the rocks were sent to be examined, and whose notes on these examinations were placed freely at the service of the writer. Thanks are also due to Mr. George C. Stone, of St. Paul, General Manager of the Minnesota Iron Co., who planned the expeditions, and aided in every way to their successful completion; and to the veteran surveyor, explorer and geologist, Mr. George R. Stuntz, whose experience in all these lines was invaluable.

Hamilton College, July 11th, 1883.

VI.

NOTE ON THE AGE OF THE ROCKS OF THE MESABI AND VERMILION IRON DISTRICTS.

BY N. H. WINCHELL.

In the report for 1878 (p. 10) the rocks of the iron-bearing belts of Vermilion lake and of the Mesabi range were parallelized with the Gunflint beds of the northern boundary, the latter being the lowest portion of the great slate-and-quartzyte group which had before been designated the Animikie group by Dr. T. Sterry Hunt.

In the report for 1880 (p. 81) the Gunflint beds are stated to be a graduation downward of the slate-and-quartzyte group; and in the same report (p. 82) the slate-and-quartzyte group is described as overlying unconformably (apparently) another formation made up o greenish schists, entirely a distinct formation, the two being separated by a conglomerate or conglomerate-breccia, the lower formation being supposed to be that which has been styled the Huronian by the Canadian geologists. This greenish magnesian schistose formation is traced, through some variation, westward along the strike of the formation as far as the east end of Basswood lake and to the Pipestone rapids (p. 91), one of its chief localities being at the mouth of the Kawasachong river. It perhaps extends to Vermilion lake (p. 95), and occupies the central portion of the lake, including Ely island. But the rocks at the south end of the lake are apparently of the slate-and-quartzyte group, which here exhibits a true slaty structure (p. 97, Nos. 389–394); while those at the north end consist of a mica-schist, embracing lenticular masses of granite (p. 100.) In the same report the iron

ore of the Vermilion lake district is stated to be in the horizon of the Gunflint beds, and to lie directly on the foregoing supposed Huronian schists. (p. 103-4.)

In the report for 1881 (p. 95) various considerations are mentioned that go to show that the slate-and-quartzyte group of the northern boundary becomes the tilted slates and gray quartzytes of Ogishke Muncie lake, and of the region of Thomson on the St. Louis river; and also that there is a red granite overlying the slate-and-quartzyte group north from Grand Marais (pp.74-79), as well as in the region south from Ogishke Muncie lake (pp. 99-102.) In the same report the slate-and-quartzyte group (the Animikie) is parallelized with the Taconic group of professor Emmons (p. 135).

In the geological reports of Wisconsin, issued recently by professor Chamberlin, the rocks of the Penokee iron range have been classed as Huronian by professor Irving (*Geol. of Wis.*, vol. iii.; p. 104.) The same reports have referred the Thomson slates and quartzytes of Minnesota to the Huronian (vol. iii., plate IX.), as well as the red quartzytes and felsytes of central Wisconsin. Professor Irving has also, more lately, stated unqualifiedly and without reserve that the Animikie rocks of the northern boundary are Huronian. (*Science*, May 4, 1883.)

In Michigan, major Brooks has placed the Marquette iron-bearing rocks in the Huronian (*Geol. Sur. of Mich.*, vol. i.; p. 66) and has described (Table iii., *Geol. of Wis.*, vol. iii.; p. 450) the "newest Huronian," as consisting of a red granite; and Dr. C. Rominger has described a conversion from horizontal slates to tilted slates, similar to that above referred to as probable in Minnesota, the two having been regarded before as different.

Quite recently Dr. T. S. Hunt, in a paper on the *Taconic question in geology*, published in the *Transactions of the Royal Society of Canada*, has not only maintained the Taconic age of the Animikie rocks but has adopted their supposed conversion into the tilted slates and quartzytes suggested by the writer in 1881, and extends them southwestward to Thomson on the St. Louis river, where he states that by the aid of Dr. J. W. Dawson he has discovered a fossil keratose sponge in some dark calcareous concretions.

If all these facts and opinions be brought to bear on the interpretation of the stratigraphy of northern Minnesota, while they cannot all be reconciled so as to make perfect harmony, the most probable result, in the opinion of the writer, would be as follows, in descending order:

Potsdam formation.	Tilted red sandstones, shales and conglomerates, changed by igneous gabbros and dolerytes locally to red quartzytes, felsytes, quartz-porphyries and to red granite. The Keweenian, and the Huronian in part, in Wisconsin.
Taconic group.	Horizontal black slates and gray quartzytes, with interbedded limestones and diorytes (the Animikie group.) changed to tilted slates, quartzytes, iron ores, and siliceous marble. The Gunflint beds, the Mesabi iron rocks, the Ogishke Muncie conglomerate (?), the Thomson slates and quartzytes, the Vermilion iron rocks;—the Huronian in part, Wisconsin and Michigan.
Huronian group?	Magnesian, greenish, soft schists, becoming syenitic and porphyritic. Seen on the north side of Gunflint lake, along the international boundary at Basswood lake, and at Vermilion lake. The Huronian in part, in Wisconsin and Michigan.
Montalban?	Mica schists, and micaceous granite, the latter lenticular within the former, at the outlet of Vermilion lake—probably also at "Granite City" in Morrison county, and at Pike rapids on the Mississippi. The Huronian in part, in Wisconsin and Michigan.
Laurentian.	Massive hornblende gneiss, gray to nearly white, rarely reddish. The international boundary north of Gunflint lake to Saganaga lake and westward; also probably the Watab and Saint Cloud "granites."

VII.

CHEMICAL ANALYSES.

REPORT OF PROF. J. A. DODGE.

CHEMICAL LABORATORY, UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, Nov 28, 1883.

Prof. N. H. Winchell:

DEAR SIR: I herewith report the following analyses of minerals and waters for the geological survey.

Chem. series, No. 84. A dark brown rock, with fossils, and a concretionary appearance. This was tested at your request, for phosphoric acid. No phosphoric acid was found.

Chem. series, No. 85. A reddish concretionary mineral, in small lumps, appearing like a zeolite. The sample taken for analysis was selected, after partly breaking up the lumps, so as to be as homogeneous as possible. Its composition was as follows:

		Oxygen.		Oxygen ratios.
Silica,	62.73 per cent.	33.45		14.61
Alumina,	13.62 " "	6.35	6.87	3.00
Oxide of iron,	1.75 " "	.52		
Lime,	5.87 " "	1.67		
Magnesia,	0.65 " "	.26	2.52	1.10
Soda,	1.83 " "	.48		
Potash,	0.68 " "	.11		
Water	12.25 " "	10.89		4.71
	99.38			

The composition seems to bring this mineral under the species *mordenite.*

Chem. series, No. 86. A nearly white, concretionary, zeolitic mineral. Composition as follows:

		Oxygen.		Oxygen ratios.
Silica,	47.25 per cent.	25.19		6.47
Alumina,	24.78 " "	11.54	11.68	3.00
Oxide of iron,	0.48 " "	.14		
Lime,	1.23 " "	.35	4.52	1.16
Magnesia,	0.71 " "	.28		
Soda,	15.05 " "	3.19		
Potash,	traces. " "			
Water,	10.37 " "	9.22		2.37
	99.87			

The composition seems to refer this mineral to the species *natrolite.*

ANALYSES OF A SERIES OF WATERS.

Chem. series, No. 126. Analysis of water from the Red river of the North at St. Vincent, collected June 10th, 1882; analyzed in first part of September, 1882, having been in the mean time kept in glass bottles.

Composition of residue from evaporation.

	Parts to 1,000,000.	Percentage.	Grains per gallon.
Silica,	13.0	4.6	0.75829
Oxide of iron and alumina,	1.0	.4	0.05833
Carbonate of lime,	97.8	34.3	5.70467
Sulphate of lime,	35.7	12.6	2.08238
Nitrate of lime,	1.1	.4	0.06416
Carbonate of magnesia,	81.9	28.7	4.77723
Phosphate of lithia,	.6	.2	0.03499
Sulphate of potash,	8.7	3.1	0.50747
Nitrite of potash,	traces.		
Bromide of potassium,	traces.		
Sulphate of soda,	21.7	7.6	1.26576
Chloride of sodium,	22.9	8.1	1.33576
	284.4	100.0	16.58904

Iodine was found to be absent. A test for organic matter was made by the permanganate method (Tidy's). The oxygen required for oxidation was 3.5 per million. The hardness was found to be 19 degrees of Wanklyn's scale. The water is notable for its hardness, owing to the sulphate of lime and the carbonates.

The above analysis was made by Wm. A. Noyes.

Chemical series, No. 127. Analysis of water from the Red river of the North at Fergus Falls; collected in June, 1882, analyzed in Sept., 1882.

Composition of residue from evaporation.

	Parts to 1,000,000.	Percentage.	Grains per gal.
Silica,	14.3	7.0	0.83412
Alumina and oxide of iron,	1.2	.6	0.06999
Carbonate of lime,	101.0	50.0	5.89133
Carbonate of magnesia,	71.4	35.4	4.16476
Carbonote of lithia,	traces.		
Carbonate of potash,	4.2	2.1	0.24919
Bromide of potassium,	traces.		
Nitrate of potash,	traces.		
Nitrite of potash,	traces.		
Carbonate of soda,	5.8	2.8	0.33831
Sulphate of soda,	1.8	.9	0.10499
Chloride of sodium,	2.3	1.2	0.13456
Total,	202.0	100.0	11.78725

Iodine, absent; phosphoric acid, traces. Test with permanganate (Tidy's), showed 1.4 parts oxygen consumed by organic matter per million parts water. The hardness was found to be 9.5 degrees.

Analyzed by Wm. A. Noyes.

Chemical series No. 128. Analysis of water from Heron lake ; collected in June, 1882 ; analyzed in Sept., 1882.

Composition of residue from evaporation.

	Parts per 1,000,000.	Percentage.	Grains per gal.
Silica,	7.1	2.6	0.41414
Alumina and oxide of iron,	1.7	.6	0.09916
Carbonate of lime,	102.7	37.7	5.99049
Sulphate of lime,	47.9	17.6	2.79241
Nitrate of lime,	5.0	1.8	0.29165
Carbonate of magnesia,	76.3	28.0	4.45058
Carbonate of lithia,	traces		
Sulphate of potash,	8.0	3.0	0.46664
Nitrite of potash,	traces		
Sulphate of soda,	18.5	6.8	1.07911
Chloride of sodium,	5.1	1.9	0.29748
Total,	272.3	100.0	15.88166

Iodine, absent; bromine, absent; phosphoric acid, absent.

Test with permanganate showed 2.6 parts oxygen consumed by organic matter per 1,000,000 water.

Hardness, 22 degrees. The water is notable for excessive hardness, due to sulphate of lime and carbonates of lime and magnesia.

Analysis by Wm. A. Noyes.

Chem. series, No. 129. Analysis of water from Pigeon river falls ; collected in Aug., 1882 ; analyzed in Sept., 1882.

Composition of residue from evaporation.

	Parts per 1,000,000	Percentage.	Grains per gal.
Silica,	7.2	14.2	0.41998
Alumina and oxide of iron,	.8	1.6	0.04666
Carbonate of lime,	23.0	45.2	1.34159
Carbonate of magnesia,	10.2	20.0	0.59497
Carbonate of lithia,	traces		
Carbonate of potash,	.7	1.4	0.04083
Nitrate of potash,	traces		
Sulphate of potash,	2.0	3.9	0.11666
Sulphate of soda,	1.9	3.7	0.10923
Chloride of sodium,	5.1	10.0	0.29748
	50.9		2.96740

Iodine and bromine, absent; nitrites, absent; phosphates, absent; borates, absent.

Test with permanganate showed 3.6 parts oxygen consumed by organic matter per 1,000,000 water.

Hardness, 3.3 degrees. The degree of hardness is low.

Analysis by Wm. A. Noyes.

Chem. series, No. 130. Analysis of water from lake Superior at Grand Marais ; collected and analyzed in Sept., 1882.

Composition of residue from evaporation.

	Parts per 1,000,000.	Percentage.	Grains per gal.
Silica,	.5	1.1	0.02917
Alumina and oxide of iron,	traces.		
Carbonate of lime,	30.8	67.4	1.79656
Carbonate of magnesia,	9.1	19.9	0.53080
Carbonate of lithia,	traces.		
Carbonate of potash,	1.9	4.2	0.11083
Nitrate of potash,	.2	.5	0.01167
Nitrite of potash,	minute traces.		
Carbonate of soda,	.5	1.1	0.02917
Sulphate of soda,	.6	1.3	0.03499
Chloride of sodium,	2.1	4.5	0.12249
Total,	45.7	100.0	2.66568

Iodine and bromine, absent ; phosphates and borates, absent.

Test with permanganate showed 0.35 parts oxygen consumed by organic matter per 1,000,000 water.

