No. 90A. Calcite.

From a vein which occurs in No. 90, but splits and runs in stringers in the face of the bluff. The fracture of No. 90 produced fragments which were subsequently surrounded by No. 90A. This calcite is granular and massive, or occasionally spongy.

Ref. Annual Report, ix, page 24.

One poor section. N. H. W.

No. 90B. Diabase. *(Coarse.)*

"Concretions from No. 90."

Ref. Annual Report, ix, page 24; Bulletin ii, pages 99, 100.

Meg. A coarse-grained rock consisting of lath-shaped, gray feldspars cutting a darker substance which is mostly pyroxene.

Mic. The section shows a coarse-grained rock composed essentially of feldspar and pyroxene, with alteration products. The pyroxene is later than the feldspar, the former sometimes occurring in large plates.

The *feldspar* is partly fresh, though most of it is more or less altered. It is commonly twinned according to the albite law. Some of the fresher grains showed equal extinction angles on either side of the twinning line, running up as high as 32°. No grains cut exactly perpendicular to a bisectrix were found, but the extinction angle would show that the feldspar is most probably *labradorite*. Many of the feldspars are clouded and sometimes almost opaque, being filled with small, gray, opaque specks. But the peculiar feature of the feldspar is its alteration to a certain mineral which occurs all through the section, and is developed in small flakes directly in the feldspar grains. This mineral has a low index of refraction, a rather high double refraction, is often arranged in radiating fibrous masses. One distinct cleavage, parallel to the length of the fibres and also to the elongation of the plates, is present and extinction is parallel to this cleavage. The elongation is sometimes positive and sometimes negative. This mineral possesses the characters of *thomsonite* and is here referred to that species.

The *pyroxene* is apparently *augite*, but it is undergoing alteration, which proceeds along the parting planes. The alteration products are *chlorite*, *hornblende* and a yellow substance composed of small flakes. Hornblende and chlorite, however, occur all through the rock independent of the augite areas. The hornblende is in small sheaths and tufts of fibres which are markedly pleochroic. Magnetite and apatite are quite common in the sections.

Three sections.

Age. Cabotian.

Remarks. This is the first rock here described that shows the feldspars altering to thomsonite. The authors know of several other occurrences of thomsonite in such diabase, viz.: Nos. 106, 200A, 627A, but perhaps none in which the origin of the

zeolite can be so directly referred to the alteration of the feldspar. Thomsonite is a frequent mineral filling amygdaloidal cavities, about Grand Marais, but rarely gathers in the cleavages of the feldspar from which it seems to be derived. Mr. A. H. Elftman, during 1895, while at work for this survey, found in the anorthosyte at Carlton peak and north of Beaver bay small masses of a mineral like thomsonite resulting from an alteration of the labradorite of the rock. This proved to be mesolite. (American Geologist, xxii, 30.) U. S. G.

No. 91. Diabase.

East side of Knife river, extending for a quarter of a mile, passing under the rock of the point, No. 90; with amygdules of white minerals. (Compare No. 641.)

Ref. Annual Report, ix, pages 24, 26.

Meg. Medium-grained, dark diabasic rock, considerably altered, having in its openings a saponite-like mineral in masses sometimes several inches across.

Mic. From the poor section at hand it can be observed that the rock is an ophitic diabase, the pyroxene in large crystals, but considerably clouded by granular opaque impurities. Whether it ever contained olivine it is impossible to discover from this section. Another section shows much glassy remnant.

One section.

Age. Cabotian. N. H. W.

No. 91A. Quartz.

From cavities in No. 91.

Ref. Annual Report, ix, page 25.

This quartz is milky or cloudy white, amorphous or irregularly granular, and contains masses of the next, both small and large.

No section. N. H. W.

No. 91B. Thalite *(with quartz, calcite, etc).*

From cavities in No. 91.

Ref. Annual Report, ix, page 25. American Geologist, vol. xxiii, page 41, January, 1899.

Meg. The larger masses, which are cream colored and amorphous or massive, are of composite nature, embracing not only thalite, but more or less of calcite, quartz and laumontite, outwardly resembling kaolin.

The mineral composing the smaller and softer nodules was probably included in what was named thalite by Owen.* It is apparently amorphous, but in thin section it is seen to be finely fibrous.

Mic. It has high double refraction, positive elongation, and parallel extinction, forming spherulitic and vermicular shapes, sometimes affording a constant black cross. It is not perfectly transparent, but has a dull translucency. In the centre of

* *Geological Report on Iowa, Wisconsin and Minnesota*, p. 600.

the amygdules is sometimes a little *calcite*. Its hardness is about that of talc, and it forms a jelly in HCl.

The vermicular forms are transversely fibrous. They recall those of the ripidolites (helminths) and of kaolinite. In proportion as they are curled up do they approach spheruliths. When the ends of the vermicular forms come together, the fibres diverge, in thin section as in a spherulith. They also diverge when the section happens to cut the convex surface, from one of the vermicular shapes. They are fairly illustrated by figure 1, page 390, of Lacroix's Minéralogie de la France et de ses colonies. The bisectrix n_g is parallel to the fibres. The images in convergent light vary. The optic angle (2 V) appears to be small.

Therefore it presents essential differences from the kaolins, the chlorites and from magnetite. Its bisictrix is n_g parallel to the fibres in place of being n_p perpendicular to a cleavage sharing in the zone of the filaments.

Specific gravity is 2.20.

Chemical analysis was made of this substance by Mr. L. B. Pease, with the following result:

SiO_2	42.38
Al_2O_3	7.37
Fe_2O_3	2.65
MgO	23.29
CaO	5.52
K_2O	0.19
Na_2O	0.36
H_2O	18.18*
Total,	99.94

Remarks. Owen's description may be summarized thus: A hydrated silicate of magnesia, combined with a new earth intermediate between magnesia and manganese: Sp. gr. 2.548; not found crystallized, composed as follows:

Water,	18.0
Silica,	42.0
Magnesia,	20.5
New earth, not taken up by sal ammoniac,	10.—12
Alumina,	4.6
Peroxide of iron,	1.5
Potash,	0.8
Manganese,	trace.

"Leaving out of account the supposed new earth, the chemical composition comes nearest to saponite and soapstone."

A similar green mineral was found by Dr. Shumard three miles above Kettle river, while Owen reports his thalite "from the vicinity of Baptism river."

By reason of the foregoing distinctions, this mineral seems worthy of specific independence. N. H. W.

*At 100° 10.38.

No. 91C. Scoria *(with prehnite)*.

From a vesicular mass in No. 91. This scoria is three feet in diameter, and forms the centre of a larger "concretion" at least six feet through.

Ref. Annual Report, ix, page 25.

Meg. The scoria itself is quite vesicular, and the framework has become rotted to a lilac-colored kaolin. The mass is held together by the growth of a hard zeolitic mineral resembling prehnite, which permeates the whole. This mineral fills the smaller vesicular cavities and lines the larger geodic spaces with a fine, roughened, botryoidal coating. Fractured surfaces show a glistening cleavage, and usually a coarse radiated crystallization which stands perpendicular to the cavity walls. The color is gray, and the hardness is about 6.

Mic. The double refraction of this mineral is high. The areas of each color are triangular, or sub-triangular, cornering together at the centre of the amygdules, thus constituting nearly circular spaces brilliantly colored and variegated. The elongation is negative, and the extinction is parallel, as those terms are used by Lacroix.* The bisectrix is n_z, and the angle 2 E is quite small, not exceeding 10°. In HCl it forms no jelly. These characters sufficiently prove the mineral to be *prehnite.*

One section.

Age. Cabotian. N. H. W.

No. 92. Laumontite.

Half way between Knife river and Agate bay. Laumontitic rock and amygdules, with calcite.

Ref. Annual Report, ix, pages 25, 26.

Meg. The laumontite is white, with a pinkish tinge, very friable, arranged radially. It fills very small amygdaloidal cavities, and constitutes masses several inches across.

Mic. It is made up of fine fibres which darken between crossed nicols at an angle with the elongation which varies from $3\frac{1}{2}°$ to 29°. The trial is made by placing some of the powdered mineral on the slide (the grains are more visible and more conveniently manipulated when mounted in balsam and covered with a thin glass) and measuring the angles between extinction and the straight elongated sides of the larger fibres. The smallest fibres have extinction nearest to parallelism with the elongation. The largest flat grains, which may be taken to be parallel with the easiest cleavage, have this extinction angle as large as 29°, varying from 23°. The largest plates, tested in convergent light, show the optic normal in the interference figure, which shows that the plane of the optic axes is in the plane of the easy cleavage. With hydrychloric acid a gelatinous silica is at once formed. These characters cannot coincide in any fibrous zeolite except in *laumontite*,† which is monoclinic.

Bulletin de la Société de Minéralogie de France, vol. viii, p. 322.

†A. Lacroix. Sur le diagnostique des zeolithes en l'absence de formes crystallines déterminables. *Bulletin de la Société de Minéralogie de France*, Tome viii, pp. 321-367, 1885.

Hence the large cleavage plates are parallel to the clinopinacoid. The acicular grains, which have a smaller extinction angle, are formed by the crossing of the two cleavages 110 and 010. Compare *Min. des Roches,* page 311.

The rock in which this zeolite is embraced is an ophitic diabase considerably decayed; evidently a continuation of No. 91.

Four preparations (two sections).

Remark. The number 92 is also applied to scoriaceous masses which are charged with calcite and quartzine, and have but little of laumontite, obtained at the same place. Layers of laumontitic and non-laumontitic rock follow each other in succession, making a zig-zag outline of the immediate coast, although its general direction is nearly straight. The firm, massive layers, forming the points of the coast, were the bottom portions of superficial flows of lava, and the vesicular layers, although not always occurring with regularity, are the more superficial portions of the same lava sheets. These alternations of hard lava-formed points and amygdaloid-lined bays continue three or four miles eastward from Knife river, in some places, where the bluffs rise thirty feet more or less above the water, several of the superimposed layers being visible at once. About Agate bay this series is again exposed.

N. H. W.

No. 93. Diabase *(with olivine).*

Point in sec. 10, T. 52–11 W. The bed, seven feet thick, forms the hight of the bluff, within a narrow bay, but overlies a bed of six feet of very laumontitic amygdaloid, which is also brecciated; under that (nine feet to the water) is a rock which has an outward resemblance to No. 91, but has less of thalite and more laumontite.

Ref. Annual Report, ix, page 26.

Meg. A very fine-grained dark, sometimes brownish rock, containing a few amygdules of chlorite, calcite and quartz.

Mic. The slide shows minute lath-shaped *feldspars* enclosed in plates of augite. Some *olivine*, much altered, is also present, and *magnetite* and *hematite.* The rock is a good example of a very fine-grained "lustre-mottled" diabase, but it is so fine grained that this lustre-mottling does not show megascopically.

One section.

Age. Cabotian. U. S. G.

No. 93A. Diabase *(with olivine).*

Underlying No. 93.

Ref. Annual Report, ix, page 26.

Meg. A brown, fine-grained rock, containing much of a yellow mineral (thalite).

Mic. Almost identical with No. 93.

One section.

Age. Cabotian. U. S. G.

No. 94. Diabase. *(Fine-grained.)*

Top of bluff, west side of Agate bay.
Ref. Annual Report, ix, page 26. Annual Report, x, page 37.

Meg. A very fine-grained rock, dark gray and brownish in color. Along small cracks, and sometimes where there are no cracks visible, the rock is colored a dark red.

Mic. Minute lath-shaped *feldspars* occur in connection with magnetite, hematite and augite, the latter sometimes in small plates embracing the feldspars, but usually in minute grains between the feldspars. This *augite* in grains is crystallized with a feldspathic base of very minute grains, and the augite and feldspar fill in the spaces between the lath-shaped feldspars.

One section.

Age. Cabotian. U. S. G.

No. 95. Diabase. *(Amygdaloidal.)*

West side of Agate bay; underlies No. 94.
Ref. Annual Report, ix, page 26. Annual Report, x, page 37.

Meg. A very fine-grained, brown rock, with abundant amygdules of pinkish laumontite. Some of the amygdaloidal cavities are lined with a yellow mineral, probably epidote.

Mic. Small lath-shaped *plagioclases* in a background of *augite*, *magnetite* and abundant *hematite*. The amygdules are filled with *laumontite*, and this mineral has often penetrated into the mass of the rock.

One section.

Age. Cabotian. U. S. G.

No. 96. Diabase *(with olivine)*.

One of the alternating beds at Agate bay. This layer underlies an amygdaloid, No. 95.
Ref. Annual Report, ix, page 26. Annual Report, x, page 37.

Meg. It is heavy, firm and dense; though with a few small amygdaloidal spots.

Mic. *Feldspars* appear as microlites, and frequently exhibit ophitic relation with the *augite*. *Magnetite* and *hematitic* coloration are in the usual amount. *Olivine* is also distinguishable. The rock is similar to many others already noted.

Two sections.

Age. Cabotian. N. H. W.

No. 97. Diabase. *(Amygdaloidal.)*

West side of Agate bay; underlies No. 96.
Ref. Annual Report, ix, page 26; Annual Report, x, page 37.

Meg. Almost exactly similar to No. 95, which see.

No section.

Age. Cabotian. U. S. G.

No. 98. Diabase. *(Amygdaloidal.)*

West side of Agate bay; underlies No. 97.
Ref. Annual Report, ix, pages 26, 27. Annual Report, x, page 37.

Meg. A dark greenish rock, very fine-grained, with a few rather large, black-green amygdules of chlorite. The same mineral occurs in cracks in the rock.

Mic. Minute lath-shaped *plagioclase* in a background of *augite* grains, among which is feldspathic material and some interstitial matter which has no or almost no effect on polarized light, and which probably represents original glassy material. The section shows a few small amygdules of radiating *chlorite*, and one foreign fragment which is composed of lath-shaped feldspars, much larger than those of the rest of the section, in a green mass of alteration products.

One section.

Age. Cabotian. U. S. G.

No. 99. Diabase. *(Amygdaloidal.)*

West side of Agate bay; underlies No. 98.
Ref. Annual Report, ix, page 27. Annual Report, x, page 37.

Meg. Almost exactly exactly identical with Nos. 95 and 97, which see.

No section.

Age. Cabotian. U. S. G.

No. 100. Diabase. *(Fine.)*

PLATE I, FIGURE 1.

West side of Agate bay; underlies No. 99.
Ref. Annual Report, ix, page 27. Annual Report, x, page 37.

Meg. A dark gray, very fine-grained, compact rock, having a few amygdules of chalcedony.

Mic. Small lath-shaped *feldspars* in a groundmass made up mostly of large *augite* plates, a fine example of lustre-mottling on a small scale. Between the augite plates is frequently a greenish to brownish material, almost opaque and containing abundant iron ore. In polarized light and under a high power, some of this material is seen to be minutely granular in structure. This feature is quite common in some of the fine-grained diabases of the Keweenawan of the south shore of lake Superior, and it is thought that this greenish to brownish material represents part of the magma that was imperfectly crystallized or was even glassy, now much altered. Compare especially plate ix, of Irving's "Copper-bearing Rocks."

One section.

Age. Cabotian.

Remark. This specimen well illustrates the lustre-mottling and the interstitial "glassy" material. U. S. G.

No. 101. Amygdaloid.

Overlying No. 100.
Ref. Annual Report, ix, page 27; Annual Report, x, page 37.

Meg. The cavities have been filled with laumontite and calcite. About one-fourth to one-third of the bulk of the rock is occupied by these minerals. The intervening rock matrix is also more or less porous, the cavities being generally empty.

No section.

Age. Cabotian. N. H. W.

No. 102. Diabase.

One of the alternating diabase sheets of the west bluff of Agate bay. Underlies No. 101.
Ref. Annual Report, ix, page 27; Annual Report, x, page 37.

Meg. This rock, outwardly, contrasts with No. 101 in its color, being dark greenish gray, while No. 101 is brown, the amygdaloidal spots being much lighter. It is medium grained, and probably olivinitic, but neither amygdaloidal nor porphyritic.

No section.

Age. Cabotian. N. H. W.

No. 103. Quartz, Veinstones, Agates, Calcite, Mesolite, Etc.

From the layers at Agate bay.
Ref. Annual Report, ix, page 27.

Meg. Quartz secretions are abundant in the form of agate, found as pebbles in the beach at Agate bay, but these must be derived from the drift clay, of which there is a heavy sheet, rather than from the rocks that immediately form the coast line. The quartz found in the trap sheets, as above enumerated, is rather in the veins and irregular openings in the rocks, and is not marked by those colored bandings to which the term agate is applicable. It is very probable, however, that these same layers, at points inland from the bay, carry quartz in the form of agate. This quartz is usually granular in appearance, except in the centre of geodes, where crystalline facets present a glistening surface. It is frequently associated with calcite, which forms independent masses distributed quite capriciously amongst the quartz, while in the geodes the last-formed mineral is sometimes in the condition of fragile fibres or spicules of laumontite, which also, in other places, was formed cotemporaneously with quartz.

In connection with some of the siliceous masses enclosed in this rock is a hard, white, finely and radiatedly fibrous mineral which is intimately mingled with the quartz.

Mic. This finely fibrous mineral pierces the *quartz* individuals in all directions, running through one and into the next with surprising freedom. The double refraction of the zeolite is very low, and it takes the colors of the quartz. In a rather

thick section it is almost impossible to determine its extinction, since it is governed in its color and its illumination by its host. When, however, the fibres make up the whole thickness of the slide the elongation is seen to be negative. Extinction is apparently about 5° from parallelism with elongation, which indicates, with other characters mentioned, that this zeolite is *mesolite* (Min. des Roches, pages 298, 314). The appearance of being sometimes positive and sometimes negative is not due to the intermingling of mesolite fibres which are positive, but this is a characteristic quality of mesolite, making it, in that respect, resemble thomsonite,* from which, however, it differs markedly in its low double refraction. After the formation of the zeolite the loose mesh was filled by infiltrating silica.

One section.

Age. Cabotian. N. H. W.

No. 104. Quartz-Laumontite. *(Scales.)*

From the layer of diabase which lies near the lake level below the buttresses of amygdaloid, at the great natural bridge at the east side of Burlington bay.

Ref. Annual Report, ix, page 27.

Meg. Compact, flesh-red, about a quarter of an inch thick, lining joints in the trap. Consists apparently of a dense intergrowth, in a granular manner, of laumontite and quartz. The scales examined consist of fragile, nearly white laumontite on one side, and of siliceous, red, granular, hard substance on the other, the two portions fading into each other.

No section.

Age. Cabotian. N. H. W.

No. 105. Diabase *(with olivine).*

Point on the coast, sec. 22, T. 53–10, just east of Silver creek.

Ref. Annual Report, ix, page 28; Annual Report, x, page 64.

Meg. Fine grained, brown, scarcely porphyritic.

Mic. *Feldspar* appears in two epochs of generation, the earlier crystals being quite rare, and having a central area charged with impurities. The smaller crystals, resulting from the final consolidation, have independent orientation amongst the *augite* crystals, the latter being almost always reddened by ferric oxide. *Olivine* forms remain, but they are converted to a greenish, almost isotropic, substance.

One section.

Age. Cabotian. N. H. W.

No. 106. Diabase *(with olivine, coarse).*

The rock of which Encampment island is composed. Compare Nos. 128 and 638. Carries masses of anorthosyte.

Ref. Annual Report, ix, page 28; Annual Report, x, page 64; Bulletin, ii, page 113.

* *Minéralogie de France*, vol. ii, p. 278.

Meg. A rather coarse, irregular and spotted rock of the diabase order. The spots are due apparently to segregations of quartz in the form of chalcedony, and perhaps to thalite disseminated through the mass of the rock. The rock is also spotted with darker areas, apparently due to aggregations of the pyroxene elements and to the formation of chlorite. The metalloidal reflections sometimes spread over adjoining parts of a large crystal which embraces the other minerals in a poikilitic manner.

Mic. It is similar in its essential characters to several other diabases already described. The *feldspar* is embraced by the pyroxene, and appears in twinned lath-shaped grains, clouded with chlorite and other inclusions, and twinned on the albite plan abundantly, and rarely on the Baveno plan. A grain cut parallel to the brachypinacoid, gives an axis of elasticity oblique to the plane of the section, the interference figure consisting of a curved black bar which crosses the field, with an extinction angle on the basal cleavage of 28°, indicating *labradorite* or *labradorite-bytownite.*

The *pyroxene* has sometimes a conspicuous close cleavage, but in general it presents the usual characters of *augite*, and is quite fresh. It has an ophitic relation to the feldspar crystals. The metalloidal reflections, apparently parallel to 010, do not appear in thin section.

Olivine is not abundant, and has been changed to *serpentine*, presenting a yellowish color in ordinary light, with a fibrous or felted structure.

Magnetite has apparently the angular form of some mineral which was posterior to the feldspars; perhaps the position of the remnants of the non-differentiated magma. Its partial change to leucoxene shows that it is titaniferous.

Thomsonite appears, both macroscopically and microscopically. It is white, finely felted and in formless secondary masses. The periphery of these geodic nests consists occasionally of a coarser radiation of the same mineral, although it might be taken, at a casual glance, for quartz. In some cases it is dirty green, but frequently differs from the central portions only in presenting a more coarsely fibrous radiation, which is not rigid and uniform, but somewhat fan-shaped. These fibres are both positive and negative, the two being in close contact. Of two spreading, fan-shaped bundles of fibre, one shows the blue of the positive crystal (on inserting the quartz teinte sensible) and the other the yellow or yellowish red. This is characteristic of thomsonite. In the same slide are smaller amounts of other zeolites, apparently *okenite* with positive elongation and *mesolite.*

Two sections.

Age. Cabotian; probably the Beaver Bay diabase. N. H. W.

No. 107. Diabase *(with olivine, coarse)*.

From the point opposite Encampment island. Compare No. 639.
Ref. Annual Report, ix, page 28; Bulletin ii, pages 112, 113.

Meg. A rock similar to No. 106, but without the metalloidal reflections, and in general better preserved; less spotted.

Mic. Essentially identical with No. 106. The only noteworthy difference is the greater amount of *magnetite*, which is disseminated in the feldspars of No. 107. In some cases these fine magnetite particles are arranged parallel with the twin lamellæ, and lie in a matrix of greenish substance which can be seen to be continuous with the *chlorite* elsewhere very common. This chlorite and the magnetite have accumulated, no doubt, simultaneously, and probably from the alteration of the remnants of the magma. This only illustrates again the frequent association of these two minerals as secondary results, and the migration of the iron element from one grain to another. This chloritic substance in the interstices of the feldspars can also be traced, sometimes continuously to the marginal parts of the feldspar, where it gradually assumes the aspect and polarization of *augite*, the magnetite powder being its constant attendant. In most cases no continuous connection can be seen between the chlorite-magnetite masses in the feldspar and the general chloritic decomposition, and some of the included masses may be older inclusions or impurities in the feldspar. They appear, however, to have the same origin as those chloritic strings which are interposed between the cleavages.

One section.

Age. Cabotian; probably the Beaver Bay diabase. N. H. W.

No. 108. Diabase *(with olivine)*.

PLATE I, FIGURE 2.

From the high bluff at the mouth of Gooseberry river.
Compare Nos. 517 and 518.
Ref. Annual Report, ix, page 28.

Meg. Medium grained, dark, with a mottled display of lighter and darker brown, showing small grains or films of *native copper*.

Mic. The section presents a fine illustration of the ophitic relation of the *augite* and *feldspar*, a phenomenon named "lustre-mottling" by Pumpelly. A single augite crystal is cut by numerous microlites of plagioclase which have various orientation. Throughout the area of this augite the opaque minerals are rare or wanting, while they are abundant in the remainder of the slide. Therefore, even in non-polarized light, the slide is spotted by light and dark portions, and when rotated between crossed nicols the augite shows its size and colors independently.