Hardness 3.5 degrees.

The water is remarkable for its purity, especially organically.

Analysis by Wm. A. Noyes.

Chem. series, No. 131. Analysis of water of artesian well at Carman, Polk county, October, 1882.

Composition of residue from evaporation.

	Parts per 1,000,000.	Percentage.	Grains per gal.
Silica,	26.2	5.7	1.529
Alumina and oxide of iron,	1.5	.3	.087
Carbonate of lime,	88.6	19.4	5.171
Carbonate of magnesia,	52.9	11.6	3.087
Carbonate of lithia,	traces.		
Carbonate of potash,	11.5	2.5	.671
Nitrite of potash,	traces.		
Carbonate of soda,	73.8	16.2	4.308
Sulphate of Soda,	47.5	10.1	2,773
Borax,	traces.		
Chloride of sodium,	156.5	34.2	9.134
Bromide of potassium,	traces.		
Iodide of potassium,	traces.		
Total,	458.5	100.0	26.760

Nitrates, absent; phosphates, absent.

Test with permanganate showed 0.85 parts oxygen consumed by organic matter per 1,000,000 water.

Hardness, 12.5 degrees.

The water is remarkable for the large amounts of carbonate of soda and chloride of sodium.

Analysis by Wm. A. Noyes.

Chem. series, No. 132. Analysis of water from Minnesota City, October, 1882.

Composition of residue from evaporation.

	Parts per 1,000.000.	Percentage.	Grains per gal.
Silica,	16.3	5.2	0 .95078
Alumina and oxide of iron,	2.5	.8	0.14583
Carbonate of lime,	182.0	57.7	10.61606
Carbonate of magnesia,	104.3	33.0	6.08382
Carbonate of lithia,	traces.		
Carbonate of potash,	1.6	.5	0.09333
Sulphate of potash,	.7	.2	0.04083
Nitrite of potash,	traces.		
Sulphate of soda,	7.7	2.4	0.44914
Chloride of sodium,	.5	.2	0.02917
Total,	315.6	100.0	18.40896

Iodine and bromine, absent; phosphates, traces; borates, absent.

Hardness 11.5 degrees.

The sample of water whose analysis is above given, also contained sulphuretted hydrogen gas. A second sample received later gave no reaction for sulphuretted hydrogen.

Analysis by Wm. A. Noyes.

Chem. series, No. 133. Analysis of water from Rock river; collected and analyzed in November, 1882.

Composition of residue from evaporation.

	Parts per 1,000,000.	Percentage.	Grains per gal.
Silica,	21.0	7.6	1.22493
Alumina,	1.0	.4	0.05833
Oxide of iron.	8.8	3.2	0.51330
Carbonate of lime,	136.0	49.6	7.93288
Sulphate of lime,	6.4	2.3	0.37332
Nitrate of lime,	traces.		
Carbonate of magnesia,	70.4	25.7	4.10643
Phosphate of lithia,	minute traces.		
Sulphate of potash,	3.3	1.2	0.19249
Sulphate of soda,	25.6	9.3	1.49325
Chloride of sodium,	2.0	.7	0.11666
Total,	274.5	100.0	16.01158

Iodine and bromine, absent; phosphates, minute trace; borates, absent. Test by permanganate showed 1.1 parts oxygen consumed by organic matter per 1,000,000 water.

Hardness, 17 degrees.

The water is notable for the large amount of iron.

Analysis by Wm. A. Noyes.

Chemical series, No. 137. An oolitic substance of a brown color, evidently consisting largely of oxide of iron. On further examination it was found that this iron compound formed the superficial part of each granule in the mass, while the interior of each granule consisted of carbonate of lime. The substance was accordingly treated as follows. After pulverizing, it was treated with cold dilute hydrochloric acid, which removed the carbonate of lime. The remaining brown matter was washed and digested in strong hydrochloric acid; this treatment brought all into solution with the exception of some siliceous matter of a nearly white color. The amount of iron in this solution was determined. The amount of combined water in the brown matter was also determined. The results of these determinations are here given:

Siliceous matter	10.56	per cent.
Oxide of iron	71.35	" "
Water	11.98	" "

The oxide of iron and the water are in the same ratio as in limonite, $2Fe_2O_3$ $3H_2O$. Hence it was concluded that the brown coating on the granules of the oolitic substance was limonite.

Work chiefly done by W. A. Noyes.

Chemical series, No. 138. A specimen of rock from Mankato, near the Red Jacket railroad bridge, as stated on label.

The sample was of a nearly white color and fine-grained, somewhat friable.

The result of the analysis is as follows:

Silica,	93.65 per cent.
Alumina,	2.15 " "
Oxide of iron	.25 " "
Lime,	.20 " "
Magnesia,	.12 " "
Potassa,	traces.
Soda,	traces.
Water,	2.25 " "
	98.62

The analysis was made by Mr. C. F. Sidener.

The specimen, as indicated by the label, was furnished by J. G. Koller, of Mankato.

Chemical series, No. 139. A specimen of rock from the same locality as the last, furnished by J. G. Koller of Mankato.

The sample was of a light red color, fine-grained and somewhat friable.

The result of the analysis is as follows:

Silica,	73.34 per cent.
Oxide of iron,	5.45 " "
Alumina,	14.75 " "
Lime,	.28 " "
Magnesia,	.05 " "
Potassa,	traces.
Soda,	traces.
Water,	4.71 " "
	98.58

The analysis was made by C. F. Sidener.

Chemical series, No. 140. A sample of a loose and friable, rather coarse-grained sandrock of a greenish brown color, furnished by Mr. ——— Norton from a point in the western suburbs of Minneapolis in proximity to certain springs highly charged with iron.

Only a partial analysis of the material was made. The material was first rubbed to a state of loose sand with water, and then sub-

mitted to a process of elutriation, in which several quantities of liquid containing finely suspended matter were obtained. These were permitted to subside, the sediment still retaining to some extent the greenish tinge of the original mass. A quantity of the finest part of this sediment, after being air-dried, was submitted to a partial analysis. It lost on ignition 18.39 per cent., water and organic matter. The remainder was found to contain 45.56 per cent. oxide of iron, the balance being finely divided sand and clay.

Microscopic examination of the same subsided matter showed a nearly homogeneous mass of very fine, rounded, light-brown particles, with here and there greenish, irregular, flat objects which were judged to be portions of some low vegetable growth.

It was concluded that the peculiar color of the mass as found was due to the vegetable matter distributed over and through it and to the brown oxide of iron, and not to any special mineral substance.

Examination of this substance by J. A. Dodge.

Chemical series, No. 141. Sample of the water of lake Minnetonka.

This sample of water was taken about half way between Excelsior and Morse's island, May 21st, 1883, by Mr. Wm. A. Noyes. The analysis was begun immediately and was completed about the first of June. The results of the chemical analysis are as follows:

	Parts per million.	Grains per gallon.
Silica,	4.8	2.8
Iron,	traces.	
Calcium carbonate,	70.0	4.088
Magnesium carbonate,	27.7	1.618
Lithium carbonate,	traces.	
Potassium nitrate,	traces.	
Potassium carbonate,	4.5	.263
Sodium carbonate,	1.4	.082
Sodium phosphate,	traces.	
Sodium chloride,	1.3	.076
Borax,	traces.	
Sodium sulphate,	traces.	
	109.7	6.407

The amount of dissolved salts is on the whole rather small. It is remarkable for the almost total absence of sulphates. The water was also found to be very pure organically, the permanganate test of Forschammer and Tidy indicating very little organic matter.

The analysis was made by W. A. Noyes.

Chemical series, No. 142. Sample of water from Hunter's Hot Springs, Montana. This analysis was made in the early part of June, 1883. The results are as follows:

	Parts per million.	Grains per gallon.
Silica,	77.4	4.517
Alumina,	1.2	.070
Oxide of iron,	traces.	
Carbonate of lime,	4.0	.233
Magnesium carbonate,	traces.	
Lithium carbonate,	traces.	
Potassium carbonate,	5.5	.321
Sodium carbonate,	150.5	8.785
Sodium chloride,	24.7	1.442
Sodium bromide,	traces.	
Sodium iodide,	traces.	
Sodium sulphide,	14.6	.852
Sodium sulphate,	10.4	.607
Sodium phosphate,	traces.	
Sodium biborate (borax),	traces.	
	288.30	16.827

The analysis was made by W. A. Noyes.

Chemical series, No. 143. Sample of a spring water from Inglewood (west of Minneapolis), furnished by Mr. Geo. P. Bradbury. This analysis was made in the early part of July. The results are as follows:

	Parts per million.	Grains per gallon.
Silica,	20.9	1.22
Oxide of iron and alumina (the latter in very small amount),	.2	.012
Calcium carbonate,	167.8	9.794
Calcium sulphate,	2.0	.117
Calcium nitrate,	minute traces.	
Calcium phosphate,	traces.	
Magnesium carbonate,	80.4	4.693
Lithium carbonate,	traces.	
Sodium sulphate,	8.3	.485
Sodium chloride,	1.3	.076
Potassium sulphate,	2.9	.169
Total determined,	283.8	16.566

This water has a considerable amount of salts in solution. Analyzed by W. A. Noyes.

Chemical series, No. 144. Sample of the material used at Mankato for making hydraulic cement. This material is of fine granular texture, and of a very light grey color.

The powdered substance was digested in hydrochloric acid, whereby the greater part of it was dissolved with effervescence due to the escape of carbonic acid gas. The composition of the insoluble and the soluble portions is as follows:

Insoluble in HCl.		*Soluble in HCl.*	
Silica,	16 per cent.	Silica,	traces.
Alumina,	5 per cent.	Alumina,	.85 per cent.
Potash,	traces.	Oxide of iron,	2.73 " "
Soda,	traces.	Calcium carbonate,	40.00 " "
	21.00	Magnesium carbonate,	31.50 " "
		Potash,	.22 " "
		Soda,	.54 " "

Combined.

Insoluble,	21.00 per cent.
Soluble,	75.84 " "
Water,	.43 " "
	97.27

The soluble portion is seen to be mainly carbonate of lime and carbonate of magnesia, with some oxide of iron, while the insoluble portion is silicate of alumina.

Analysis by C. F. Sidener.

Chemical series, No. 145. Sample of hydraulic cement made at Mankato.

This material was found to effervesce very little with hydrochloric acid. It was accordingly analyzed as a silicate, by fusion, in the usual manner. The result of the analysis is as follows:

Silica,	16.24 per cent.
Alumina,	5.35 " "
Oxide of iron,	4.71 " "
Lime,	38.53 " "
Magnesia,	22.73 " "
Potash,	1.81 " "
Soda,	.57 " "
Water.	.51 " "
Carbonic acid,	9.26 " "
	99.71

Analysis by C. F. Sidener.

Chemical series, No. 146. A sample of clay of a light color, compact and dry.

This was analyzed by fusion in the usual manner for silicates. The result of the analysis is as follows:

Silica,	68.70 per cent.
Alumina,	18.04 " "
Oxide of iron,	1.53 " "
Lime,	1.24 " "
Magnesia,	.56 " "
Potash,	5.28 " "
Soda,	.24 " "
Phosphoric oxide,	.09 " "
Water,	1.40 " "
Organic matter,	traces.
	97.08

The material is rather remarkable for containing so much potash, which probably exists in it in the form of finely divided potash feldspar.

On ignition this clay changes only a little in color, becoming slightly brownish.

Analysis by C. F. Sidener, mainly.

Very respectfully yours,

JAMES A. DODGE.

NOTE. The foregoing substances were derived as follows:

No. 84. Was furnished by Mr. James M. Young. It was from the drift, and had the appearance of being similar to the phosphatic nodules derived from the Cretaceous in South Carolina. It was found at the main Two rivers, in Morrison county, a locality where the Cretaceous strata are known to exist. Mus. Reg. No. 4711.

No. 85. Zeolitic mineral from the trap rocks of the north shore of Lake Superior, Sec. 29, T. 57,6, a few miles west of Little Marais. It is number 634 A, of the geological survey series of crystalline rocks. Tenth annual report, p. 63.

No. 86. From Beaver Bay; found filling thin seams in the feldspar masses, from one-fourth to one-half an inch thick. It is a light flesh-colored, zeolitic mineral, with a radiated structure; corresponds to No. 637 A, of the series for the crystalline rocks. Tenth annual report, p. 64.

No. 126. Water from the Red river of the North, at Saint Vincent. Collected June 10, 1882, by Mr. C. F. Sidener.

No. 127. Water from the Red river of the North at Fergus Falls. Collected by Mr. Sidener, June, 1882.

No. 128. Water from Heron lake, Jackson county. Collected in June, 1882, by Mr. C. F. Sidener.

No. 129. Water from the falls of Pigeon river; obtained through Mr. Henry Mayhew, August, 1882.