Olivine grains are small, and are apt to be entirely opaque or turned to a hematite red by ferric oxide, thus resembling *bowlingite*.

Two sections.

Age. Cabotian; probably the Beaver Bay diabase. N. H. W.

No. 109. Diabase (*with olivine*).

From the falls of Gooseberry river, S. W. ¼ sec. 22, T. 54–9.
Ref. Annual Report, ix, page 28.

This rock shows the same characters as No. 108, and is probably from the same layer. There are in the slide evidences of the existence of a portion of the magma still in a glassy state. Such areas are translucent and clear in ordinary light and dark between the nicols, but yet showing an incipient crystallization, which in some cases seems to allow light to pass as through included microlites.

Age. Cabotian; probably the Beaver Bay diabase. N. H. W.

No. 109A. Thalite, Calcite, Mesolite, Etc.

From No. 109. Falls of Gooseberry river.
Ref. Annual Report, ix, page 28.

Meg. Numerous cavities in No. 109 are filled with secondary minerals. These cavities are not always of the definite forms of amygdaloid, but are often large and irregular.

Mic. Among these secondary minerals are *thalite*, *calcite* and *mesolite*, the last having the same appearance of positive and negative fibres as rock No. 103.*

Age. Cabotian. N. H. W.

No. 110. Aporhyolyte.

From sec. 12, T. 54–9, east of Gooseberry river. Rises gradually from the level of the lake at the western end, with an apparent "dip" toward the west; rises in a bluff about forty feet high, and recedes with a dip in the other direction, after an extent of about forty rods.

Compare Nos. 119, 127, 520, 519, with which this rock is closely allied. Compare, also, Nos. 68 and 74, of which this rock seems to be the analogue if not the chronologic equivalent. No. 78, with which this rock was compared in the field notes, is probably not the same kind of a rock.

Ref. Annual Report, ix, pages 28–31, 38; Annual Report, x, page 38.

Mic. This rock contains some porphyritic *quartzes* and some porphyritic crystals of a *plaigoclase*. The former are sub-rounded and were evidently generated prior to the eruption which separated this rock from the parent magma. There is also much *quartz* of later date, which embraces the small crystals of the other minerals poikilitically.

The rock is wholly, but micro-crystalline, and approximates toward the "red rock" of the region. The existence of a plagioclastic feldspar in a porphyritic condition shows the magma was rather too basic to form a typical granite, but would come nearer an andesitic rock. The most of the feldspathic crystalline matter is too fine and too much stained with hematite to be susceptible of exact determination, but it is presumed to be of orthoclastic composition.

One section.

Age. Cabotian. Red Rock series. N. H. W.

*Voir *Minéralogie de France*, vol. ii, p. 278, where Lacroix says the allongement of mesolite is sometimes negative and sometimes positive without intermixture of natrolite.

No. 111A. Diabase. *(Fine.)*

West side of little bay in sec. 7, T. 54–8 W.; from a small island.
Ref. Annual Report, ix, page 29; Annual Report, x, page 39.

Meg. A very fine-grained, heavy, dark gray rock, whose component minerals cannot be distinguished megascopically. The rock contains a few small (not exceeding one-eighth of an inch in diameter) amygdaloid-like cavities now filled, or only lined, with minute quartz crystals.

Mic. This rock in structure and composition, except that it lacks the chloritic amygdules, is quite similar to No. 98.

One section.

Age. Cabotian.

Remark. Directly overlies rock No. 110, and probably belongs immediately above the rock of the bluff at the mouth of Gooseberry river. U. S. G.

No. 111B. Amygdaloid. *(Decayed.)*

West side of little bay in sec. 7, T. 54–8 W. From another small island.
Ref. Annual Report, ix, page 29; Annual Report, x, page 39.

Meg. The rock is yellowish green in color, is earthy and very much decayed, and contains green areas of chlorite (?) apparently filling amygdules. The rock appears to be a much decayed, basic amygdaloid.

No section.

Age. Cabotian. U. S. G.

No. 112. Diabase.

Splitrock point; holds masses of No. 113 (anorthosyte).
Ref. Annual Report, ix, pages 29, 30; Annual Report, x, pages 40, 139; American Association for the Advancement of Science, vol. xxx, page 162.

Meg. A dark gray, compact, very fine-grained diabasic rock.

Mic. The section is made up of long lath-shaped plagioclases, showing more or less flow structure by their arrangement. These plagioclases are imbedded in a groundmass composed of large plates of augite, greenish alteration material, and an opaque black substance, much of which is magnetite, but some of which may represent original glassy material.

No section.

Age. Cabotian; Beaver Bay diabase.

Remark. In the field description of this rock, No. 524 is referred to. No. 524 is a good example of an olivine diabase, and it is considerably coarser grained than No. 112. U. S. G.

No. 112A. Calcite and Stilbite.

From a vein in No. 112.
Ref. Annual Report, ix, pages 29, 30.

The specimen shows the full width of the vein, having a selvage of rock on each edge, and exhibiting a thickness (in the vein) of five and one-half inches. Of this thickness four and one-half inches consist of calcite, and about one-half inch of stilbite encloses the calcite on each side. The stilbite is orange yellow. Cleavage pieces give the interference figure of n_m, the axial plane lying in the plane (010) parallel with the easy cleavage.* N. H. W.

No. 113. Labradorite. (*Rock.*)

Embraced in the dark trap at Splitrock point.
Ref. Annual Report, ix, pages 29, 30; Annual Report, x, pages 40, 139; American Association for the Advancement of Science, vol. xxx, page 162.
Compare Nos. 115A, 123A, 128, 810, 814, 816, 818.

Meg. A massive, homogeneous, gray, coarsely crystalline rock, consisting wholly of one mineral, which is a striated feldspar. Specific gravity by Westphal balance, in methyl iodide, is 2.703.

Mic. A coarsely crystalline *plagioclase* showing much albite twinning and occasional dashes of pericline. Fresh, affording a fine preparation for the microscope, it is one of the most useful rocks of the state for the study of the plagioclases. In thick section it polarizes in brilliant tints, but in those that do not exceed 0.03 millimeters in thickness, it is in the gray colors of the first order of Newton's scale While the grains are sometimes much shattered by reason of pressure, yet in all directions it affords numerous large plages amongst which can be found those perpendicular to the bisectrices and to the optic axes.

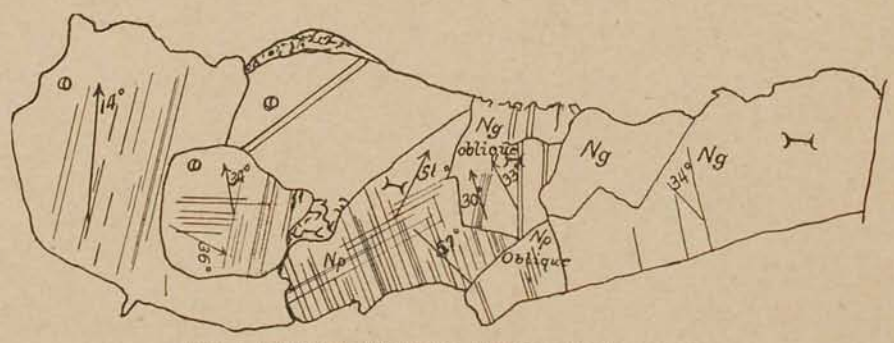


FIG. 6. THE FELDSPAR IN ANORTHOSYTE, NO. 113.

In the figure (No. 6) the symbol ⟩–⟨ indicates that the grain in which it occurs is cut perpendicular to a bisectrix; ⊙ signifies an oblique section; n_g and n_p signify sections perpendicular to the bisectrices of least and greatest elasticity respectively, *i. e.*, to the axes expressed by the German symbols c and a. The figures denote the angles of extinction on the grains on which they are written.

Fine dust-like impurities are seen to intercept the passage of non-polarized light. These are in the meshes of the broken grains, and also run in lines across the

*Bull. Société Minéralogie de France, vol. viii (1885), p. 345.

unbroken. These are principally chlorite flakes, magnetite powder, and occasionally hematite and perhaps of biotite.

In a section perpendicular to n_g the extinction is 33° to 34°, and on n_p is 57° to 61°; on a section $0\bar{1}0$ it is 20°, all of which agree well with M. Fouqué (Bull. Société Minéralogie de France, vol. xvii, page 428) for *labradorite*. The specific gravity, given above, is also a strong indication of *labradorite*. In a section perpendicular to an optic axis, extinction continues during a complete revolution. Foregoing (figure 6) is the appearance of a part of the thin section of No. 113, showing the outlines of the grains, their cleavage, and their optical character in convergent light. A test by the Boricky method gave microliths composed of lime and of soda.

Age. A transported block of Cabotian anorthosyte embraced in the Beaver Bay diabase.

Remark. The stratigraphic and chronologic relations of this rock to the associated rocks will be found discussed in the chapter on the structural geology; also, in vol. iv, pages 299–302. N. H. W.

No. 114. Diabase *(with olivine)*.

Splitrock river. Occurs under the anorthosyte (No. 113) and to the east of it.
Ref. Annual Report, ix, page 30; Bulletin ii, page 103.

Meg. An ordinary dark diabase, of medium grain, containing brownish blotches. The feldspar is whitish, especially where weathered.

Mic. The following is Dr. Wadsworth's description (Bulletin ii, page 103):

"The structure of the section is ophitic and it is composed of divergent *plagioclase* crystals cutting the irregular *augite* masses. The section also contains much *magnetite* and *olivine*, which is altered along its edges and fissures to a yellowish brown serpentine. The feldspars are clear, showing brilliant polarization, while the augite is pale brown and contains much disseminated magnetite dust. The magnetite has, in places, a rectangular and oblique grating structure."

One section.

Age. Cabotian. U. S. G.

No. 115. Diabase *(with olivine)*.

Splitrock point (Castle Danger). Massive dark rock, holding masses of feldspar rock (No. 113).
Ref. Annual Report, ix, page 30; Bulletin, ii, page 104.
Compare Nos. 116, 118, 524.

Meg. Medium grained, resembling the rock composing Encampment island, but less changed.

Mic. The *plagioclase* is twinned and embraced ophitically by the augite. It shows a green chloritic stain, which runs in the cleavage and fissures.

The *augite* has the usual two prismatic cleavages, and the parting of the orthopinacoidal face, which is characteristic of *diallage*. Some of it is decayed, giving rise to a chloritic substance and to *magnetite*.

Olivine is present in two grains of considerable size, one of which shows an optic axis and one bisectrix in the field, and the other a quick, dim, dark cross as an interference figure, which maneuvers like the figure of the optic normal. Hence the section is parallel to 001. Its fissures are filled with serpentinous (?) growths of a yellowish brown color. Cleavage not apparent, but irregular fissures. There is, however, an irregular, scant distribution of minute, elongated inclusions or impurities, parallel to which extinction takes place, thus revealing the orientation, and the cleavage parallel to 010. These grains, taken together, are tolerably fresh, and would furnish good sections on which to measure the double refraction.

One section examined.

Age. Cabotian. Beaver Bay diabase. N. H. W.

No. 115A. A Mass of Anorthosyte Rock.

Embraced in No. 115 at Splitrock point.
Ref. Annual Report, ix, page 30; Bulletin, ii, page 104.

Meg. A mass of granular, well preserved plagioclase feldspar, with a very little of the ferro-magnesian silicates.

Mic. Albite and pericline macles are common. There is also a banded extinction which crosses some of the larger grains which is neither albite nor pericline. These bands are not sharp, but fade into each other, and sometimes they experience a progressive shadow which runs over several in conjunction. These bands are also curved, as if resulting from a zonal growth in the crystal. Many of the grains are cut singularly perpendicular to an optic axis. The section being rather thick this indefiniteness in the outlines of the bands may be due to superposition, and their curvature to a distortion caused by the rock No. 115 during the period of transport as a foreign mass. The generally shattered condition of the feldspars points to the latter cause. Indeed, the curvature in one case is accompanied by a breaking, which shows it is attributable to some cause later than the formation of the bands.

Augite and *magnetite* are rare, the former in small grains that are very fresh, showing not a particle of secondary matter. There are also greenish chloritic masses that have been produced by an alteration of some mineral, perhaps from the broken feldspar.

One section examined.

Age. Cabotian. N. H. W.

No. 115B. Diabase.

Phase of No. 115, at the mouth of Splitrock river.
Ref. Annual Report, ix, page 30.

A finer-grained, vein-like belt runs through No. 115 and seems to be associated with very coarse plagioclases, as if derived from some of the Cabotian anorthosytes.

N. H. W.

No. 116. Diabase *(with olivine)*.

A point half way between Splitrock river and Two Harbor bay, having a conspicuous basaltiform structure. A heavy stratum.

Ref. Annual Report, ix, pages 30, 32; Annual Report, x, page 139; Proceedings of the American Association for the Advancement of Science, vol. xxx, page 162; Bulletin ii, page 113.

Meg. In the hand specimen this rock cannot be distinguished from No. 114.

Mic. The following is Dr. Wadsworth's description (Bulletin ii, page 113):

"The structure is ophitic and contains *plagioclase, augite, olivine, magnetite, biotite,* and much deep green *viridite.* The viridite and yellowish brown biotite occur in the feldspar, which is more altered than the augite. The olivines have mainly been changed to dark green or dark brown masses."

One section.

Age. Cabotian; Beaver Bay diabase. U. S. G.

No. 117. Diabase. *(Fine.)*

Point of Two Harbor bay; the *Two Harbor rock*, often so-called, in the field notes.

Ref. Annual Report, ix, pages 30, 31, 40; Annual Report, x, page 141; Annual Report, xiii, pages 100 (No. 154), 102.

Mac. Heavy, fine-grained, compact, brown or brownish-black, thinly-bedded rock. In some places coarsely crystalline and reddish, containing small quartz geodes and crystals, the last making it appear like a quartz-porphyry. These red parts sometimes cross the mass in the form of veins, but not as veins. They are welded on and graduate into the main mass as if due to some difference in the orientation or in the manner of crystallization as well as in the composition.

Mic. A thin section made from the brown and homogeneous portion, which really makes up, here, the largest part of this rock, exhibits a very fine-grained idiomorphic relation between the microliths of *feldspar* and the other minerals, showing the rock has cooled from fusion, whatever the origin of the materials. These microliths extinguish practically parallel to their length.

Augite, although in small grains, the mineral that envelops partially the feldspars, can be distinguished by its behavior in ordinary light and by its cleavage and color, as augite. *Hematite, magnetite, chlorite* and apparently a little *quartz* are associated in making up the rest of the rock.

A thin section from the red, quartz-bearing portion of this rock presents a different aspect. It is a quartz-porphyry, the quartz crystals being mostly angular, lying in the midst of finer crystals reddened by ferric oxide. Occasionally large crystals of orthoclase (?) much decayed and sometimes presenting a zonal structure, also appear in the finer matrix. The quartzes sometimes enclose small portions of the reddened matrix. This portion of this rock seems to belong to the "red-rock" series, so-called, which is an accompaniment of the anorthosyte series which is sup-

posed to be the same as the great gabbro range from Duluth to Pigeon point. The other portion, which still is hardly separable from this, is more basic and allied to the real traps of the region. It is, at any rate, very closely connected, structurally and stratigraphically, with the "red-rock" series, and for the present that is all that can be said of their origin.

Age. Cabotian (?); perhaps of the same origin and age as Nos. 632 and 635; one of the thin lava sheets cotemporary with crumbling conglomerates.

Remarks. The stratigraphic order of the main rock masses, as made out along this part of the coast, is given in Parts I and III. The exact nature of this rock could not be made out in the field. It was sometimes believed to be a metamorphic sedimentary rock, but it was finally left unsettled until more detailed examination could be made, with the following note:

"As to the Two Harbor rock, its character and origin are still to be determined by more minute examination of the samples collected, and by further field observations. It has been referred to as a metamorphic rock, in some of these notes, but it has also very much the aspect of a fine-grained igneous rock. It has the jointage as well as the general homogeneity of trap; the red bands crossing it and the geodic spots seen on its surface, perhaps having originated from the overlying sedimentary conglomerate. It does not have the appearance of being exactly the equivalent of the quartzless red rock at Duluth, but it must occupy very nearly the same stratigraphic position." (Tenth Annual Report, page 115.)

From a careful correlation of notes made on the stratigraphic order of the eruptives of this locality, published in the ninth and tenth annual reports, and a comparison of petrographic characters, this rock is placed below a series of alternating trap and amygdaloid sheets represented by the Gooseberry River series and probably by the Agate Bay series. (Compare No. 176.) There may be, however, a fault by which the Two Harbor rock has been lowered, its horizon being about the same as Nos. 632 and 635, *i. e.*, Manitou. N. H. W.

No. 118. Diabase *(with olivine)*.

Conical hill at the head of Two Harbor bay.
Ref. Annual Report, ix, page 31.

Meg. There are two hand specimens of this rock. The first is a medium grained diabase, presenting a somewhat earthy, decayed appearance, and there has been a slight reddening of the rock. The second is a fresh, lustre-mottled diabase, and was evidently picked up on the lake shore. The weathered surface shows indistinctly large gray areas between which are narrow bands of a darker greenish yellow color. There are a few small areas which appear like diabase of coarser grain than the mass of the rock.

Meg. The section from the first hand specimen shows a diabase of medium grain with the *plagioclase* and *augite* usually much altered. No lustre-mottling is visible, but the rock is too much changed to show the remains of this structure. The section from the second specimen shows large plates of augite holding the plagioclase laths and small grains of *olivine*. The rock is quite fresh and forms an excellent example of the lustre-mottled olivine diabases. The olivine and magnetite are grouped in indistinct areas or lines, leaving the central part of many of the augite plates practically free of these minerals, thus causing the mottled appearance of the hand sample.

Two sections.

Age. Cabotian. Beaver Bay diabase. U. S. G.

No. 119. GRANITE.

High point, evidently near the centre of sec. 33, T. 55–8 W. Compare Nos. 127, 520, 519, 526.
Ref. Annual Report, ix, page 31; Annual Report, x, page 40.

Meg. A medium grained granite, composed of quartz and pink feldspar.

Mic. The section shows *quartz* and feldspar (probably *orthoclase*) in a granular aggregate, although the feldspar at times has a tendency to an idiomorphic development. The two minerals are frequently intergrown in small areas of *micropegmatite*. The feldspar is highly altered and cloudy, and in places has no effect on polarized light. On account of its highly altered nature no attempt was made to determine its species, although it is most probably orthoclase. Some *magnetite* is present; also much disseminated *hematite*.

One section.

Age. Cabotian.

Remark. This is considered a phase of the "red rock" of the region. U. S. G.

No. 120. ANORTHOSYTE.

Beaver bay. Probably at west point of the bay. See No. 637.
Ref. Annual Report, ix, page 32; Final Report, vol. i, pages 196–199.

Meg. A coarse-grained aggregate of gray plagioclase. It is somewhat altered and reddened in places. No other mineral is present.

Mic. Similar to No. 113.

One section.

Age. Cabotian. Gabbro.

Remarks. For chemical analysis and description, see under No. 637, which represents the same rock as this number. U. S. G.

No. 121. DIABASE *(with olivine, coarse)*.

West side of second small bay above Beaver Bay entrance.
Ref. Annual Report, ix, page 32; Bulletin, ii, page 77.

Coarse augite crystals embrace tabular crystals of plagioclase, but rather in the form of a mosaic than in the ophitic manner, *i. e.*, the plagioclase is in so large

proportion, and in so large crystals, that the augite simply fills angular spaces between the feldspars. The rock also contains magnetite, a little chlorite, biotite and olivine.

Age. Cabotian; Beaver Bay diabase. N. H. W.

No. 122. Diabase (?) *(Granulitic gabbro?)*

PLATE I, FIGURE 4.

On the inside and east side of the second small bay above Beaver bay entrance. Columnar.
Ref. Annual Report, ix, page 32.

Meg. A fine-grained, granular, gray rock, compact and fresh. The minerals composing the rock cannot be made out macroscopically. The rock has a "sugary" appearance, reminding one of the rocks to which the term "muscovado" has been applied (see Twenty-first Annual Report, pages 143–152).

Mic. The rock is composed essentially of feldspar, pyroxene and magnetite.

The *feldspar* is by far the most abundant mineral. It occurs in grains and crystals varying from those which are nearly idiomorphic and lath-shaped to completely allotriomorphic individuals. Under a low power these lath-shaped feldspars appear quite prominent and are sharply defined, but under a high power their outlines are seen to be usually only partly idiomorphic and frequently allotriomorphic. The feldspars which do not approach the lath-shaped form are usually the larger in size, and not uncommonly these allotriomorphic individuals are of considerable size and embrace the pyroxene and magnetite, as well as the lath-shaped feldspars in part, in a poikilitic manner (plate I, figure 4). The feldspar is commonly abundantly twinned according to the albite law, but the larger grains are not usually as abundantly twinned as are the lath-shaped crystals, but no fixed distinction can be drawn between them. Equal extinction angles one either side of the composition face not uncommonly run up as high as 27° or 28°, but were not noticed higher than this. A section furnishing a positive bisectrix perpendicular, gave an extinction of 18° while another showing the negative bisectrix gave an angle of 62°. All of these results point to labradorite as the feldspar of the rock.

The *pyroxene*, which was earlier than the microlitic feldspars, is in small, more or less roundish grains, and is not idiomorphic. Cleavage is not well developed, but a fine parting is distinct, and the mineral can be referred to *diallage*. It often contains numerous magnetite inclusions and is altering to a greenish yellow fibrous mineral.

Magnetite is quite common in grains of about the same size as the diallages. *Apatite* is also common, both in minute short prisms and in slender needle-like forms. A little *biotite*, evidently secondary, is also present.

As to order of consolidation of the minerals: It is clear that the magnetite and diallage preceded the labradorite. This mineral, both the lath-shaped and the allotriomorphic individuals, includes the first two minerals. The lath-shaped labrador-

ites are earlier than the rest of the feldspar, although no sharp line can be drawn between them, and the completely allotriomorphic labradorites were the last to crystallize. In structure this rock differs from any already described in this work. In general it resembles the fine-grained granulitic dolerytes described by Judd from the Tertiary flows of Ireland and Scotland.* U. S. G.

Remark. This is the first instance of the occurrence of such a rock in the coast series. Its resemblance to the "muscovado" division of the gabbro suggests that it may exist here in the form of a transported block, having been included in the great sheet (Nos. 114, 115, 116, etc.) in the same manner as the blocks of anorthosyte. Sufficient field notes are wanting. (See, however, No. 137.) N. H. W.

No. 123. Diabase *(with olivine)*.

From the bluff east of Castle Danger. Resembles No. 116.

Ref. Annual Report, ix, page 32; Annual Report, x, page 139; American Association for the Advancement of Science, vol. xxx, page 162.

Meg. Uniform and medium grained, dark gray, having the aspect of an ordinary diabase.

Mic. The rock is composed of the usual minerals, in the usual petrographic structural relations, and needs no further specification. It is a fresh rock and makes a good illustrative slide. Doubtless from the same mass as No. 114, etc.

Age. Cabotian; Beaver Bay diabase. N. H. W.

No. 123A. Anorthosyte.

Block lying within No. 123.

Ref. Annual Report, ix, page 32; Annual Report, x, page 64.

Meg. A coarse mass of plagioclase similar to Nos. 113 and 120.

No section.

Age. Cabotian anorthosyte. U. S. G.