No. 130. Water from lake Superior, near Grand Marais; obtained through Mr. Henry Mayhew, September, 1882.

No. 131. Water from an artesian well at Carman in Polk county; obtained through chief engineer C. C. Smith, Sept. 1882.

No. 132. Water from the mineral spring of C. F. Bryan, near Minnesota City. Collected in September, 1882. From Mr. C. F. Bryan.

No. 133. Water from the Rock river, sec. 19, T. 103, 44, near Luverne, Rock county; obtained through Hon. J. P. Kniss, November, 1882.

No. 137. Oölitic ferruginous rock from the Trenton, or Hudson River shales, fossiliferous, at the horizon of the *green shales*, at the railroad cut near Fountain, Fillmore county. Mus. Reg. No. 4978.

No. 138. Sample from the clay lying between the Shakopee limestone and the Jordan sandst[illegible]mmediately south of the Red Jacket railroad bridge, near Mankato, Blue Earth county. Furnished by Mr. J. G. Koller.

No. 139. Same as the last, but of a red color.

No. 140. Greenish, ferruginous, somewhat gritty substance, found about six feet below the natural surface, on land of W. W. Norton, near Minneapolis, or in a ditch by the roadside, about a mile north of Minnehaha creek, in the extension of Park avenue, in the valley of drainage from a marsh to Minnehaha creek, occurring somewhat as a bog ore.

No. 141. Water from lake Minnetonka, obtained by Wm. A. Noyes, May 21, 1883.

No. 142. Water from Hunter's Hot springs, Montana [illegible]urnished by Dr. Hunter, June, 1883.

No. 143. Water from a natural spring at Inglewood (west of Minneapolis), furnished by Mr. George P. Bradbury, June, 1883.

No. 144. Hydraulic limestone, used by the Standard Cement company, at Mankato, selected by [illegible]he superintendent. Oct. 1883.

No. 145. Hydraulic lime, manufactured from the strata of the Shakopee formation, by the Standard Cement company at Mankato. Furnished by the superintendent.

No. 146. White clay, lying between the Shakopee limestone (dislodged) and the Jordan sandstone, on L' Huillier mound, at the mouth of the Blue Earth river.—N. H. WINCHELL.

VIII.

MUSEUM REPORT FOR 1882.

During the year 1882 the usual increase has been made in the collections of the museum. Four hundred and sixty-four entries have been made in the register. Some of these entries, as heretofore, are for the purpose of preserving records of specimens that are yet to undergo scientific examination, and are not enumerated in the following list of registrations. They have, however, been labeled and numbered to correspond with the records. These unnamed specimens are derived largely from the geological survey. The others are entered in the register under the names which they have when they come to us, unless known to be wrong, whether presented or obtained by exchange.

Exchanges have been made with Prof. C. U. Shepard, John H. Goodale, Prof. S. Calvin, and Dr. J. W. Hood.

The principal donors to the museum registered in 1882 were Dr. E. S. Dana, Gen. H. H. Sibley, Lieut. A. W. Vogdes, A. J. Noyes, F. D. Anthony, N. H. Winchell, Cora E. Goode, W. J. McGee, W. H. Shelton, C. L. Herrick, J. C. Kassube and Horace V. Winchell. All these donations, and others, are enumerated in the following list.

SPECIMENS REGISTERED IN THE MUSEUM IN 1882.

Serial Number.	OBTAINED. When.	OBTAINED. Whence.	NAME.	No. of Specimens.	Locality.	Formation	Collector and Remarks.
4691	1882	C. U. Shepard.....	Meteoric Iron.....wt., 41.5 grs	1	Aeriotopos, Col.....	.....	By exchange with Prof. C. U. Shepard.
4692	"	"	" " .... " 7.05 "	1	Morro do Rizio (Santa Catarina), Brazil.....	.....	By exchange with Prof. C. U. Shepard.
4693	"	"	" " ..... " 6.2 "	2	Putnam Co., Georgia...	.....	By exchange with Prof. C. U. Shepard.
4694	"	"	" " ..... " 105.6 "	2	Toluca, Mexico.....	.....	By exchange with Prof. C. U. Shepard.
4695	"	"	" " ..... " 5.4 "	1	Mejillones, Chili..	.....	By exchange with Prof. C. U. Shepard.
4696	"	"	" " ..... " 3.8 "	S'v'rl	Zacatecas, Mexico.....	.....	By exchange with Prof. C. U. Shepard.
4697	"	"	" Stone..... " 0.4 "	1	Vouille, France	.....	By exchange with Prof. C. U. Shepard.
4698	"	"	" " ..... " 3.1 "	1	Cabarras, N. C.....	.....	By exchange with Prof. C, U. Shepard.
4699	"	"	" " ..... " 2.4 "	F'wr'd	Bishopville, S. C.....	.....	By exchange with Prof. C. U. Shepard.
4700	"	Presented	Incrustation from Giant Geyser.....	1	National Park.....	Recent....	From Frank Bush ; presented by Prof. H. S. Baker.
4701	"	"	"Satin spar," rose-colored.....	1	Monument Park, Col...	.....	Presented by Dr. A. F. Elliott.
4702	"	"	Pyrargyrite ("ruby silver").....	1	Georgetown, Col.....	.....	" " " " "
4703	"	By purchase.....	"Rock soap".....	1	Near San Buenaventura, Cal.....	....	From I. F. Saxly, obtained through Rev. C. B. Sheldon.
4704	1881	By exchange	Staurolite crystals.....	Indf.	....	.....	From Prof. C. U. Shepard.
4705	"	"	Staurolite, twinned & intergrown crystals..	"	....	.....	" " " "
4706	1882	Presented	Sandstone	3	Dresbach	St. Croix...	Presented by J. S. Tostevin, of St. Paul.
4707	"	"	Columbite, fine crystals.....	1	Branchville, Conn.....	.....	Presented by Dr. Edw. S. Dana of Yale College.

4708	1882	Presented.	Columbite crystals with calcite	2	Branchville, Conn		Presented by Dr. Edw. S. Dana, of Yale College.
4709	"	"	" .massive	1	" "		Presented by Dr. Edw. S. Dana, of Yale College.
4710	"	"	Chalcopyrite crystals, on quartz	1	" "		Presented by Dr. Edw. S. Dana, of Yale College.
4711	"	Geol. & Nat. Hist. Survey	Phosphatic, (?) ferruginous nodule	1	Main Two Rivers, Mor. Co	Drift from the Cret.	Presented by James M. Young.
4712	"	Presented	Silicified wood	10	Valley of the Yellowstone, Montana		Presented by Gen. Sibley.
4713	"	"	Opal and chalcedony fragments	16	Ofallon creek, Montana		" " " "
4714	"	"	Quartz (chalcedony) fragments	10	Mouth of Green river, Dak		" " " "
4715	"	"	Pyrite concretions	2	Near Sentinel Butte		" " " "
4716	"	"	Gypsum	1	Heart river, Dakota		" " " "
4718	"	"	"Horn Silver"	1	Tin Cup Mining Dist'ct, Gunnison Co., Col		" " J. W. Bird.
4719	"	"	Oolyte	2	Stillwater		" " A. D. Roe.
4720	"	By exchange	Andalusite (chiastolite)	5	Lancaster, Mass		From John H. Goodale.
4721	"	"	Clay stones (concretions in clay, modified drift)	8	Headwaters of the Connecticut river in N. H.	Recent	" " "
4736	"	Presented	Deposit from Castle Geyser	1	Yellowstone Nat. Park	"	Presented by D. P. Jones.
4737	"	"	Deposit from hot springs	6	Mt. Johnson, near Gibbon Geyser Basin, Yellowstone Nat. Park		" " A. J. Noyes.
4738	"	"	" " " "	1	Yellowstone Nat. Park		" " "
4739	"	"	" " " "	1	" " "		" " "
4740	"	"	" " " "	5	" " "		" " "
4741	"	"	" " " " ("Paint-pots")	8	" " "		" " "
4742	"	"	Horse-shoe, coated by the Mammoth Sp'g	1	" " "		" " "
4743	"	"	"Geyser-egg" (pencil-writing indelible)	1	" " "		" " "
4744	"	"	Sulphur, crystalline	4	Sulphur Mt., 12 miles above the Great F'lls of the Yellowstone, in the National Paak		" " "
4745	"	"	Obsidian	1	Obsidian Mtn., Yellowstone Nat. Park		" " "
4746	"	"	Silicified wood	2	Yellowstone Nat. Park		" " "
4747	"	"	Gold-bearing quartz	2	Bear Gulch, 6 ms. S. of the Yel. Nat. Park, Wyoming		" " "
4748	"	"	Silver and Gold,—(the latter "retort")	Indef	Summit Valley dis'ct, S'lv'r Bow Co., Mont'a		" " "
4749	"	"	Silver ore, Original mine	3	" " "		" " "
4750	"	"	" " Gagnon lode	2	" " "		" " "
4751	"	"	" " Bell mine	1	" " "		" " "
4752	"	"	" " Star West mine	3	" " "		" " "

Specimens registered in the museum in 1882.—Continued.

Serial Number.	OBTAINED. When.	OBTAINED. Whence.	NAME.	No. of Specimens.	Locality.	Formation	Collector and Remarks.
4753	1882	Presented	Silver ore, Star West mine	2	Summit Valley disc't, S'lv'r Bow Co., Mont'a		Presented by A. J. Noyes.
4754	"	"	" " Anselmo mine	3	" " "		" " "
4755	"	"	" " Mountain Boy mine	2	" " "		" " "
4756	"	"	" " Trarona mine	1	" " "		" " "
4757	"	"	" " Black Chief mine	1	" " "		" " "
4758	"	"	" " Vulcan mine	1	" " "		" " "
4759	"	"	" " Alice mine	1	" " "		" " "
4760	"	"	*Graptolithus pristis*, Hall	3	Near Sandy Hill, N. Y.	Utica Sl'te	" " Prof. C. W. Hall.
4761	"	"	Iron ore, hematite; Mastodon mine	1	Mastodon, Mich., Lake Superior region		" " F. D. Anthony.
4762	"	"	" " " Porteos Explorat'ns.	1	Near Mastodon, Mich., L. Superior region		" " "
4763	"	"	" " " Carry mine	1	Near Vulcan, Mich., L. Superior region		" " "
4764	"	"	" " " Cascade mine	1	Cascade, Mich., Lake Superior region		" " "
4765	"	"	Iron ore, hematite; Quinnesec mine	1	Quinnesec, Mich., L'ke Superior region		" " "
4766	"	"	" " " ("steel ore") Cleveland mine	1	Ishpeming, Mich., L. Superior region		" " "
4767	"	"	Iron ore, hematite; Cleveland mine	3	" "		" " "
4768	"	"	" " " ("slate ore"), N. Y. mine	1	" "		" " "
4769	"	"	From Ropes Gold and Silver mine	3	" "		" " "
4770	"	"	Core from diam'd drill, 400 ft. b'l'w surface	4	" "		" " "
4771	"	"	Iron ore, hematite, South Republic mine	1	Near Republic, Mich., L. Superior region		" " "
4772	"	"	" " " Breen mine	2	Wancedale, Mich., L'ke Superior region		" " "
4773	"	"	" " " Metropolitan mine	1	Metropolitan, Mich. Felch Mt. range, L Superior region		" " "

4774	1882	Presented.....	" " "	3	Felch Mt., Mich., L. Superior region.....	.....	Presented by F. D. Anthony.		
4775	"	"	Quartz (jasper).....	1	" "	.....	"	"	"
4776	"	"	Marble.....	1	" "	.....	"	"	"
4777	"	"	Iron ore, hematite, covered by botryoidal limonite.....	1	Superior mine, Ishpeming, Mich., L. Superior region	.....	"	"	"
			[Prof. S.'s No.						
4778	Oct. 3, '82	By exchange.....	Pihlite (cymatolite) 2322	1	Chestfield, Mass	.....	From Prof. C. U. Shepard.		
4779	"	"	Serpentine (chrysotile) in deweylite.2323	1	Templeton, Canada.....	.....	"	"	"
4780	"	"	Apatite, red-brown..... 2324	1	Grattan, Ontario, Can..	....	"	"	"
4781	"	"	Chalcophanite on hetærolite 2325	1	Sparta, New Jersey ..	....	"	"	"
4782	"	"	Hematite and Quartz.. 2326	1	Fowler, N. Y	.....	"	"	"
4783	"	"	Garnet (uwarowite) on nickeliferous augite 2327	1	Wakefield, Canada.....	.....	"	"	"
4784	"	"	Psilomelane 2328	1	Woodstock, Alabama..	.....	"	"	"
4785	"	"	Hausmannite..... 2329	1	Ilmenau, Thuringia....	.....	"	"	"
4786	"	"	Uraninite and gummite 2330	1	Mitchell Co., N. C.....	....	"	"	"
4787	"	"	Apatite (yellow)..... 2331	1	Odegarden, Norway....	.....	"	"	"
4788	"	"	Cancrinite and bluish green nephelite (elæolite)..... 2332	1	Litchfield, Maine..... .	.....	"	"	"
4789	"	"	Libethenite..... 2333	1	Cornwall, England.....	.....	"	"	"
4790	"	"	Celestite.... 2334	1	Bristol, England.....	.....	"	"	"
4791	"	"	Vesuvianite (cyprine) and zoisite (thulite)..... 2335	1	Tellemark, Norway...	.....	"	"	"
4792	"	"	Crocidolite..... 2336	1	Templeton, Canada....	....	"	"	"
4793	"	"	Anthophyllite, with chalcopyrite and pyrrhotite 2337	1	Villa Rica, Georgia.....	.....	"	"	"
4794	"	"	Cuprite..... 2338	1	Ural Mts.....	.....	"	"	"
4795	"	"	Celestite..... 2339	1	Herrengrund, Hungary	.....	"	"	"
4796	"	"	Martite, in syenite..... 2340	1	Dresden, Saxony.....	... .	"	"	"
4797	"	"	Hydrotalcite..... 2341	1	Vernon, New Jersey...	.....	"	"	"
4798	"	"	Mimetite (hedyphane)..... 2342	1	Langban, Sweden...	.....	"	"	"
4799	"	"	Cassiterite..... 2343	1	Cornwall, England.....	....	"	"	"
4800	"	"	Cuprite..... 2344	1	" "	.....	"	"	"
4801	"	"	Œrstedite..... 2345	1	Chesterfield, Mass.....	.....	"	"	"
4802	"	"	Pinite (killinite)..... 2346	1	" "	.....	"	"	"
4803	"	"	Orthoclase (perthite) 2347	1	Perth, n'r Burgess, Can	.....	"	"	"
4804	"	"	Bornite and cuprite..... 2348	1	Plumas Co., California.	.....	"	"	"
4805	"	"	Scapolite, massive, blue..... 2349	1	Templeton, Canada....	.....	"	"	"
4806	"	"	Titanite (lederite)..... 2350	1	Grattan, Renfrew Co., Canada	.....	"	"	"
4807	"	"	Amphibole and albite..... 2351	1	Snarum, Norway.....	.....	"	"	"
4808	"	"	Pyroxene (augite)..... 2352	1	Templeton, Canada....	.....	"	"	"
4809	"	"	Orthoclase, twin crystals 2353	1	Furhsberg, Silesia.....	.....	"	"	"
4810	"	"	*Eozoon Canadense*, Dawson..... 2354	1	Templeton, Canada...	... .	"	"	"
4811	"	"	Scapolite and pyroxene (augite)..... 2355	1	" "	.. ..	"	"	"
4812	"	"	Glauconite with apophyllite.....2356	1	Ghauts Mts., India.....	.. ..	"	"	"
4813	"	"	Octahedrite (anatase)..... 2357	1	Tavesch, Grisons	.....	"	"	"

Specimens registered in the museum in 1882.—Continued.

Serial Number.	OBTAINED. When.	OBTAINED. Whence.	NAME.	No. of Specimens.	Locality.	Formation	Collector and Remarks.
4814	Oct. 3, '82	By exchange.....	Greenockite (yellow powder), in a compact rhodonite (fowlerite), tephroite, garnet, and willemite (troostite)? [Prof. S,'s No. 2358	1	Franklin, N. J.....	....	From Prof. C. U. Shepard.
4815	"	"	Willcoxite and centhophyllite 2359	1	Franklin, N. C.....	.....	" " "
4816	"	"	Perofskite 2360	1	Ackmatowsk mine, Russinsk, Urals.....	.....	" " "
4817	"	"	Tridymite, in trachyte.....2361	1	Siebengeberge, Prussia	.....	" " "
4818	"	"	Spinel (rubies),—(in test-tube) 2362	Many	Ceylon	.....	" " "
4819	"	"	Cancrinite.....2363	1	Litchfield, Maine.....	.....	" " "
4820	"	"	Garnet.....2364	1	Templeton, Cannda.....	....	" " "
4821	"	"	Talc (rensselaerite). 2365	1	" "	....	" " "
4822	"	"	Malachite on chalcocite, which contains silver..... 2366	1	Turriinsk, Urals.....	.....	" " "
4823	"	"	Guano (pyroclasite) 2367	1	Moneta island, West Indies..	.....	" " "
4824	"	"	Pelhamine.....2368	1	Pelham, Mass.....	.....	" " "
4825	"	"	Apatite, in red calcite.....2369	1	Grattan, Canada.....	.....	" " "
4826	"	"	Titanite, amphibole, and augite.....2371	1	Templeton, Canada...	.....	" " "
4827	1882	Presented.	Cement stone, from Buck's quarry.....	1	Mankato, Minn.....	Shakopee limestone	Presented by Hon. D. Buck.
4828	"	"	Travertine ("petrified moss")..	1	Two miles S. of Osceola Mills, Wis.....	Recent springs.	" Prof. C. W. Hall.
4829	"	"	Rock salt.....	1	England.....	.....	" " "
4830	"	"	Granite, with Amazon stone as feldspar.	1	Mt. Desert, Maine	....	" Prof. J. A. Dodge
4831	"	exchange.....	*Acervularia davidsoni*, Ed. & H.....	1	Iowa City, Iowa.....	Hamilton, Dev.....	From Prof. S. Calvin.
4832	"	"	*Favosites billingsii*, Rom.....	1	Bartlett's Mills, Ontario Canada.....	Hamilton, Dev.....	" " "
4833	"	"	*Favosites placenta*, Rom. (two varieties)..	2	Bartlett's Mills, Ontario Canada.....	Hamilton, Dev.....	" " "

4834	1882	By exchange.....	*Heliophyllum halli*, Ed. & H.....	2	Bartlett's Mills, Ontario, Canada.....	Devonian..	From Prof. S. Calvin.	
4835	"	"	*Cystiphyllum americanum*, Ed. & H.....	2	" "	Hamilton, Dev.	" " "	
4836	"	"	*Pachyphyllum woodmani*, White, (rare)..	1	Lime Cr'k, Rockford, Ia	Dev. shales	" " "	
4837	"	"	*Cyathophyllum multiplicatum*, Owen.....	2	Manchester. Iowa.....	Niagara, U. Sil.	" " "	
4838	"	"	*Terebratula linklaeni*.....	3	Fayette, Iowa.....	Devonian	" " "	
4839	"	"	*Spirfera pennata*, Owen	2	Independence, Iowa ...	Hamilton Dev	" " "	
4840	"	"	" *mucronata*, Con.....	7	Widder, Ontario, Can.	" "	" " "	
4841	"	"	" *hungerfordi*, Hall	5	Lime creek, Iowa.....	Devonian.	" " "	
4842	"	"	" *whitneyi*, Hall.....	2	" " "	"	" " "	
4843	"	"	" *orestes*, H. & Whitf..	3	" " "	"	" " "	
4844	"	"	" *aspera*, Hall.....	1	Pine creek, Muscatine Co., Iowa.....	"	" " "	
4845	"	"	" *parryana*, Hall.....	2	" " "	"	" " "	
4846	"	"	*Athyris vittata*, Hall.....	13	" " "	"	" " "	
4847	"	"	" " "	3	Iowa City, Iowa	Hamilton, Dev.	" " "	
4848	"	"	*Leiorhynchus altus*, Calvin.....	3	Solon, Iowa.....	Devonian.	" " "	
4849	"	"	*Pentamerus oblongus*, Sowerby.....	3	Iowa	Niagara, U. Sil....	" " "	
4850	"	"	*Atrypa aspera*, var. *occidentalis*.....	2	Independence, Iowa...	Devonian.	" " "	
4851	"	"	" *reticularis*, Lin.....	6	" "	Hamilton, Dev.	" " "	
4852	"	"	" " "	9	Pine creek, Muscatine Co., Iowa.....	Devonian.	" " "	
4853	"	"	" " "	9	Lime creek, Iowa.....	"	" " "	
4854	"	"	" *hystrix*, Hall.....	5	" " "	"	" " "	
4855	"	"	*Orthis impressa*, "	4	Hackberry Grove, Iowa	Hamilton, Dev.	" " "	
4856	"	By exchange	*Strophodonta reversa*, Hall.....	3	Lime creek, Iowa.....	Devonian.	" " "	
4857	"	"	" *hybrida*, H. & W.....	3	" "	"	" " "	
4858	"	"	" *canace*, H & W.....	2	" "	"	" " "	
4859	"	"	" *exilis*, Calvin...	3	" "	"	" " "	
4860	"	"	" *arcuata*, Hall.....	2	" "	"	" " "	
4861	"	"	*Productella dissimilis*, Hall.....	2	" "	"	" " "	
4862	"	"	*Naticopsis gigantea*, H. & W. (casts).....	3	" "	"	" " "	
4863	"	"	*Batocrinus rotundus*, Shum.....	2	Burlington, Iowa.....	Burlington beds, Sub-Carboniferous.....	" " "	
4864	"	"	*Trigonocarpus*.....	2	Youngstown, Ohio.....	Coal Measures	" " "	
4865	"	By purchase	*Goniasteroidocrinus tuberosus*.....	1	Crawfordsville, Indiana	.....	From Prof. D. A. Bassett.	
4866	"	"	*Onychocrinus exculptus*	1	" "	.....	" " "	
4867	"	"	*Platycrinus hemisphericus*.....	1	" "	....	" " "	

Specimens registered in the museum in 1882.—Continued.

Serial Number.	OBTAINED. When.	OBTAINED. Whence.	NAME.	No. of Specimens.	Locality.	Formation	Collector and Remarks.
4868	1882	By purchase	*Scaphiocrinus æqualis*	1	Crawfordsville, Indiana	.....	From Prof. D. A. Bassett.
4869	"	"	*Poteriocrinus decadactylus*	1	" "	.....	" " "
4870	"	"	*Platyceras equilaterdlis*	3	" "	.....	" " "
4871	"	Presented	Sandstone, dressed blocks	2	Dresbach, Minn	St. Croix	Presented by J. F. Tostevin, of St. Paul.
4872	"	"	" " " (from weathered beds)	1	" "	"	Presented by J. F. Tostevin, of St. Paul.
4901	Aug. 1881	Presented	Magnetite	1	Eastern Tennessee	.....	Presented by Gen. Wilder.
4902	"	"	Sandstone	2	Top of Lookout Mt., Tenn	Sub-Carboniferous	Presented by N. H. Winchell.
4903	"	"	Oolyte	1	Near Sherwood, Tenn	"	" " " "
4904	"	"	Limestone	1	Central Kentucky	St. Louis limestone, Sub-Carboniferous	" " " "
4905	"	"	" (variegated)	1	High Bridge, Ky	Trenton	" " " "
4906	"	"	" (fine-grained)	1	" "	"	" " " "
4907	"	"	Limestone	6	Montreal, Canada	"	" " " "
4908	"	"	Limestone cut by dyke of igneous rock	1	Mt. Royal, Montreal, Can	"	" " " "
4909	"	"	Eruptive rock, coarse-grained	3	" " "	...	" " " "
4910	"	"	" " fine-grained; dyke cutting the limestone	1	" " "	.....	" " " "
4911	"	"	Metamorphic rock	1	" " "	.....	" " " "
4912	Aug. 1882	"	Apatite	2	Ottawa, Canada	.....	" " " "
4913	"	"	Hematite	1	Haycock Iron Location, 7 miles from Ottawa, Canada	.....	" " " "
4915	1877	Geol. & Nat. Hist. Survey	Lignite (fragments in a bottle	Many	Newberg, Mitchell Co., Iowa	Devonian.	N. H. Winchell.
4916	"	Geol. & Nat. Hist. Survey	Peat, interglacial,—18 inches thick	Much	Sec. 12, Windom, Mower Co	Interglaial	" "