No. 124. Granite.

Bluff at Beaver Bay entrance, on the west side. Much jointed, semi-basaltic, supposed to be the equivalent of No. 119 (see No. 526).

Ref. Annual Report, ix, page 32; Annual Report, x, page 141; Proceedings of the American Association for the Advancement of Science, vol. xxx, page 164; Bulletin viii, page xxxiii.

Meg. A compact, fine-grained rock of a dull pinkish color. Small feldspars and quartz are seen to make up most of the rock. There are also small grains and needle-like forms of a black mineral.

Mic. In ordinary light a very few, rather clear feldspar crystals are seen in a cloudy, indistinct groundmass; also a few clear sub-angular quartz grains. Under polarized light the groundmass breaks up into irregularly and not distinctly outlined areas of *feldspar* intergrown with *quartz* to form micropegmatyte. Some of the feld-

*J. W. Judd: *Quarterly Journal, Geology Society*, vol. xlii, pp. 49-97, 1886.

spar areas show the cross grating twinning of *microcline*. *Magnetite* in small grains is present, and much dust-like magnetite and *hematite*. It is not certain what composes the dark mineral in the hand specimen. The slide shows a few small areas, outlined by magnetite grains, which areas probably represent the dark mineral of the hand specimen. In some cases the feldspar of the groundmass penetrates into these areas, and again they are composed of very fine grains and fibres.

One section.

Chemical analysis. The following analysis of this rock was made by Prof. J. A. Dodge, and first published in the Thirteenth Annual Report, page 100 (No. 155).

SiO_2	71.15
Al_2O_3	12.40
Fe_2O_3	5.21
FeO	.75
CaO	1.90
MgO	1.13
K_2O	2.40
Na_2O	1.70
H_2O	2.12
Total	98.76

The analysis (No. 1) quoted in Bulletin viii is not of this rock, but of No. 526, which is regarded as similar to No. 124.

Age. Cabotian; granitic red rock. U. S. G.

No. 124A. Diabase.

Dike rock, within No. 124.
Ref. Annual Report, ix, page 32.

Meg. A fine-grained, dark-gray, diabasic rock, with a somewhat earthy decayed appearance. It resembles somewhat No. 122.

No section.

Age. Manitou (?) U. S. G.

No. 125. Tuff. *(Altered.)*

Northwest from Beaver bay, S. E. ¼ sec. 2, T. 55–8.
Ref. Annual Report, ix, page 32.

Meg. Soft, reddish amygdaloid; explored for copper. Several test-holes and surface trenches have been dug on various sides of a conical hill, made up of alternating layers of reddish-brown firm rock (trap ?) and soft amygdaloid very much like the layers that form the hill west of Agate bay. This amygdaloid is so soft when wet, and so fragile when dry, that it can be crushed in the hand. It has a soapy feel and a dull red color. The grain and structure, when examined under the loop, suggest the tuffaceous nature of the soft portions of this rock. These irregular and tortuous variations in the grain and color, and the whole rock, though now feebly cemented into a fragile mass by the prevalent product of its own decay (thalite), seems to have been originally of fragmental origin. The few white amygdules seen are of the nature of kaolin, and seem to have resulted from accumulations

in preëxisting cavities. It is, at least, about on the horizon of the rock at Knife river.

Age. Cabotian.

N. H. W.

No. 126. Diabase. *(Coarse.)*

From about one-half mile up the creek, which enters the lake at Black beach, a few miles west of Beaver bay, about the centre of sec. 22, T. 55–8. This rock by its own disintegration furnishes the titanic iron sand of the beach.

Compare rock Nos. 106 and 107, etc., to which this rock may be referred, structurally and petrographically.

Ref. Annual Report, ix, page 32; Annual Report, x, page 139; Annual Report, xv, page 213; Bulletin ii, pages 76, 77; Bulletin vi, pages 140, 420; American Association for the Advancement of Science, vol. xxx, page 162.

Meg. Coarsely crystalline diabase, of a gray color, glittering with metallic reflections of magnetite and the schillerizations of the pyroxene.

Mic. Beautifully ophitic rock, the coarse *plagioclases*, somewhat decayed showing albite, pericline and Carlsbad twinning. A grain cut perpendicular to a bisectrix proves to be n_g (c) and its extinction angle is 28°, which falls between *labradorite* and *labradorite-bytownite*. It is hardly necessary to search for further determinative characters. This seems to be the character of the plagioclase in these basic eruptives, almost without exception, at least in normal circumstances.

Augite. This mineral seems to take on the schillerization when it begins to decay. That this is augite and not hypersthene, is evident from its strong refraction and the frequent appearance of an optic axis in the zone 001:100. In one section a bisectrix (n_p) is in the field with an optic axis. By means of the apparatus of Lacroix* this distance is measured, and the optic angle in air is found to be approximately 85° 8′, which would give 2 V=48° ±, if the index of refraction on n_p be taken at 1.712.† Not much value attaches to this result, owing to the necessity of operating on the half angle and the obliquity of the bisectrix. At any rate the result is smaller than is usual for augite. This mineral is also considerably decayed, and the product of such change seems to be, as remarked by Wadsworth,‡ a dirty green fibrous product.

Quartz is found in a mass of decomposition products resulting, according to Wadsworth, from alteration of the groundmass. It also forms a micro-pegmatyte in in the feldspars. Three sections examined.

Age. Cabotian; Beaver Bay diabase.

Remark. The writer formerly identified the foregoing described augite as hypersthene, and gave to the rock the name hyperyte, but the mineral is no doubt the same that occurs usually in this connection.

Prof. W. S. Bayley has assumed, probably from the geographic position of this rock (Journal of Geology, vol. ii, page 819), that it is no part of the gabbro, and that

* This instrument is described in the *American Geologist*, vol. xvii, p. 79 (1896).

† *Minéraux des Roches*, p. 265.

‡ *Bulletin iii, Geological Natural History Survey of Minnesota*, p. 76.

the iron sand to which it gives rise on decay cannot be compared with that of the titanic ores of the gabbro. From considerations given in the chapter on structural geology, it will be seen, however, that the Beaver Bay diabase is to be parallelized with the gabbro at Duluth and at Short Line Park, and that these are the surface representative of the great "basal flow" from the gabbro batholyth, and would necessarily partake of its ferriferous character. N. H. W.

No. 127. Apobsidian.

"From near the mouth of the river at Beaver bay. A metamorphic rock presenting another condition of No. 124; frequently jointed, breaking so easily along predetermined planes that it falls, under the hammer, into small fragments, making it difficult to get a fresh fracture. In the main it is slaty, but its texture is tough and its exterior is angular. It is ashen gray, but has, between the laminations, thinner lighter laminations of apparently siliceous matter; suddenly rises in a knob and disappears under the drift. In color, structure and texture this differs from any rock before seen on the shore. It rises about sixty feet and extends about 120 feet. Microscopically it appears to consist of quartz in fine grains, in a noncrystalline base. It extends more or less back from the mouth of the creek, toward the west, and appears slightly on the other side of the creek (see No. 528)." (Ninth Annual Report, pages 32, 33.)

Ref. Annual Report, ix, pages 32, 33, 39, 53; Annual Report, x, pages 41, 112, 113, 141; Annual Report, xiii, page 100 (No. 156), 103; Proceedings of the American Association for the Advancement of Science, vol. xxx, page 163; Bulletin viii, page xxxiii; U. S. Geol. Survey, Mon. 5, page 107 (No. 790).

Meg. An aphanitic, ashen-gray rock, hard and siliceous. It is crossed by short bands of a lighter color which rather suddenly cease, and are sometimes bent. These bands are an eighth of an inch, or less, in width, and are white or pinkish except for a narrow central line which is darker colored and seems to be mostly quartz. No crystalline grains can be seen in the rock.

Mic. In ordinary light nothing can be seen but a colorless, transparent and structureless groundmass in which are minute grains of hematite and magnetite and small, gray, semi-opaque cloudy areas, with an occasional small rounded greenish or yellowish grain appearing like epidote. Under polarized light the groundmass breaks up into small, irregular, not sharply outlined areas of quartz which include the other minerals of the rock poikilitically. The semi-opaque, cloudy areas are supposed to be feldspathic, but they are very minute and are practically isotropic, so they cannot be determined definitely. In places these poikilitic areas of quartz are larger than common, but nowhere do they attain the size of the areas shown in No. 68; in fact, No. 127 would hardly be supposed to be poikilitic when certain parts of the section were examined under a low power. One of the sections is cut across one of the bands which are so prominent a feature of the hand sample. The band appears simply as a clearer line which is made up of quartz grains and some of the iron ore and cloudy grains of the mass of the rock. Nothing can be seen to show why the borders of these bands appear so distinct in the hand specimen. The borders appear exactly like the rest of the section, although there is perhaps a slightly greater accumulation of the cloudy material of the groundmass.

Two sections.

Chemical Analysis. The following analysis was made by Prof. J. A. Dodge, and first published in the Thirteenth Annual Report, page 100 (No. 156):

SiO_2	71.99
Al_2O_3	12.36
Fe_2O_3	4.99
FeO	.56
CaO	.85
MgO	.72
K_2O	2.45
Na_2O	.99
H_2O	2.92
Total	97.83

Age. Cabotian.

Remarks. The groundmass of the rock is identical with that of some altered obsidians, and the bands may be well referred to original chains of spherulites. The rock is here referred, without much hesitation, to a devitrified obsidian; *i. e.*, an apobsidian. This rock is undoubtedly the same as No. 528. U. S. G.

No. 128. Labradorite. *(Crystals.)*

Near the mouth of Beaver creek, a few rods to the north of it; large feldspar crystals formerly weathered out of a crumbling block of the gabbro, lying at the upper side of the beach. These crystals were within fifteen feet of another upheaved outcrop of rock like No. 127.

Ref. Annual Report, ix, page 33; Annual Report, x, page 139; Bulletin Société Francaise de Minéralogie, vol. xix, page 90; American Association for the Advancement of Science, vol. xxx, page 162.

The crystals are large, more or less fragmentary, only one being sufficiently entire to show some of the faces of the form. This is represented by the following figures. A larger crystal was broken and cut for chemical and for microscopical examination. The crystal examined was at first thought to be a simple crystal, but on measuring the angles with a common goniometer it was found not to agree with that supposition. Further search revealed the presence of two directions of easy cleavage, thus indicating the two bases (001) of a Carlsbad twin. The other, larger, crystal showed the line of junction of the twins much more distinctly. From this a powder was produced, the thin cleavage pieces showing very perfectly not only the purity of the crystal but the following extinctions:

Extinction on 010, 25° to 27° (about 26°).

Extinction on 001, 7° to 11° (about 9°).

Specific gravity, 2.72 (in methyl iodide).

Test by the Boricky method gave numerous microliths of fluo-silicate of calcium, and a few of sodium.

Some of the fine powder was boiled for over an hour in hydrochloric acid. The fragments were somewhat affected, but the larger grains still polarized brilliantly between crossed nicols. Even the smallest retained their forms. In the platinum crucible this powder was mingled with an aniline color (vert de méthyle) in solution in water, in order to show, by the permanent coloration, the presence of gelatinous

silica. After washing thoroughly, the remaining grains were all found to be stained more or less but retained their forms, and in some of them the power of polarizing light remained. It is probable that the finest grains were lost in the process of washing. No distinctly gelatinous silica was observed.