4917	1877	Geol. & Nat. Hist. Survey	Iron ore, concretionary	1	Austin		" "	
4918	1882	Presented	Lignite	M'ny	Valley of the Redwood river	Cretace'us	Presented.	
4919	"	"	Black clay, 85 feet below the surface	Svr'l.	Melotte, Dakota	"	Presented by C. H. Prior.	
4920	"	"	Drillings from a well, 149 feet deep	"	New Richland, Waseca Co	"	" " C. E. Whelpley.	
4921	"	"	Brass, melted and crystallized, from the heated journal of a car-wheel	1	Minnesota		" " N. H. Winchell.	
4922	"	"	Limestone fragments from the drift	12	Vicinity of Rockford, Wright Co	Drift	" " H. Ellington.	
4924	"	"	Concretion of sandstone, spike-like	1	Sec. 21, T. 98, R. 4, Iowa		" " " "	
4951	"	"	Stalactites and stalactitic crust	3	Olmsted Co	Recent springs	Presented by Miss Cora E. Goode.	
4955	"	"	Native gold and silver, with argentite	1	Vein of the Bodie mine, Bodie, Cal.		Presented by H. Augustus Whiting.	
4956	"	"	Couuntry rock, with fronds of native silver	1	Bodie mine, Bodie, Cal.		" " "	
4957	"	"	Arenaceous shale, cont'in'g scales of fishes	40	Raiload well, Aberdeen, Dakota	Cret.(?)	Presented by C. H. Prior.	
4958	"	"	Concretion, calcareous	1	Dakota	"	" M. A. Morey.	
4959	"	"	Limestone	2	Decorah, Iowa	Trenton	" " W. J. McGee.	
4960	"	"	Dolomite	3	State Quarry, Anamosa, Stone City, Iowa	Niagara	" " "	
4961	"	"	"	4	Farley, Iowa	"	" " "	
4962	"	"	"	2	Lemont, Illinois	"	" " "	
4963	"	"	Limestone	2	Buffalo, Scott Co., Iowa	Hamilton	" " "	
4964	"	"	Oolyte	2	Le Grand, Iowa	Kinderh'k	" " "	
4965	"	"	Hydraulic dolomite	4	Iowa Falls, Iowa	"	" " "	
4966	"	"	Sandstone	1	Fairfield, Iowa	St. Louis	" " "	
4967	"	"	Dolomite	2	Pella, Iowa	"	" " "	
4968	"	"	Limestone	1	Sigourney, Iowa	Carbonif's.	" " "	
4969	"	"	Sandstone	2	Buffalo, Scott Co., Iowa	Coal Measures	" " "	
4970	"	"	Gypsum	1	Fort Dodge, Iowa	Jur. or Triassic	" " "	
4979	"	Geol. & Nat. Hist. Survey	Sandstone	7	Lewiston, Winona Co	Jordan	N. H. Winchell.	
4980	"	" "	"	22	Dresbach, "	St. Croix	"	
4985	"	" "	Conglomerate	5	" "	"	"	
4986	"	" "	Sandrock, with fucoidal markings	12	" "	"	"	
4987	"	" "	Soil (loess-loam)	Much	St. Charles, "	Recent	"	
4988	"	" "	Sub-soil	"	" "	"	"	
4989	"	" "	"	"	Pickwick, "	"	"	
4990	"	" "	Brick-clay	"	Dresbach, Winona Co.	Alluvial	"	
4991	"	" "	Brick, red; (Sherwood & Johnson)	1	" " "		"	
4992	"	" "	" pressed, sunburned; (Sher. & John.)	1	" " "		"	
4993	"	" "	" red; (Biesanz)	1	Winona, " "		"	
4994	"	" "	Limestone	1	LaCrosse, Wisconsin	St. L'wr'nc	"	

Specimens registered in the museum in 1882.—Concluded.

Serial Number.	OBTAINED. When.	OBTAINED. Whence.	NAME.	No. of Specimens.	Locality.	Formation	Collector and Remarks.
4995	1882	Geol. and Nat. Hist. Survey.	Calcarous concretions	20	Bryan's, near Minnesota City	Lœss-loam	N. H. Winchell.
5003	"	" "	Concretions from the green shales	50	Sec. 16, Minneola, Goodhue county	Hudson River	"
5007	"	Presented	Slabs showing glacial striation and polishing.	4	Quarry opp. the University, Minneapolis	Trenton	Presented by C. L. Herrick.
5018	"	"	Pebble, black, ½ inch long; in Trenton limestone	1	Minneapolis	"	" "
5068	"	Geol. and Nat. Hist. Survey.	Calcite, in drusy cavity	1	"	"	N. H. Winchell.
5120	"	" "	Calcite crystals	4	"	"	C. L. Herrick.
5145	1881	Presented	Brick-clay	3	Collingwood, Meeker county	Modified Drift	Presented by Mr. Pendergast.
5146	"	"	Peat	2	Near Coon creek, Anoka Co	Recent	" Dwight Mitchell.
5147	"	"	*Orthis Kassubæ*, Winchell	1	Minneapolis	Trenton	" J. C. Kassube.
5148	"	"	" *perveta*, Con	1	"	"	" "
5149	"	"	" *subæquata*, Con	2	"	"	" "
5150	"	"	" *tricenaria*, Con	1	"	"	" "

Archæological Additions to the Museum in 1882.

74. Fragments of Indian pottery. From the northwest shore of Mille Lacs. Collected by Warren Upham.

75. Lock of Dirt-in-the-Face's hair, braided. Miles City, Montana; Nov. 1, 1881. Presented by Col. J. B. Clough.

76. Arrow-point of chert; narrow. From a mound at Dresbach, Winona county. Presented by George B. Dresbach, Jr.

77. Copper chisel, 1½ to 2 inches broad, 6 inches long. From the same mound at Dresbach. Presented by George B. Dresbach, Jr.

78. Copper chisel, 1 to 1⅛ inches wide, 7 inches long. From the same mound with the preceding. Presented by John H. Mosse.

79. Piece of pottery, also from the same mound at Dresbach. Presented by John H. Mosse.

80. Fragment of a human skull. From the same mound. Presented by John H. Mosse.

81. Piece of pottery, from the largest (nine feet in hight) in a group of sixteen mounds, N. E. ¼ of sec. 31, Greenwood, Hennepin Co. (at junction of creek, outlet from Lake Sarah, with the Crow river.) Presented by H. Ellington.

82. Fragment of a bone, from the same mound with the last. Presented by H. Ellington.

83. Angular fragments of chert (chipped?). Found between Mankato and South Bend, and presented by Rev. Louis J. Hauge.

84. Lance-head of gray chert, notched at base, unsymmetrical. Record lost.

85. Imperfect arrow-point of gray quartzyte. Record lost.

86. Arrow-points of flint and chert; three, all notched at base. Records lost.

87. Spear-point of quartzyte. From Martha's Vineyard. Presented by Mrs. Maj. C. J. Allen.

88. Arrow-point of flint, small, triangular. From Martha's Vineyard. Presented by Mrs. Allen.

89. Low, conical disk of limonite, polished, with a thin edge. From Sherwood, Tennessee. Presented by N. H. Winchell.

90. Rose-quartz arrow-point, with unnotched base. From Sherwood, Tennessee. Presented by N. H. Winchell.

91. Small, quartz arrow-point. From Sherwood, Tennessee. Presented by N. H. Winchell.

92. Arrow-points (six) of chert, with notched base. From Sherwood, Tennessee. Presented by N. H. Winchell.

93. Stone implements (five), with broad, notched base. From Sherwood, Tennessee. Presented by N. H. Winchell.

94. Implements (five) of chert, rudely chipped. From Sherwood, Tennessee. Presented by N. H. Winchell.

95. Chert clippings (twenty-three.) From Sherwood, Tennessee. Presented by N. H. Winchell.

96. Stone arrow-points (forty), notched at the base. From Waterloo, Alabama. Presented, Oct., 1882. by C. L. Herrick.

97. Stone arrow points (five), triangular, notched at base. From Waterloo, Ala. Presented, Oct., 1882, by C. L. Herrick.

98. Stone arrow-points (nineteen), unnotched. From Waterloo, Ala. Prerented by C. L. Herrick.

99. Large arrow-point, of concretionary chert. From Waterloo, Ala. Presented by C. L. Herrick.

100. Unsymmetrical stone arrow-points (six). From Waterloo, Ala. Presented by C. L. Herrick.

101. Stone lance-heads (nineteen). From Waterloo, Ala. Presented by C. L. Herrick.

102. Fragmentary stone arrows and lance-points (seventy-seven). From Waterloo, Ala. Presented Oct., 1882, by C. L. Herrick.

103. Stone hatchets and fragments (fifteen). From Waterloo, Ala. Presented by C. L. Herrick.

104. Elongated implements of stone (twenty). From Waterloo, Ala. Presented by C. L. Herrick.

105. Implement of red chert. From Waterloo, Ala. Presented by C. L. Herrick.

106. Stock from which stone implements were made (twenty-eight pieces). From Waterloo, Ala. Presented, Oct., 1882, by C. L. Herrick.

107. Stone chippings (eighty-five). From Waterloo, Ala. Presented by C. L. Herrick.

108. Implement of dark, reddish-brown quartzyte. From Decatur, Alabama. Presented, Oct., 1882, by C. L. Herrick.

109. Implement (hide-dresser) of trappean rock. From Decatur, Ala. Presented by C. L. Herrick.

110. Fragments (eighty-one) of Indian pottery. From Eastport, Mississippi. Presented by C. L. Herrick.

111. Shells (thirty-two gasteropods and three lamellibranchs) from shell-bed (pre-historic kitchen-midden?) in bank of the Tennesse river, Waterloo, Alabama. Presented, Oct., 1882, by C. L. Herrick.

APPENDIX.

MINNESOTA LAWS RELATING TO MINES AND MINING.

ABSTRACTED BY C. L. HERRICK.

GENERAL LAWS.

GENERAL LAWS, 1858, p. 250. This is a general act to regulate corporations for manufacturing, mining, agricultural, mechanical and chemical purposes, defining the methods of association, the capital stock, the rights of stock-holders and their joint and individual liabilities for the debts and obligations of the corporation.

GENERAL LAWS, 1860, p. 173. *An act to authorize the formation of corporations for mining, smelting, or manufacturing iron, copper, silver or other ores or minerals.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. All corporations organized under the provisions of this act, shall be capable of suing and being sued in any court of this state, and may have a common seal, and alter the same at pleasure, may elect or appoint in such manner as they shall determine, all necessary officers and agents, and may fix their compensation and determine their duties and make from time to time, such by-laws not inconsistent with the constitution and laws of this state, as a majority of the stock-holders shall direct.

SEC 2. Any number of persons not less than three, who shall, by articles of agreement in writing, associate according to the provisions of this act, under any name assumed by them, for the purpose of engaging in and carrying on mining, smelting or manufacturing iron, copper, silver or other minerals, and who shall comply with the provisions of this act, shall with their successors and assigns constitute a body politic and corporate in fact and name, under the name assumed by them in their articles of association.

Provided. No company shall take a name previously assumed by any other company.

SEC. 3. Before any company formed under this act shall commence business, the president and directors shall cause their articles of association to be filed with the secretary of state of this state, and also a copy thereof with the register of deeds of the county in which its principal business is to be conducted; where said articles shall be recorded at length in books prepared for that purpose.

SEC. 4. The articles of every such association shall be signed by the persons associating in the first instance, and acknowledged before some persons authorized by law to take the acknowledgement of deeds, and shall state

First. The distinct purpose for which the association is formed.

Second. The amount of their capital stock and the number of shares.

Third. The amount of capital stock actually paid in.

Fourth. The place in the state where their office for the transaction of business is to be held, and the county or counties in which their business is to be carried on.

Sixth. The term of its existence, not to exceed thirty years.

SEC. 5. The amount of capital stock in every such corporation shall, in no case be less than ten thousand (10,000) dollars nor more than five hundred (500,000) dollars, and shall be divided into shares of fifty dollars each; but the capital stock and number of shares may be increased at any regular meeting of the stockholders.

Provided. The amount of capital when so increased shall not exceed the sum of five hundred thousand (500,000) dollars.

SEC. 6. The purposes for which such corporations shall be established, shall be distinctly and definitely specified in the articles of association; and it shall not be lawful for said company to appropriate its funds for any other purpose.

SEC. 7. Any two of the signers of such articles of association may call the first meeting of the corporators for the purpose of organizing the company, at such time and place as they may appoint, by giving personal notice to each corporator, or by publishing the same in some newspaper at least fifteen days before the time appointed for such meeting.

SEC. 8. The stock, property and business of such corporation shall be managed by not less than three nor more than seven directors, as the articles may determine, one of whom shall be a resident of the state; they shall hold their offices for one year, and until their successors shall be duly chosen. The time and place of the meeting of stockholders for the election of directors and other purposes, shall be fixed by the by-laws, and at all such meetings each share of stock shall be entitled to one vote.

SEC. 9. The directors of every such corporation shall choose one of their number president, and shall appoint such other officers and agents as the articles of association or by-laws may require, who shall hold their offices for one year, or until a majority of the stockholders choose others in their stead. The majority of directors for the time being, shall have power to fill any vacancy which may happen in their board by death, resignation, or otherwise, until the next regular meeting of the stockholders.

SEC. 10. The directors may call in the subscription to the capital stock of such corporation by installments in such portion and at such times and places as they shall think proper, by giving notice thereof as the by-laws shall pre-

scribe, and in case any stockholder shall neglect or refuse payment of any such installment for the space of sixty days after the same shall have become due and payable, and after he shall have been notified thereof, the stock of said delinquent stockholder may be sold by the directors at public auction, at the office of the secretary of such corporation, giving at least thirty days notice in some newspaper in the county in which said office is located.

Provided. That if said stockholder is a resident of this state, the stock shall be sold at the business office of said corporation in the county in which its business is conducted, giving at least thirty-days notice thereof in some newspaper printed in the county and if no newspaper is published in said county, then it shall be published in some newspaper at the capital of the state, and the proceeds of such sale shall be first applied in payment of the installment called for, and the expense of the sale, and the residue shall be refunded to the person entitled to the same, and such sale shall entitle the purchaser to all the rights of a stockholder to the extent of the shares so bought.

SEC. 11. A majority of the directors of any such corporation for the time being, convened according to the by-laws, shall constitute a quorum for the transaction of business; and those holding a majority of the stock at any meeting of the stockholders shall be capable of transacting the business of the meeting, and at all such meetings stockholders may vote in person or by proxy duly filed.

SEC. 12. If it shall so happen than an election of directors shall not take place at the annual meeting, such corporation shall not in consequence thereof be dissolved; but an election may be held at any time thereafter by giving thirty days notice thereof in the manner provided in the by-laws of the company.

SEC. 13. Every such incorporation shall have power to acquire, hold, and transfer all such real and personnl estate as the directors shall adjudge necessary or convenient for the purpose of conducting, carrying on, or disposing of the business of such corporation.

Provided. That its real estate held at any one time shall not exceed three thousand acres.

SEC. 14. The stock of any such corporation shall be deemed personal property, and shall be transferable only on the books of such company in such form as the directors shall prescribe, and such corporation shall at all times have a lien upon the stock or property of its members invested therein for all debts due from them to such corporation, which may be enforced by advertisement and sale in the manner provided for selling delinquent stock.

Provided. That assessors and all other officers, whose duty it may be to assess property for purposes of taxation, may take into consideration the productiveness or unproductiveness of the mine, stock and improvements thereto belonging, and value the same accordingly.

SEC. 15. The directors shall cause a record to be kept of all stock subscribed and transferred, and of all business transactions, and their books and records shall at all times be open to the inspection of any and every stockholder; they shall also when required present to the stockholders reports in writing of the situation and amount of business of the company, and declare and make such dividends of the profits from the business of the company, not reducing the capital stock, while they have outstanding liabilities.

SEC. 16. The directors of any company organized under this act, shall have power to establish one or more offices without this state, and transact business thereat.

Provided, however. That an office shall always be maintained in this state where legal processes may be served on the person in charge thereof.

SEC. 17. Each stockholder in any company organized under this act, shall be liable for the debts of the company to the amount of stock held or owned by him therein.

SEC. 18. This act shall take effect from and after its passage.

Approved Feb. 24, 1860.

GENERAL LAWS, 1860. p. 258. *An act to amend an act entitled "An Act to regulate corporations for manufacturing, mining, agricultural, mechanical and chemical purposes," passed Aug. 12, 1858.* This amendment provides that any corporation created before the passage of the original act may by vote of its stockholders avail itself of its privileges.

GENERAL LAWS OF MINNESOTA, 1864, p. 111. *An Act to provide for a geological survey of the north shore of lake Superior, within the limits of this state, and other mineral and coal districts, and to appropriate money therefor.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. That there be and is hereby appropriated, out of any moneys in the treasury not otherwise appropriated, the sum of two thousand dollars, to be expended, or so much thereof as may be necessary, under the direction of the governor, in causing to be made a geological survey of the mineral lands on the north shore of lake Superior, within the limits of this state, and also all other mineral or coal districts of the state, and the governor is hereby authorized to appoint a suitable person or persons to make such survey, whose report of the same shall be made to the governor, and by him transmitted to the Legislature.

Approved March 4, 1864.

GENERAL LAWS OF 1865, p. 84. *An Act to continue the geological survey of the mineral lands of the north shore of lake Superior.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. That the governor be and is hereby authorized and empowered to appoint some suitable person to continue the geological survey of the mineral lands of the north shore of lake Superior, lying in the state of Minnesota, and also other mineral bearing districts within the limits of the state.

SEC. 2. Such person so appointed shall before entering upon his duties under the provisions of this act, take and subscribe an oath to diligently and faithfully discharge such duties to the best of his ability. And he shall proceed at as early a day as practicable to continue such survey under the direction

of the governor. He shall make analysis of metal-bearing rocks that may be obtained during such survey, to the end that the commercial value thereof may be ascertained, and he shall report the same to the governor on or before the first day of January A. D. eighteen hundred and sixty-nine. He shall also make and report sectional maps showing the location of minerals examined and analyzed and as far as in his power, report upon the extent of the coal fields on the waters of the Big Cottonwood river, and the extent of such other mineral deposits as he may find, and such report shall be transmitted by the governor to the Legislature.

SEC. 3. The governor shall have power to draw from the state treasury out of moneys not otherwise appropriated, a sufficient amount to pay the actual and necessary expenses incurred by such person so appointed under the provisions of this act, not to exceed the sum of one thousand dollars.

SEC. 4. This act shall take effect and be in force from and after its passage.

Approved March 7, 1865.

GENERAL LAWS 1865, p. 85. *An Act to enable N. C. D. Taylor to continue the geological exploration of the country in the valley of the St. Croix, within this state.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. That the sum of one thousand dollars be and the same is hereby appropriated and ordered to be set apart to N. C. D. Taylor out of any moneys in the treasury not otherwise appropriated, to enable him to continue the geological exploration of the country in the valley of the St. Croix, within this state, and that he report to the next Legislature the result of his labors.

SEC. 2. This act shall take effect and be in force from and after its passage.

Approved March 2, 1865.

GENERAL LAWS, 1866, p. 80. *An act to regulate mining upon the public lands of the United States, within the State of Minnesota.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. The miners and inhabitants of any section of this state in which there may be mines of gold, silver or other metals, upon the public lands of the United States for which patents have not been issued, may meet and form a mining district, not to exceed in extent five miles square, fix the boundaries, adopt a name, and pass such rules and regulations for such districts as may be deemed by them necessary for the location, holding, recording and working of mines or mining claims upon such public lands of the United States within such district. They may also elect a recorder for said district, and provide his qualifications, duties, fees and liabilities,

Provided. That no such mining claim shall exceed in extent two hundred feet square, and

Provided, further. That no such mining claim shall be made except by actual occupancy.

SEC. 2. On the trial of any action in any court of this state involving claim to or the possession of any such mine or mining claim, or involving any right growing out of any such mine or mining claim, the rules and regulations so adopted in said district, or authenticated copies thereof, may be given in evidence, and so far as applicable shall govern the case.

SEC. 3. The term "mines" and "mining claims" as used in the preceding sections, shall be construed to embrace all water rights, ditches, flumes, timber claimed, or other interest appurtenant, necessary or auxiliary to a mine or mining claim, or the working thereof.

SEC. 4. The majority of the miners of such mining district, attending at a meeting, upon reasonable notice, may at any time change, alter, amend or repeal any of such rules and regulations previously adopted.

SEC. 5. This act shall take effect and be in force from and after its passage.

Approved March 2, 1866.

GENERAL LAWS, 1866, p. 98. *An Act to continue the geological survey of the State of Minnesota, and to appropriate money therefor.*

Be it enacted by the legislature of the State of Minnesota.

SECTON 1. Henry H. Eames is hereby appointed state geologist for the term of one year, commencing January 1st., 1866. He shall be commissioned by the governor, and it shall be his duty to continue the geological survey of the state, and prepare a report of such survey, subject to the provisions of section 2, chapter 39, of the general laws of Minnesota for 1865.

SEC. 2. The following sums of money are hereby appropriated out of any money in the state treasury not otherwise appropriated, for the prosecution of the geological survey for the year 1866.

For salary of state geologist, two thousand dollars, to be drawn monthly on the last day of the month.

For expenses of survey in mining districts and experiments on ores, and all incidental expenses of work, shall not exceed three thousand dollars, to be drawn upon the satisfactory vouchers of the state geologist, and accounts of expenditure to be furnished by him to the state auditor.

SEC. 3. The state geologist shall have his office in the capitol building, and shall there arrange and keep a collection of specimens of all minerals and such other interesting materials, which he may find in his explorations of the state. Said office shall be open to the public.

SEC. 4. The state geologist shall devote his time, labor and exertions exclusively for the benefit of the state at large, and shall afford no advantage whatever to any private enterprise or speculation.

SEC. 5. This act shall take effect and be in force from and after its passage.

GENERAL LAWS OF MINNESOTA, 1867, p. 40. *To regulate mining upon the public lands of the United States within the State of Minnesota.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. That all mineral districts to be hereafter formed in this state shall conform to the township lines of six miles square.

SEC. 2. That all mineral claims shall be made in person by the party claiming, and any claim not thus made, is invalid.

SEC. 3. That when a mineral vein or lode or lead, containing gold, silver, cinnabar, or copper is discovered, the party making the discovery shall be entitled to two hundred feet on said vein or lode or lead as a discovery claim, with one hundred feet of land on either side of said vein, lode or lead, for its convenient working; and he shall also be entitled to an additional claim of two hundred feet on said vein, lode or lead, with one hundred feet of land on either side of said vein or lode or lead, for its convenient working, according to the act of congress, passed July 26, 1866.

SEC. 4. That to receive mineral claims the person making them shall measure off correctly, the number of feet allowed by law and shall post up a notice of said claim, of a substantial nature upon a stake or tree, at the end of every two hundred feet, upon which shall be written the name of the vein, with date of taking, name of claimant, number of claim and its general direction.

SEC. 5. That the claimant shall, within the three months from the time of posting up a notice of his claim, in compliance with the law, sink a shaft on said claim three feet deep by five feet square, and shall take from the bottom of the shaft so sunk, specimens of the rock, properly labelled, with the name of the vein, name of claim and name of claimant, thereon, number of claim, east or west, with a correct description of said claim, and file with the register of deeds of the county in which the mineral district is situated, and the register of deeds, after being satisfied that the said claimant has complied with the requirements of the law, and that he has not exceeded the two hundred feet, shall issue to said claimant and record the same, a certificate with description of claim, that said claim has been properly secured under the provisions of the law.

SEC. 6. That in case the claimant fails to sink a shaft three feet deep by five feet square, within the three months specified, then he shall forfeit all right to the claim, and any other party can come in and take possession.

SEC. 7. That whenever any citizen of the United States or those who have declared their intentions to become citizens, shall have complied with the provisions heretofore set forth, then they shall have rightful possessions of all claims made under and by virtue of this act for the space of one year from the date of the claim made, then all right and title to said claim shall be forfeited and another claimant may come in and take possession and secure a title under the law.

SEC. 8. That any person found tearing or mutilating any notice posted on any mineral claim in this state, shall be subject to arrest and imprisonment and on conviction, shall be fined not less than $50 nor more than $500.

SEC. 9. That the term "mineral claim," as used in the preceding sections, shall embrace all water rights, ditches, flumes, timber claimed, or other interest appurtenant, necessary or auxiliary to a mine or mining claim or the working thereon.

SEC. 10. That the fees of the register of deeds shall be as follows: Recording claim $1.00; transfer of claim 25 cents for each folio of one hundred words, and 25 cents for each certificate.

SEC. 11. That it shall be necessary to place in the hands of the register of deeds a description of each claim for record, within thirty days from the date of taking.

SEC. 12. That in case any mineral district in this state is located in an unorganized county, the claim shall be recorded in the organized county to which such unorganized county has been attached for judicial purposes, and the register of deeds of said organized county, shall perform the duties and receive the fees as provided by law.

SEC. 13. That it shall be the duty of all registers of deeds in counties where mineral claims are filed, to make a report every three months to the secretary of state of the number of claims taken, number of shafts sunk, and the general condition of the mines.

SEC. 14. This act shall take effect and be in force from and after its passage.

Approved March 6, 1867.

GENERAL LAWS, 1872, p. 86. *An Act to provide for a geological and natural history survey of the state and entrust the same to the University of Minnesota.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. It shall be the duty of the board of regents of the University of Minnesota to cause to be begun as soon as may be practicable, and to carry on a thorough geological and natural history survey of the state.

SEC. 2. The geological survey shall be carried on with a view to a complete account of the mineral kingdom as represented in the state, including the number, order, dip, and magnitude of the geological strata, their richness in ores, coals, clays, peats, salines and mineral waters, marls, cements, building stones and other useful materials, the value of said substances for economical purposes and their accessibility; also an accurate chemical analysis of the various rocks, soils, ores, clays, peats, marls and other mineral substances, of which complete and exact record shall be made.

SEC. 3. The natural history survey shall include, first, an examination of the vegetable productions of the state, embracing all trees, shrubs, herbs and grasses, native or naturalized in the state; second, a complete and scientific account of the animal kingdom as properly represented in the state, including all mammalia, fishes, reptiles, birds and insects.