The edges and faces that are preserved are shown by the following figures, which represent opposite sides of the twinned crystal, natural size:

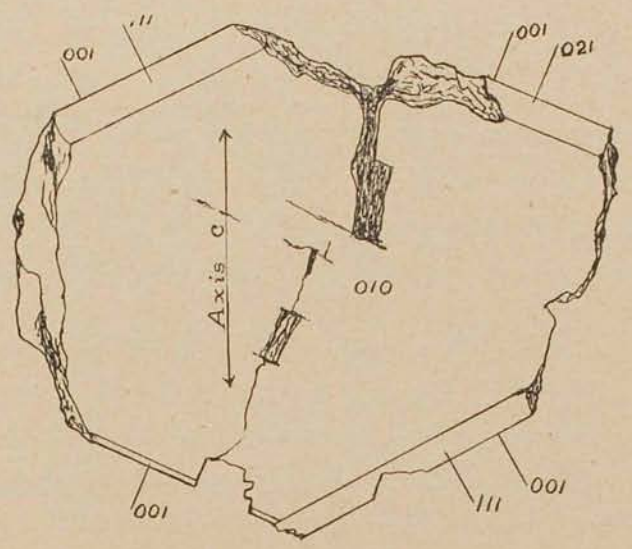


FIG. 7.

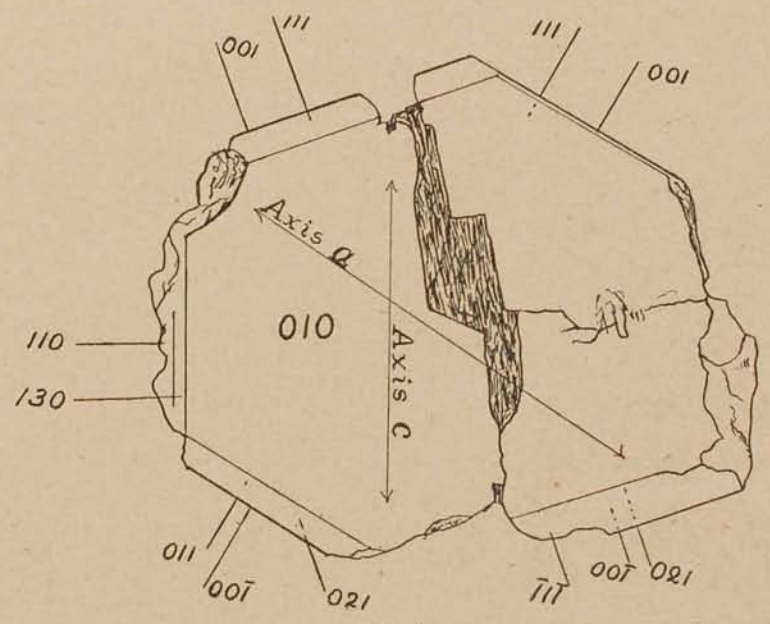


FIG. 8.

Angles were measured with a hand goniometer, on the faces, 010, as follows. In most cases the faces are large and intact, affording reliable posé for the arms of the goniometer. The exposed surfaces, 010, are positive in each twin, the contact and twinning surface is —010. The obtuse angle 001 ∧ 010 is conventionally at the top, and at the right of the observer.

Angle 001 ∧ 010= 94° 40′ (calculated by Descloizeaux, at 93° 20′).

Angle 130 ∧ 010=145° 10′.

Angle 110 ∧ 010=118° 30′ (?) (calculated by Descloizeaux, at 120° 53′).

Angle 001 ∧ 0$\bar{1}$0= 83° 15′ (observed by Marignac, 86° 40′).

Angle 021 ∧ 010=133°.

Angle $\bar{1}1\bar{1}$ ∧ 010=114° 50′ (observed by Marignac, 114° 40′).

Angle 02$\bar{1}$ ∧ 001=135° 20′.

Dana gives none of the exterior angles of labradorite. Descloizeaux has mentioned those measured by Marignac, and has calculated several others.*

Of the angles measured from this crystal, the following are not given by Marignac, as quoted by Descloizeaux: 02$\bar{1}$ ∧ 010; 02$\bar{1}$ ∧ 001; 130 ∧ 010.

The crystal has a gray color, but when broken it is very pure and glassy. Thin sections cut at random show that it is sparsely twinned on the albite plan, and apparently on the pericline plan.

Chemical analysis (No. 250) by Prof. C. F. Sidener, gave the following results:

Silica, SiO_2	50.75 per cent.
Alumina, Al_2O_3	32.80 "
Ferric oxide, Fe_2O_3	.22 "
Ferrous oxide, FeO	none
Calcium oxide, CaO	13.69 "
Magnesium oxide, MgO	.04 "
Potassium oxide, K_2O	.12 "
Sodium oxide, Na_2O	2.60 "
Titanic oxide, TiO_2	none
	100.22

Calculated as a plagioclase, this composition indicates a feldspar between Ab_1An_2 and Ab_1An_3, or labradorite-bytownite.

Five sections and three preparations.

Age. Cabotian.

Remark. In several places crystals of labradorite have been seen in the great gabbro mass of the state, and sometimes even larger than this, but they were firmly embraced in the matrix. Such have been seen frequently to have the size of an inch or more across the brachypinacoid and rarely five or six inches. But the crystal here described is larger than any hitherto extracted from the rock elsewhere in Minnesota, and we have not been able to find a description of a labradorite crystal so large described from any place. N. H. W.

No. 129. APORHYOLYTE.

An isolated outcrop a short distance northeast of the mouth of Beaver creek, in Beaver bay. Lies on No. 130.

Compare No. 140. Forms a buttress fifty-five feet wide and twenty-five feet high. Apparently dips south at 30°.

Ref. American Association for the Advancement of Science, vol. xxx, page 164; Annual Report, ix, pages 21, 33; Annual Report, x, page 141.

* *Manuel de Minéralogie*, Tome i, p. 303.

Meg. Similar to No. 127, but porphyritic with orthoclase (?) and with quartz. The outcrop has no evenly laminated arrangement, but is frequently jointed and easily falls to pieces.

Mic. The *feldspars* and *quartzes* are about equally abundant, and each so distributed that there is one in the area of about one-eighth of a square inch, the former being flesh-colored and sometimes a quarter of an inch in length and the latter about one-sixteenth of an inch across, with rounded outlines. They are embraced in a light-purplish matrix which evidently was originally glassy. This matrix is now filled with a multitude of rounded opaque microliths probably consisting of iron oxides, with scattered light-yellow grains of irregular shapes, having a strong refractive index which are probably of sphene. Sometimes these grains of supposed sphene occur in the quartz phenocrysts, but generally they are scattered through the matrix. In the case of their existence within the earlier quartz, it is apparent, in the single instance observed, that the quartz was broken, and some part of the glassy magma entered in that way; this became later the gathering place of the titanium mineral. In the same quartz crystal is seen a single *apatite* spicule (?) but this has no connection with the fracture plane mentioned. It has irregular perpendicular cross-fractures, and between the nicols it darkens when parallel with either thread. It presents colors of biréfringence, though the section is less than .003 millimeters in thickness, and hence it may not be apatite. In the devitrified matrix, however, are other apatite spicules.

Three of the *quartzes*, illustrated below, are so situated as to indicate that they were probably at first embraced in one crystal. They have the same aspect between crossed nicols in the manner of distribution of lines of minute impurities. That marked *a* has an interference figure consisting of a dark bar, which, spreading considerably as it crosses the field, seems to become curved as it leaves, in either direction, the concave side being in advance, in the direction in which the bar moves, and hence the first part of the bar to leave the field. This is characteristic of a uniaxial crystal, especially of quartz, cut very obliquely to the optic axis. That part marked *b* is apparently perpendicular to a bisectrix of a biaxial crystal, *i. e.*, two dark hyperbolic curves approach each other from opposite quadrants and unite to form a dark cross in the centre of the field. But this phenomenon is not necessarily demonstrative of the presence of a biaxial crystal since a thin section of quartz cut parallel to the optic axis affords the same interference figure. That part marked *c* has an interference figure like that in *a*, but more rigid and darker. It indeed has the aspect of the recurring arms of the black cross of a uniaxial crystal. The direction of extinction in each part is marked by

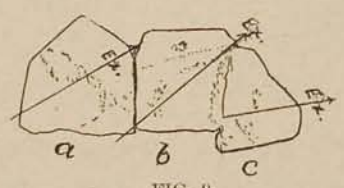


FIG. 9.

the line crossing it. It is necessary to conclude that these grains are derived from a single quartz crystal which has been broken and the fragments slightly dislodged from each other.

The *feldspars*, seen in the thin sections, have a distinct cleavage, but no twinning. They are generally charged with ferruginous and other impurities. There are no glassy feldspars visible in the sections made, and they are very rare, or entirely wanting in the hand sample. There are, however, a few cleavable feldspars, visible macroscropically, which are quite different from the flesh-colored feldspar phenocrysts, but they are hardly distinguishable from the quartzes. None of these appear in the sections examined.

The matrix, as now altered, between crossed nicols becomes very dark, but in some parts of the slide it is permeated by quartz which has been formed in the process of devitrification. This quartz is sometimes in interlocking areas, each having its own orientation, clouded only by the secondary microliths, and occasionally it is gathered in what may have been fissures or other cavities, and is clear and pure. The orientation of this clear quartz, however, governs the extinctions in that of the adjoining matrix, and it is plainly of the same date and origin. The porphyritic quartzes, in a similar manner, govern the quartz orientation in the adjoining matrix, but they as plainly preceded the poikilitic quartz in the matrix. The contact of these quartzes with the colored matrix is sharp, while the matrix gradually thins out about the poikilitic quartz, some of its substance sometimes being isolated in specks or spots in a dwindling manner within the quartz. It may be assumed safely that the poikilitic borders of the porphyritic quartz are of the same date as the poikilitic quartz of the body of the rock.

Three sections; one preparation.

Age. Cabotian; red-rock series.

Remark. This rock is one of the quartz porphyries of Irving, but as it has changed from a surface and glassy condition, as evidenced by an occasional vesicular structure visible in the hand samples and indicated by its general rhyolitic nature, it is more accurately described as a rhyolyte, to which the prefix *apo* is attached as suggested by Miss Bascom, to correspond with its altered present condition. N. H. W.

No. 130. Apobsidian.

A short distance northeast of the mouth of Beaver creek, lying below No. 129, suddenly thrust upward. *Ref.* Annual Report, ix, page 33.

Meg. The pieces at hand afford two kinds of rock, one a gray, cherty-looking very fine-grained rock, apparently embraced in the other, which is also brownish to gray, but somewhat coarser and apparently belongs with the Two Harbor series

(see general section of the rocks of this vicinity in Part III). They both contain considerable quartz.

Microscopically they are not the same rock. One is an ophitic brown diabase, in which many grains of quartz, of angular forms, are scattered through the whole, lying between the *plagioclases* and the magnetite. The plagioclase is so decayed that it cannot be determined any closer. It is in lath-shaped microliths, brownish red with *hematite*; also, between crossed nicols, specked with numerous minute transparent inclusions, which are apparently in part calcite, and muscovite, and in part quartz. No augite is visible, and some minute grains which polarize so feebly as to be almost dark between crossed nicols, surrounded by opaque rims, are probably the remains of original *olivine*. *Magnetite* is abundant, probably after augite. This rock retains its evident ophitic structure. All its original minerals are so far gone that only the plagioclase can be identified with certainty by its form.

The other rock is very different. It consists almost wholly of secondary quartz, but this quartz is so charged with other substances that it is nearly or quite opaque. While some of the grains are quite small, others are of considerable (microscopic) size. They are all so filled with magnetite and other much finer impurities, which are unidentifiable, that between crossed nicols the section is semi-dark. This quartz has not its original form, but has been rearranged by contact with the other rock. It has a spongy, sometimes even an ophitic, manner of enclosing the other substances, evidently being subsequent to them. Each siliceous area darkens independently and entirely, though often divided into several independent grains. In some places an imperfect, radiated, spherulitic structure is evident. This is shown by the occurrence of a permanent black cross, which, as the stage is revolved about the point of crossing of the threads, retains its arms constantly parallel to the threads.

Throughout the quartz is another polarizing mineral which sometimes is indistinctly pegmatitic with the quartz, extinguishing at positions not in unison with the extinction of the quartz. It seems to be imperfectly developed crystallographically and chemically, in that respect resembling the quartz, but not limpid. It is presumed to be a feldspar, probably anorthoclase, judging from the nature of the feldspar in the rocks associated with this in the same region, but it is impossible to determine it microscopically.