SEC. 4. The said surveys and examinations shall be made in the manner and order following: first, the geological survey proper, together with the necessary and implied mineralogical investigations, all of which shall be undertaken so soon as may be practicable, and be carried forward with such expedition as may be consistent with economy and thoroughness; second, the botanical examinations; third, zoological investigations; *provided*, however, that whenever said board of regents may find it economical to prosecute different portions of the surveys in conjunction, or that the public interest demands it,

they may, in their discretion, depart from the above prescribed order. And in the employment of assistants in the said surveys the said board of regents shall at all times give the preference to the students and graduates of the University of Minnesota, *provided* the same be well qualified for the duties.

SEC. 5. The said board of regents shall also cause to be collected and tabulated such meterological statistics as may be needed to account for the varieties of climate in the different parts of the state, also to cause to be ascertained [by] barometrical observations or other appropriate means the relative elevations and depressions of the different parts of the state; and also on or before the completion of the said surveys, to cause to be compiled from such actual surveys and measurements as may be necessary, an accurate map of the state, which map when approved by the governor, shall be the official map of the state.

SEC. 6. It shall be the duty of the said board of regents to cause proper specimens, skillfully prepared, secured and labelled, of all rocks, soils, ores, coals, fossils, cements, building stones, plants, woods, skins and skeletons of animals, birds, insects and fishes, and other mineral, vegetable and animal substances and organisms discovered or examined in the course of said surveys, to be preserved for public inspection free of cost, in the University of Minnesota, in rooms convenient of access, and properly warmed and lighted, ventilated and furnished, and in charge of a proper scientific curator; and they shall also, whenever the same may be practicable, cause duplicates in reasonable numbers and quantities of the above named specimens, to be collected and preserved for the purpose of exchanges with other state universities and scientific institutions, of which the Smithsonian Institute at Washington shall have the preference.

SEC. 7. The said board of regents shall cause a geological map of the state to be made, as soon as may be practicable, upon which, by colors, and other appropriate means and devices, the various geological formations shall be represented.

SEC. 8. It shall be the duty of the said board of regents, through their president to make, on or before the second Tuesday of December in each and every year, a report showing the progress of the said surveys, accompanied by such maps, drawings, and specifications as may be necessary and proper to exemplify the same to the governor, who shall lay the same before the legislature; and the said board of regents upon the completion of any separate portion of the said surveys shall cause to be prepared a memoir or final report, which shall embody in a convenient manner all useful and important information accumulated in the course of the investigation of the peculiar department or portion, which report or memoir shall likewise be communicated through the governor to the legislature.

SEC. 9. To carry out the provisions of this act the sum of one thousand dollars per annum is hereby appropriated to be drawn and expended by the [said] board of regents of the University of Minnesota.

SEC. 10. This act shall take effect and be in force from and after its passage.

Approved March 1, 1872.

GENERAL LAWS, 1873, p. 255. *An Act to aid the geological and natural history survey of the state and to amend chapter thirty-three of the general laws, approved March first eighteen hundred and seventy-two, authorizing such survey.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. The state lands known as "state salt lands," donated by the general government to aid in the development of the brines of the State of Minnesota, shall be transferred to the custody and control of the board of regents of the University of Minnesota. By said board of regents these lands may be sold in such manner, or in such amounts as they may see fit, the proceeds thereof being held in trust by them, and only disbursed in accordance with the law ordering a geological and natural history survey of the state.

SEC. 2. It shall be the duty of said board of regents, as soon as practicable, to cause a full and scientific investigation and report of the salt springs of the state, with a view to the early development of such brine deposits as may exist within the state.

SEC. 3. The board of regents of the University of Minnesota, shall cause the immediate survey and investigation of the peat deposits of the state of Minnesota, accompanied by such tests and chemical examinations as may be necessary to show their economical value, and their usefulness for the purpose of common fuel, a full report thereon to be presented to the legislature as soon as practicable.

SEC. 4. A sum of two thousand dollars is hereby appropriated annually (in lieu of one thousand dollars) for the purposes of the geological and natural history survey, until such time as the proceeds of the sales of the salt lands shall equal that amount, when such annual appropriation shall cease.

SEC. 5. The sum of five hundred dollars is hereby appropriated for the purchase of apparatus and chemicals for the use of the geological and natural history survey, the same to be expended by order of the board of regents of the University of Minnesota.

SEC. 6. It shall be the duty of the board of regents of the University of Minnesota, to cause duplicate geological specimens to be collected and to furnish to each of the three normal schools, suites of such specimens, after the University collection has become complete.

SEC. 7. When the geological and natural history survey of the state shall have been completed, the final report on the same by the said board of regents shall give a full statement of the sales of salt lands hereby given into the custody and control of the board of regents of the University of Minnesota, together with the amount of money, received therefrom, and of the balances, if any left in the hands of the said board of regents.

SEC. 8. This act shall take effect and be in force from and after its passage.

Approved March 10, 1873.

GENERAL LAWS, 1876, p. 44-46. *An act to authorize the formation of corporations for mining and smelting ores, and for manufacturing iron, copper and other metals.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. Any number of persons not less than three, desiring to form a corporation for the purpose of mining or smelting ores or minerals, or for both purposes, or for the purpose of manufacturing iron, steel, copper, or other metals, may do so upon complying with the provisions of this act; and any corporation so formed shall be entitled to the rights and privileges and be subject to the duties and obligations herein prescribed and shall have perpetual succession.

SEC. 2. Such persons shall sign and severally acknowledge articles of incorporation, which shall declare that they do thereby associate together and agree upon said articles, for the purpose of forming a corporation under the provisions of this act; and which said articles shall also contain.

First. The name of the corporation, which shall not be the same as that previously assumed by any other corporation in this state.

Second. The general nature of the business to be carried on, and the place of the principal office or headquarters of the company.

Third. The names and places of residence of the persons so associating to form such corporation.

Fourth. The amount of the capital stock of said corporation.

SEC. 3. Such articles shall be executed in duplicate, one of which shall be deposited for record in the office of the register of deeds of the county where said company shall establish its principal office, and the other with the secretary of state; and upon being so deposited, said corporation shall be deemed to exist under this act for the purposes specified in said articles, as a manufacturing and mechanical corporation, under the constitution and laws of this state, and may sue and be sued in the corporate name, and in such corporate name may contract and be contracted with, and transact and carry on the business mentioned in said articles, and may purchase, acquire, hold, use, sell transfer, convey, rent and lease all such real and personal property and effects as may be necessary or convenient for the purposes of said corporation. A certified copy of said articles from the said register of deeds, or from the secretary of state, shall be evidence in all courts of such corporation.

SEC. 4. The amount of capital stock of any such corporation shall in no case be less than ten thousand dollars, nor more than two million five hundred thousand dollars, and shall be divided into shares of twenty-five dollars each, and each share shall be entitled to one vote at any meeting of the stockholders, and may be represented by the holder thereof in person, or by his proxy, under written appointment. The capital stock may be increased by a majority vote of the stockholders at any regular meeting thereof, but not so as to exceed said maximum amount.

SEC. 5. Such corporation may prescribe and adopt by-laws for the management of its business and affairs, by a board of directors, trustees, committee or other officers or agents, and provide for their election or appointment, and prescribe their duties, and may require bond from any officer for the faithful dis-

charge of duties, and may by such by-laws prescribe in respect to all matters appertaining to the business and affairs of said corporation, not inconsistent with the provisions of this act, nor the constitution or laws of this state. Such by-laws may be made, altered or amended by the directors, trustees or committee clothed with the general management of the affairs of such corporation, but the stockholders, at any regular meeting, may repeal or alter any by-laws, or adopt new ones, and such action shall remain binding until repealed or changed by the stockholders themselves at some regular meeting. Such corporation shall keep a record of all proceedings had at meetings of stockholders, and also of all proceedings had or taken by the board of directors, trustees, or committee having charge of its affairs, and such record shall be subject to the inspection of all stockholders at all reasonable times. A copy of all by-laws, duly certified, and all amendments and alterations of the same, shall be filed for record with the register of deeds where said articles of incorporation are recorded, and also with the secretary of state, and shall not become operative or valid until so filed. Until otherwise provided, the persons executing such articles of incorporation shall constitute a board of directors, with full power and authority to make by-laws and manage the affairs and business of such corporation.

SEC. 6. The stock of any such corporation shall be deemed personal property and may be issued, sold and transferred as may be prescribed by resolution or by by-laws of said corporation or its managing board, but no stock so issued or sold, purporting to be full paid, shall be subject to any further assessment in the hands of the lawful holder thereof, without his consent. Upon the issuance of stocks the lawful holders thereof shall constitute the members of such corporation, and a majority in amount thereof may call a meeting of the stockholders at any time, irrespective of any by-laws, at the principal office of the company, or at the capital of the state, upon giving thirty days notice by publication in a newspaper published at the place of such office, if there be such paper, and if not, then a paper published at the capital.

SEC. 7. The directors or managing officers of any such corporation may meet and transact business without this state, as may also the stockholders, by by-laws therefor; and offices may be established without this state. *Provided*, that an office shall always be maintained in this state, where legal processes may be served on such corporation, and such service upon an officer or director, if personally made, shall be deemed personal service upon the corporation.

SEC. 8. Any corporation organized under this act for the purpose of mining ore which has to be smelted or otherwise treated to extract the metal, may take, acquire, and hold stock in another corporation organized for the purpose of smelting or otherwise extracting the ore, if a majority of the stock holders shall so elect.

SEC. 9. Such corporation may mortgage its property, or any part thereof, by a vote of a majority of its stock, but not otherwise; and no real estate of any such corporation, or any interest therein, shall be sold, leased or conveyed, without the consent of a majority, in amount, of the stockholders.

SEC. 10. Any officer of any corporation organized under this act, or any other person or persons who shall fraudulently issue, or cause to be issued, any stock, scrip or evidence of debt of such corporation, or who shall sell, or offer for sale, hypothecate or otherwise dispose of any such stock, scrip or other evidence of

debt knowing the same to be so fraudulently issued shall be deemed guilty of felony, and on conviction thereof, shall be imprisoned in the state prison not more than ten nor less than one year.

SEC. 11. This act may be altered or amended at the pleasure of the legislature, but not so as to divest or impair any right of property acquired under the same.

SEC. 12. This act shall take effect and be in force from and after its passage.

Approved February 24, 1876.

GENERAL LAWS, 1881. *An Act to encourage mining in this state by providing a uniform rule for the taxing of mining property and products.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. That all corporations now organized or that may be hereafter organized under the laws of this state for the purpose of carrying on the business of mining, smelting or refining copper or iron ores, or for the purposes of mining coal within the state, may pay into the state treasury annually, on or before the first day of January in each year, in lieu of all taxes or assessments upon the capital stock, personal property, income and real estate of such corporation, in or upon which real estate such business of mining may be carried on, or which real estate is connected therewith and set apart for such business, the following amounts, that is to say: on and for each ton of copper fifty (50) cents; on and for each ton of iron ore mined and shipped or disposed of, one cent for each ton; and for each ton of coal mined the sum of one cent per ton; each ton to be estimated as containing two thousand two hundred and forty (2,240) pounds; one-half of such payments to be credited to the general fund of the state, and the other half credited to the county or counties in which such mines are located.

SEC. 2. That it shall be the duty of each and every corporation accepting the provisions of this act to make return in writing, and report to the state auditor on or before the fifteenth (15) day of December in each year, a true and full statement of each and every ton of copper or iron ore or coal mined and sold or disposed of during the year preceding the date of such return; which statement shall be verified by the oath of the president and secretary of such corporation. That any such officer who shall knowingly make or sign any false and untrue statement in such report or return, shall be deemed guilty of perjury and on conviction thereof shall be punished as provided in chapter twenty-seven (27) of of the general statutes of 1878.

SEC 3. That any corporation now organized under the laws of this state, or that may hereafter be organized therein for the purpose of mining, smelting or refining copper or iron ores, or for mining coal, may, by resolution duly adopted by its board of directors, accept all the provisions of this act, and that upon the filing of a certified copy of such resolution of acceptance in the office of the secretary of state for this state, such corporation shall be bound by the provisions of this act, and thereafter be entitled to all the benefits thereof.

SEC. 4. This act shall take effect and be in force from and after its passage.

Approved November 22, 1881.

SPECIAL LAWS.

(1849–75, INCLUSIVE.)

Mining Companies.

Great Western Mining Company of Pennsylvania, 1870, p. 444.
Boston and Minnesota, 1855, p. 111; 1866, p. 230.
Minnesota, 1856, p. 248; 1868, p. 409; 1869, p. 357.
North Shore, 1857, p. 212.
Pittsburg and Minnesota, 1855, p. 156; 1856, p. 107; 1864, p. 353.
Lake Superior and Puget Sound, 1871, p. 368.

Belle Plain Salt Company.

1870, pp. 424-421; 1871, p. 365; 1872, p. 428.