Four sections.

Age. Cabotian; red-rock series.

Remark. This rock is probably a phase of No. 129. It is non porphyritic, either with quartz or feldspar, and every feature which appears under the microscope would permit of its having resulted from devitrification of an original glass, after solidification. Yet it may perhaps also be supposed that these micropegmatitic struct-

ures were generated in a magma before complete cooling, or as a consequence of original rapid cooling, in which case the German nomenclature would impose on this rock the name granophyre, the French equivalent being micropegmatoid. It is probable that by Irving it would have been placed with the felsytes. N. H. W.

No. 131. Gabbro. *(Granulitic.)*

Beaver Bay. From a point six rods northeast of No. 130.
Ref. Annual Report, ix, page 33.

Meg. A dark fine-grained rock similar to No. 122.

Mic. The section is composed of plagioclase, pyroxene, magnetite, biotite, apatite and green alteration products. The plagioclase is in part idiomorphic and partly allotriomorphic, the structure of the rock being granular. Some of the plagioclase is clear, shows no twinning and no cleavage and might be mistaken for quartz. A number of such grains were examined, but no quartz was found. The pyroxene (probably diallage) is in minute rounded grains. Some of the smaller grains may possibly be olivine, but this point cannot be determined definitely because of the small size of the grains and the thickness of the section. The rock, as a whole, is similar to No. 122, but that rock has more of the idiomorphic plaigoclases than the one here considered.

One section.

Age. Cabotian.

Remarks. Consult Part III for a statement of the structural relations of the various rocks occurring in the vicinity of Beaver bay. U. S. G.

No. 131A. Stilbite and Calcite.

Incrustations on openings in No. 131. Beaver bay.
Ref. Annual Report, ix, page 33.

The incrustation consists of two minerals interlayered with one another. One is white, and consists of calcite. The other is brownish red and has a radiated crystallization, becoming tabular. The two minerals are also intermixed irregularly. In powder the wedge-shaped cleavage pieces of the red mineral extinguish nearly or quite parallel with their principal elongation. Good cleavage pieces, however, have this extinction at 5° to 7°, and they also show the emergence of an optic normal in convergent light. The optic plane is therefore parallel to the easy cleavage. These characters sufficiently indicate *stilbite*. Still, a test was made for gelatinous silica in hydrochloric acid, without result, and another, by the Boricky method, with hydrofluosilicic acid, which gave numerous crystalliths of fluosilicates of lime in a great variety of forms.

One section; two preparations.

Age. Vein in Cabotian anorthosyte. N. H. W.

No. 132. Diabase *(with olivine)*.

Beaver Bay. Holds feldspar (anorthosyte) masses.
Ref. Annual Report, ix, pages 33, 34.

Meg. An ordinary olivine diabase of medium grain. The rock needs no further description. It is part of the great "trap" sheet of the Beaver Bay region which here encloses masses of anorthosyte.

One section.

Age. Cabotian. Compare Nos. 131 and 532. U. S. G.

No. 132A. Granite *(and aporhyolyte; inclusion)*.

This red or light red rock is embraced in No. 132 in the manner of nodules and patches, and in veins along the joints running in different directions across the face of the rock.
Ref. Annual Report, ix, page 33.

Meg. The specimens at hand consist of coarsely radiated nodules, suggesting stilbite, but they are not of a homogeneous mineral. Indeed, the radiated structure breaks up into a granitoid structure which prevails wholly on one-half of the bulk of the specimen, making a reddish granite. In the midst of the red coarsely-radiated rock are porphyritic quartzes and magnetites, and spicules of a green mineral which do not run always parallel with the structure, but cross it at various angles. Where the radiated structure breaks up into the granular, the red substance of the mass is seen to maintain a pegmatitic relation to quartz, which latter is in zigzag and angular grains and strings.

Mic. The most of the section presents a feldspathic reddened aspect, as if it resulted from an orthoclastic rhyolyte. *Quartz* is abundant, and in the form of isolated grains as well as a pegmatitic growth. In the former condition it has controlled the orientation of the poikilitic quartz surrounding it. There are some quartzes that have embayments and cavities that have been filled with a structure that appears to be the same as the orthoclastic substance surrounding them. The appearance is that of a sub-crystalline magma from which this quartz first consolidated. The reddened substance in many cases is spherulitic, at least fibrous, and the quartz orientation and extinction prevail over considerable areas of these fibres. In other places the fibres break up into a more granular structure, the quartz areas become large and still poikilitically spread over the surrounding orthoclastic substance, which, in other places, assumes a parting, resembling an incipient cleavage and an orientation of its own, though still clouded by the red impurities. The strongly radiated aspect of the hand sample is seen to be due to a spherulitic growth of the orthoclastic ingredient of the rock. It is an interesting fact that here the spherulitic form gradually assumes a granular one, and that the secondary nature of the poikilitic quartz in the latter is as evident as in the former.

But perhaps the most interesting feature of this rock is the occurrence of *labradorite* feldspar in secondary growth. It embraces the reddened orthoclastic substance in precisely the same poikilitic manner as does the secondary quartz. It was mistaken for quartz at first, being clear and plainly of secondary date. A section, however, was found cut perpendicular to n_z, on which extinction on a cleavage is 33°, which, according to the determinations of Fouqué, shows labrador-bytownite. Some of these crystals are of considerable microscopic size, but it is but rarely that they are free from the red substance over areas sufficiently large to operate on with convergent light. They are usually simple crystals and when they are cut transversely they are seen to run athwart the red fibres, and to spread independently amongst them. In but one instance was seen an albite (or Carlsbad) twinned section.

The green spicules mentioned as piercing the fibres of the spheruliths is a monoclinic pyroxene. In a section perpendicular to the prism axis, an optic axis is visible, and by means of it the direction of the optic plane is seen to be parallel to a third cleavage, or parting. The latter is hence parallel to the brachypinacoid (010), as in *diopside*. The long lath-shaped sections, which are more nearly parallel to the vertical crystallographic axis, usually show no cleavages, but are crossed irregularly by transverse coarse cracks which are approximately perpendicular to the prism axis.

This mineral has high double and single refraction, and in all respects, so far as its characters are ascertainable, it agrees with *diopside*.

There is also apparently a little *rutile*, manifesting its four systems of cleavages, much darkened by iron oxide, and clouded by gray leucoxene. Three sections were made, one at random, through the granular or granophyric portion, one parallel to the prevalent structure, and one perpendicular to it.

Age. Cabotian.

Remark. Whatever may be its source, whether from deep-seated acid magma, or from fusion of the clastics of the region, this "red rock" material manifests here distinctly a secondary origin for the quartz, whether micropegmatitic or poikilitic in its manner. There was also at the time of the generation of the quartz, a cotemporary growth of a basic feldspar which has optic characters, indicating labradorite, which permeated the acid element without uniting chemically with it. The smallness of the masses of this red rock included *in* the basic eruptive gave occasion for sudden transitions from characteristically basic phenomena to acid, without the lapse of sufficient time, in sudden cooling, for chemical union, and at the same time indicates a limited and probably local origin for the red material. The phenomena here may be compared with the descriptions given by Bayley of the contact phenomena on Pigeon point.*

* *Bulletin cix, U. S. Geol. Survey.*

No. 133. DIABASE *(with altered magmatic glass)*.

From the second island in Beaver bay, counting from the west.
Ref. Annual Report, ix, page 34; Bulletin ii, pages 59, 70, plate II, figure 1.

Meg: A dark-gray, heavy basic eruptive, apparently from the great sheet of trap which all along from Silver creek and Encampment island carries masses of feldspar. It glitters with metalloidal reflections of a pyroxene which embraces other minerals ophitically. Its coarse granular structure and its freshness here cause it to resemble the gabbro of which pieces are embraced in it at other points in the vicinity. It resembles No. 132. Compare Nos. 221, 222 and 223.

The *feldspar* is very fresh and is taken for labradorite. A small crystal of the feldspar which is entire, represented below, lies surrounded by the green, massive chlorite (?) and is cut exactly parallel to 010. It is not twinned, so far as can be seen. It has extinction at —37°. By comparing this with the table of extinctions given by Rosenbusch (translation by Iddings, page 300) it is evident that the feldspar is more basic than usual for labradorite, and that the species is near *anorthite*. Fouqué, however, gives *anorthite* at 41°. There are in the section several Carlsbad twins, also; in one case cut nearly perpendicular to the zone of symmetry, as shown by the four points of equal illumination for all the bands, each of the twins being also twinned on the albite plan.

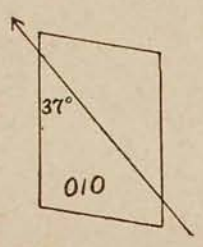


FIG. 10.

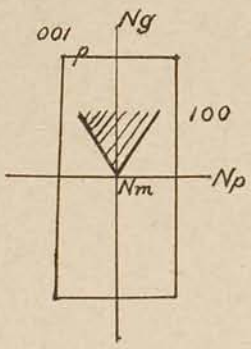
The *pyroxene* element is strongly refracting and doubly refracting, appearing like augite with a tendency toward diallage owing to the secondary cleavage which is seen in nearly all the grains, parallel to which extinction takes place; indeed, there seems to be but one crystal of this pyroxene in the slide, since extinction in this mineral is simultaneous throughout. There is a remarkable contrast, as noticed in several other instances, between this pure pyroxene and the greenish substance which is generally supposed to be the product of its alteration, and in some instances this contrast, in this rock, is between two adjacent masses which have no gradation toward each other. The green substance in this case does not result from a change in the pyroxene, but is more than likely to be a portion of the residual magma. This green substance is in the feldspar surrounded in a manner like that of the pyroxene, and it is sometimes irregularly disseminated sparsely through the feldspar, from which it is separable as clearly as from the augite.

Owing to the fact that by Wadsworth this pyroxene element is called enstatite (Bulletin ii, page 70), a more particular examination was made. Outwardly, and microscopically, as Wadsworth remarks, its appearance in common light is identical with that of diallage, which is a secondarily (?) cleaved form of augite; and but for the fact that he has pronounced it enstatite there would be no suspicion that it could

be different from the pyroxene in this rock generally. The fact that extinction takes place parallel to the fibrous inclusions seems to be the character which determined him to designate it enstatite, since in enstatite such alteration to greenish bastite, the axis of the fibres being parallel to the vertical axis of the original mineral, is a common phenomenon.

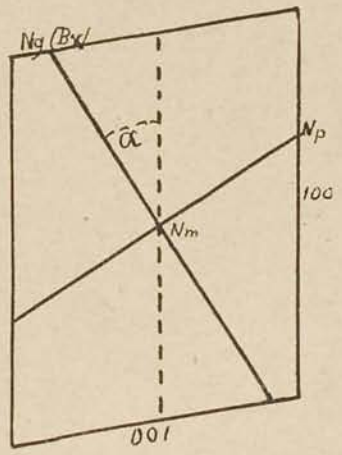
COMPARATIVE CHARACTERS OF ENSTATITE AND AUGITE.

Enstatite.	*Augite.*
Orthorhombic.	Monoclinic.
Specific gravity, 3.1.	Specific gravity, 3.3 — 3.5.
Easy cleavage, 010.	Easy cleavage, 110, $1\bar{1}0$.
Positive bisectrix, n_g.	Positive bisectrix n_g.
Plane of the optic axis, 010.	Plane of the optic axes, 010.
Dispersion about n_g $\rho > v$.	
(+) 2 V=70°.	+ 2 V = 60° to 68°.
n_g (yellow)=1.674.	n_g = 1.733 to 1.728.
n_m =1.669.	n_m = 1.717 to 1.712.
n_p =1.665.	n_p = 1.712 to 1.706.
$n_g - n_p$ =0.009 (mean) weak.	$n_g - n_p$ = 0.022, strong.
Prismatic angle of scant cleavages, in basal sections.	Prismatic angle, to which easy cleavages agree, shown by basal sections.
(110 $\wedge$ $1\bar{1}0$)=88° 20′.	(110 $\wedge$ $1\bar{1}0$) = 87°.
	Twinned with itself on 100 and rarely on $\bar{1}22$; with amphibole on 100; with biotite, 001 of the mica is applied to 110 of augite.
Refraction, strong.	Refraction, strong.