Minnesota Salt Company.

1856, p. 176; 1870, p. 421.

SPECIAL LAWS, 1855, p. 156. *An act to incorporate the Pittsburg and Minnesota Mining Company.*

SECTION 1. The corporators and their powers and liabilities under this charter.

SEC. 2. Limitation of the capital stock which is declared personal property.

SEC. 3. Rights and privileges to be enjoyed by the company and its power over lands.

SEC. 4. Stock to be deemed personal property, and transferable only on the books of the company.

SEC. 5. How and by whom the property of the corporation shall be controlled.

SEC. 6. Of the time and manner of electing directors.

SEC. 7. When this act shall take effect.

SEC. 8. The county of Carver declared organized, and the election of officers authorized until whose election the said county is attached to Hennepin county for judicial purposes.

SEC. 9. This act declared a public act.

SEC. 10. Power to modify and to amend reserved.

Approved March 3, 1855.

SPECIAL LAWS, 1855, p. 111. *An Act to incorporate the Boston and Minnesota Mining company.*

SECTION 1. Corporate name, the Boston & Minnesota Mining company—its seal, the manner of electing its officers and the establishment of by-laws.
SEC. 2. Capital stock and shares of the company.
SEC. 3. The rights and privileges to be enjoyed by the company.
SEC. 4. The stock of the company declared personal property.
SEC. 5. The affairs of the corporation to be managed and conducted by a board of not less than three nor more than seven directors, who shall decide the manner and proportions in which stock shall be paid in.
SEC. 6. Of the place and manner of electing directors.
SEC. 7. When this act shall take effect.
SEC. 8. This act declared a public act.
SEC. 9. The right to modify and amend reserved.
Approved March 3, 1855.

SPECIAL LAWS OF MINNESOTA, 1856, p. 176. *An Act to incorporate the Minnesota Salt Company.*

SECTION 1. Names of corporators and name and style of company.
SEC. 2. Rights and privileges of corporators.
SEC. 3. Stock not to exceed $500,000.
SEC. 4. Number and power of board of directors.
SEC. 5. In force on and after passage.
SEC. 6. Subject to legislative alteration.
Approved February 20, 1856.

SPECIAL LAWS, 1856. *An Act to revive, amend and continue an act entitled, "An Act to incorporate the Boston and Minnesota Mining Company," approved March 30, 1855, and to revive the corporation thereby created.*

SECTION 1. Revives act of Territorial Assembly relative to Boston Mining Company.
SEC. 2. Amends section one of said act, by naming certain parties to constitute the corporation.
SEC. 3. When act to take effect.
Approved March 3d, 1855.

SPECIAL LAWS, 1856, p. 248. *An Act to Incorporate the Minnesota Mining Company.*

SECTION 1. Names of corporators, created body corporate.
SEC. 2. Rights and privileges of corporation.
SEC. 3. Amount of capital stock.
SEC. 4. Affairs, by whom managed.

SEC. 5. By-laws to provide for election.
SEC. 6. Sum to be paid into the territorial treasury.
SEC. 7. To continue in force twenty years.

Approved Feb. 25, 1856.

SPECIAL LAWS, 1868, p. 409. *An act to amend chapter 149, of the Session Laws of 1856, entitled "An Act to Incorporate the Minnesota Mining Company.*

SECTION 1. Board of Incorporators, name and style of said company to be Minnesota Mining Company.
SEC. 2. To enjoy all rights and privileges incident to a mining corporation.
SEC. 3. Capital stock not to exceed one million dollars in one hundred dollar shares.
SEC. 4. Property to be managed by a board of directors elected annually.
SEC. 5. Date and place of elections, second Monday in March, in Minneapolis.

SEC. 7. President, etc., to be chosen by the board of directors and all certificates of stock or shares to be signed by president and countersigned by secretary under seal of the company.
SEC. 8. Act to be in force fifty years, but may be amended by the legislature after ten years.
SEC. II. Books for subscription to be opened in Minneapolis on the second Monday of March, 1868.
SEC. III. Act to be in force from and after its passage.

Approved March 5, 1868.

SPECIAL LAWS, 1868, p. 357. *An Act to amend Section one, of chapter one hundred and seventeen, of the Special Laws of the year 1868, relating to the Minnesota Mining Company.*

SEC. 1. Name changed to "Burnt Rock Mining Company" and vested with the usual obligations and privileges.

Approved March 3, 1869.

SPECIAL LAWS, 1870, p. 421. *An Act to aid the Belle Plaine Salt Company in the development of Salt Springs at Belle Plaine.*

SEC. 1. Grant of six sections of land to.
SEC. 2. Expenditure of the amount of $1600 entitles the company to one section of land till six such amounts have been expended.
SEC. 3. Such lands not to be sold by the company for less than $2.50 per acre; such rates to be reported to the governor. The company to be liable to the state for all money so procured not invested in carrying on business.

SEC. 4. A duty of one cent per bushel of manufactured salt, till an aggregate sum shall have been so paid equal to the value of such lands received at $2.50 per acre.

SEC. 5. The state reserves the right to impose any duty upon the product of salt springs, which may be discovered upon such lands granted.

SEC. 6. Any authorized officer may administer the necessary affidavits or oaths.

SEC. 7. To be in effect from and after its passage.

Approved Feb. 28, 1870.

SPECIAL LAWS, 1870, p. 424. *An act to amend the above act.*

SEC 1. Amends Sec. 5 of Chap. 114 special laws of 1870. All liabilities and obligations to the state which the said company shall be under or may assume, shall attach to assigns or representatives in case of sale or transfer.

Approved March 4, 1870.

SPECIAL LAWS, 1870, p. 444. *An Act authorizing the Great Western Mining Company of the State of Pennsylvania, to transact business in this state.*

SECTION 1. Said company authorized to purchase and hold real estate necessary to carry on the business of mining in this state.

SEC. 2. To appoint a resident agent in this state at Thompson City, upon whom service of process may be made.

SEC. 3. To be in force from and after its passage.

Approved March 1, 1870.

SPECIAL LAWS, 1871, p. 368. *An Act to further aid the Belle Plaine Salt Company in the development of salt springs at Belle Plaine.*

SECTION 1. Six additional sections of "salt lands" upon the same conditions as above, *provided* that the favorable opinion of some competent geologist, to be appointed by the governor, shall be secured.

SEC. 2. To be in force from and after its passage.

Approved March 6, 1871.

SPECIAL LAWS, 1871, p. 365. *An Act authorizing the Lake Superior and Puget Sound Company of the State of Maine to transact business in this State.*

Such powers are granted as are necessary for the purpose of carrying on its business.

An agent to be appointed at Crow Wing.

SPECIAL LAWS, 1882, p. 428. *An Act granting to the Belle Plaine salt company land in aid of the work of said compang.*

Be it enacted by the Legislature of the State of Minnesota.

SECTION 1. That six sections of the "salt lands" of the state are hereby granted to the Belle Plaine salt company, for the purpose of aiding the same in the continuance of its work, upon the terms and conditions hereinafter named.

SEC. 2. Whenever the said company shall have bored to the depth of two hundred feet below the bottom of the present bore or well, the said company shall be entitled to a conveyance of two sections of said land, and whenever said company shall have bored to the further depth of two hundred feet, or four hundred feet from the bottom of its present bore or well, the said company shall be entitled to a conveyance of two additional sections of said land, and whenever the said company shall have bored to the depth of five hundred feet from the bottom of the present bore, the said company shall be entitled to a conveyance of of the other two sections of said land. Upon proof satisfactory to the governor that said company has fulfilled the terms and conditions entitling the same to any installment of said lands, the governor shall certify that fact to the state auditor, and upon filing such certificate together with a certificate signed by the president and secretary of said company, that the lands described therein have been selected by the said company under the grant made by this act, in the office of the state auditor, he shall receive and record the same, and thereupon the title to the lands so selected shall vest in the said company, which shall thereby become and be the owner thereof in fee.

Provided, however. That in making the said selections of said lands the said company shall not be allowed to select the whole or any part of any section of land on which any of the salt springs selected by the state is located, or more than three sections selected and located by the state as applicable or appurtenant to any one spring.

SEC. 3. Should the said company get through the rock at less than five hundred feet below the bottom of the present well, and there find salt deposits of sufficient strength to be profitably worked, and should cease boring therefor, and that fact be proven to the satisfaction of the governor, the said company shall receive a pro rata proportion of the said lands—upon such proof the governor shall certify the fact to the state auditor, which certificate, with a certificate of the said company, filed and recorded in the office of the state auditor as aforesaid, shall vest the title of the lands so selected in said company as herein before provided.

SEC. 4. This act shall take effect and be in force from and after its passage.

Approved February 29, 1872.

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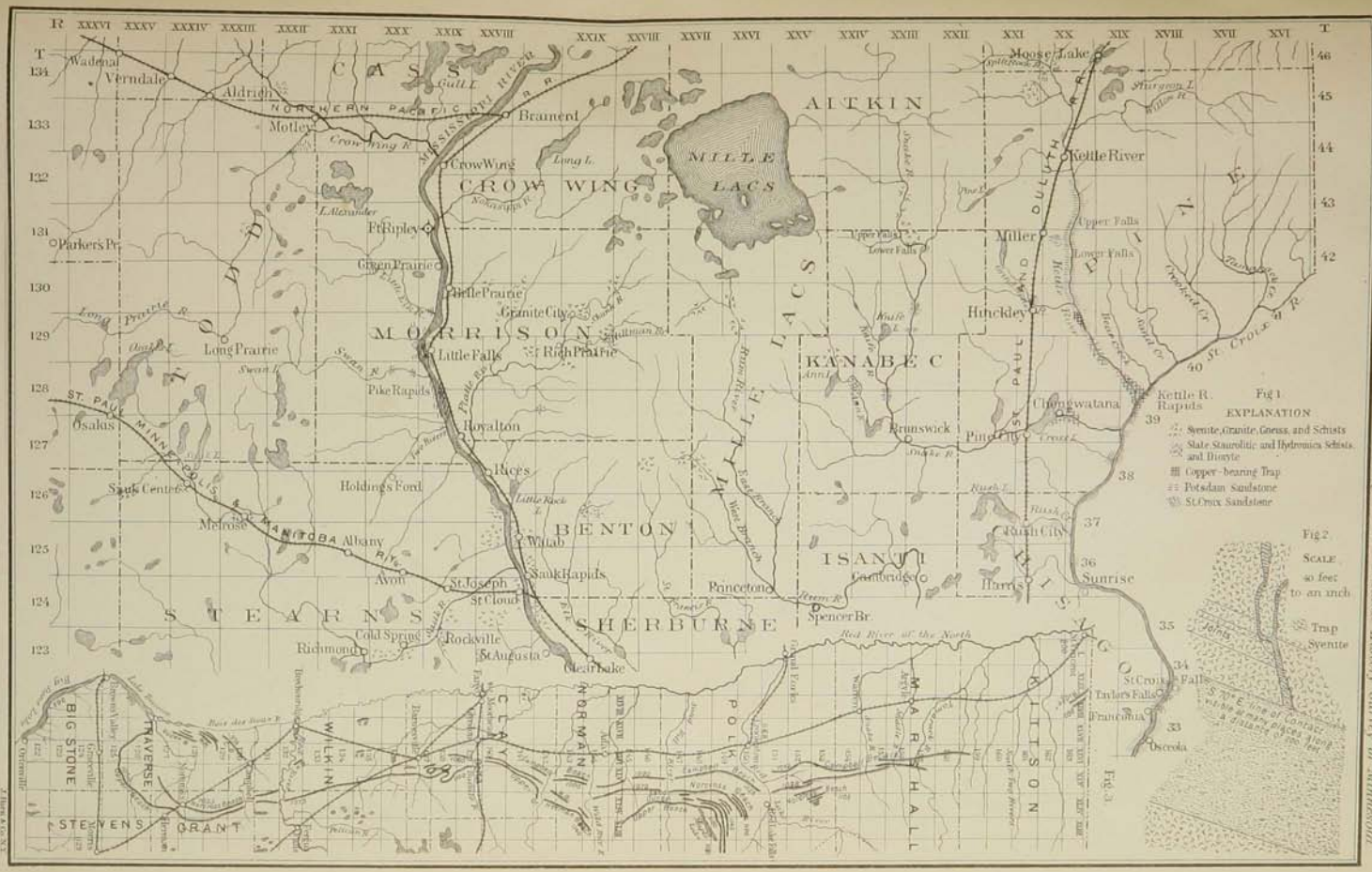
PLATE 1.

Fig. 1. Map showing rock-outcrops in central Minnesota.

Fig. 2. Dikes of trap in syenite, sec. 28, T. 134, R. 32 (see page 88).

Fig. 3. Beaches of lake Agassiz.

By Warren Upham.



Geological and Natural History Survey of Minnesota