Section 010.

FIG. 11. OPTICAL SCHEME OF ENSTATITE.



Section 010

FIG. 12. OPTICAL SCHEME OF AUGITE.

Talcose fibrous alteration in easy cleavage parallel to 010; axis of the fibres parallel to the vertical axis.	Schillerization in secondary cleavage parallel to 100; its elongation is perpendicular to the edge 100:010 (diallage).
Easy (brachypinacoidal) cleavage always parallel.	Easy (prismatic) cleavages are all parallel in sections 100 and 010. Other sections in the zone 001:100 have the angle of the cleavages bisected by the extinction position.
Prismatic cleavage, imperfect and irregular.	
Section 100 shows bisectrix perpendicular.	Section 100 shows an optic axis oblique.
Optically positive.	Optically positive.

It is evident that the distinguishing characters are to be found in the comparison of the double refraction, the specific gravity, and the direction and perfection of the

easy cleavages. There is also a difference in the elongation of the fibres resulting from initial disintegration. If the orientation can be determined, the interference figure seen in 100 in enstatite is characteristically different from that seen in augite, in the same face.

The section of this mineral shows throughout a near perpendicularity to some axis of elasticity. On searching further a portion is found near the margin of the slide, in which this bisectrix is quite visible, and on testing it in the usual way with the sensitive-tint quartz plate, it appears that the section is too thick to be susceptible to the usual observation and comparison with Newton's scale. The direction of the plane of the optic axes is found by this interference figure to be vertical to the elongation of the fibres of the intercalated impurities. It is hence perpendicular to the cleavage in which they lie. These fibrous impurities, however, find access, in the first instance, along the cracks formed by a very irregular cleavage (?), spreading out from these as they cross the fine cleavage. At the same time there is a third cleavage, perpendicular to the elongation of the fibres, but this is not conspicuous. It is, however, very straight and clear, and is visible best in faint light. Its lines are short and interrupted, and are not everywhere discoverable. Its interrupted and scant occurrence has operated to prevent, except in occasional instances, the entrance and display of the fibrous impurities along its cracks. The great irregularity and the coarseness of the oblique transverse cracks rather exclude them from the category of cleavages, and there are left only the two rectangular cleavages parallel to which extinction takes place. In the figure below, which represents the grain in which the bisectrix is best visible, the second cleavage is hardly found, but some irregular cracks, probably governed in their direction by it, appear perpendicular to the fibrous cleavage.

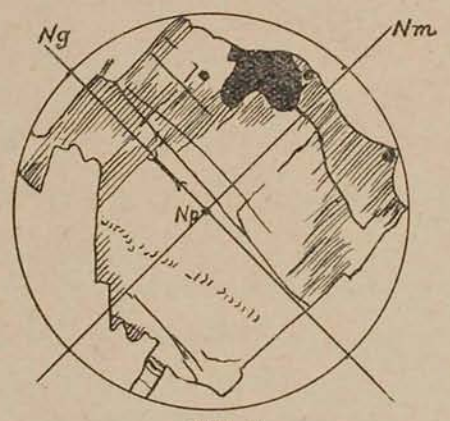


FIG. 13.

In order to determine which bisectrix is in the field of the microscope it is necessary to resort to the mica of quarter undulation. Knowing the direction of the optic axial plane, this plate is inserted in such a manner that its axis is parallel to

the axial plane, and hence in coincidence with one of the bisectrices lying in the section examined. This interposition causes the colors of the interference figure to rise from rose-red to blue. The same result is obtained by selecting a point in the grain being examined, where, by a local thinning of the section, as by an edge, the colors appear in parallel bands following each other from the thin edge to the thicker part in the order *yellow*, *red*, *blue*, *green* to yellow again. By this alternation the great thickness of the section is shown, and these four grand divisions of the scale of Newton each correspond to the same amount of change as is produced by the quarter undulation mica plate. On inserting this plate over such an edge, between crossed nicols in convergent light, in the manner above stated, each of these bands rises in the color scale of Newton a quarter wave-length, showing that the bisectrix in agreement with the axis of the mica plate is the same as that of the mica plate, viz., n_g. Hence the bisectrix, which is perpendicular in the thin section, is n_p or a. This also shows the orientation of the section is perpendicular to the plane of the optic axes and nearly perpendicular to the axis of greatest elasticity.

It is evident that with this orientation it is not possible to distinguish, by optical characters, a monoclinic crystal (augite) from an orthorhombic one (enstatite), since the crystalline characters and the angles would be symmetrical with the extinction in both. This is the case with all sections in the zone of symmetry of a monoclinic mineral.

A section of enstatite or hypersthene perpendicular to n_p would show a parting or cleavage parallel to 010.

A section of augite perpendicular to n_p might show two systems of cleavage at right angles, viz., one parallel to 100 or to 001, and an interrupted cleavage parallel to 010, as well as the rhombic intersections of the prismatic cleavages.

Considering the direction of elongation of the fibres, it is shown above that in enstatite they are parallel to the vertical axis lying in 010, and hence perpendicular to the axis n_m. In augite they are elongated perpendicular to the edge 100:010; and as they lie in 100 they are perpendicular to 010, and hence parallel to n_m.

As seen by the above figure, this shows that the mineral in this respect agrees with augite.

Again, by making use of the difference of double refraction, the same result is reached in the following manner. Taking the feldspar in the thin section for labradorite and finding its highest interference color, it proves to be bluish-green. This color is produced by the difference of the refractive indices of the axes of elasticity that lie in the thin sectoin, *i. e.*, by $n_g - n_p$. This value, as given by the table in Mineraux des Roches, page 323, is 0.008. In order to get this color for labradorite it appears that the thickness of the thin section must exceed the range of the colored

plate (Table des Biréfringences) of the same volume, and is evidently greater than .08 millimeters. Now this pyroxene mineral gives, as its highest interference color, at this thickness a color green. But this must be the green of the third order since there are two violet tints visible below it, one on the surface of the thin section, and one on the oblique edges.

For augite $n_g - n_m = 0.016$. $n_m - n_p = 0.006$. $n_g - n_p = 0.022$.

For enstatite $n_g - n_m = 0.005$. $n_m - n_p = 0.004$. $n_g - n_p = 0.009$.

From this it appears that, making a little allowance for the obliquity of the thin section, the value 0.016 would agree well with a green in the third order for augite in a section of the thickness of over 0.08 millimeters, while for enstatite, at 0.005, it would be impossible to produce a green of the third order in a section of this thickness, perpendicular to n_p, if at all.

A test by the Boricky method of microchemical examination showed many short minute forms taken for fluosilicate of lime, and flattened elongated rhombohedra that result from the presence of magnesia. This result is not conclusive, owing to the resemblance of the micro-crystals of lime in this test, to those of magnesia, and hence the possibility of both these forms coming from magnesia of an enstatite. Still both lime and magnesia are strongly indicated.

In order to be still more sure of this conclusion, the rock was powdered. On attempting to separate the pyroxene by iodide of methyl it was found that the specific gravity of the mineral is so near that of the iodide of methyl that while most of the feldspar floated, some of it was carried down with the pyroxene and magnetite. Indeed, on examining with a loop the powder consisting largely of pyroxene, it was seen that not only had the pyroxene carried down small quantities of the labradorite, but some magnetite had also acted in the same way, and that hence the separated pyroxene powder was not pure. However, eight or ten small grains were mechanically separated from the powder. These were entirely free from labradorite, and their size was about one-fourth to one-tenth the size of a pinhead.

These grains were dissolved in hydrofluoric acid, with added sulphuric, and evaporated to dryness. The residue was dissolved in water with a few drops of hydrochloric acid, and on slow evaporation on a glass slide, under the microscope, minute spangles and radiated clusters of gypsum were formed, indicating the presence of lime.

With another portion of the same residue a further test was made, viz., dissolved in hydrochloric acid, and after adding chlorhydrate of ammonia and ammonia the resulting precipitate (iron and alumina) was filtered away. The filtrate was tested for lime by adding oxalate of ammonia, which also gave a copious precipitate, again indicating lime. The presence of lime differentiates this mineral from enstatite, and with the other characters shows it is really augite.

These results sufficiently show that the mineral is augite, in the rare position of being cut nearly perpendicular to a bisectrix (n_p), thus bringing two cleavages, one of which is rarely seen in augite, at right angles to each other in the same grain.

One section examined, the same as that examined by Dr. Wadsworth.

Remark. Another section having been made of rock No. 133, the dubious characters do not appear, but the characteristic cleavages of augite are evident, as below, in which, along with the prismatic faces 110(M), may be seen also the pinacoidal, 010 and 100. Those parallel with the prism faces make an angle of nearly 90°, and those parallel with the pinacoids also form a right angle, the section being cut about perpendicular to the prism. These augites are of older generation than the feldspar, or cotemporary with it, and they tend toward diallage more strongly than those of later origin—at least only the prismatic cleavage appears in the ophitic augites, usually, but in the idiomorphic ones the pinacoidal cleavages are often prominent. Sometimes they are completely surrounded by a portion of the non-differentiated magma, there being no appearance of decay in the augite, but the line of separation between it and the magma being perfectly distinct and sudden. The same is true when this augite comes into contact with the feldspar.

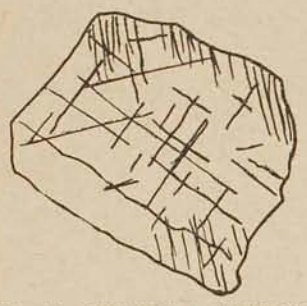


FIG. 14. PRISMATIC SECTION OF AUGITE IN NO. 133.

The altered *residuum of the magma* is green, embraces all the other minerals, and is massive, giving a dense or "felted" polarization which renders it nearly opaque between crossed nicols. No fibrous structure is visible. It is probably some form of chlorite.

There is also in this section a mineral which is brown, and, according to Prof. Lacroix, resembles *bowlingite.* (Minéralogie de France, part I, page 442. Compare, also, Mineralogical Magazine, vol. i, page 154.) In the original description of bowlingite, by Hannay, it is said to be green—"of a fine, deep green color by transmitted light." Lacroix connects this mineral with the mineral *iddingsite* described by Lawson (Bulletin of Mining, California, i, page 31, 1893) which is usually a dark chestnut brown, but occasionally green.

The *magnetite* in this rock may be primary, as there is no decay (or but very slight) visible in any of the elements, yet its form is very irregular. It embraces idiomorphic feldspars (compare figure 4, page 99) and small quantities of the devitrified glassy magma. Some stout apatites are cut perpendicular to the vertical axis, and others are included in the larger feldspars.

Age. Cabotian; Beaver Bay diabase. N. H. W.

No. 134. Granite. (*Red.*)

Third island below Beaver bay.

Ref. Annual Report, ix, pages 34, 35; Annual Report, x, page 141; Annual Report, xiii, pages 100 (No. 157), 103; Proceedings American Association for the Advancement of Science, vol. xxx, page 164; Bulletin ii, page 127; Bulletin, viii, page xxxiii.

Meg. A medium-grained granitic rock composed essentially of red feldspar and quartz. In places it has whitish blotches, as if from the decay of the feldspar.

Mic. An ordinary example of the granular red rocks of the Cabotian, composed of *quartz* and *feldspar*; the latter is probably mostly orthoclase, but is reddened and almost opaque, and has almost no effect on polarized light. *Magnetite* occurs in small amount. In places the quartz and feldspar have intergrown to form micropegmatyte.

One section.

Chemical Analysis. The following analysis was made by Prof. J. A. Dodge, and was first published in the Thirteenth Annual Report, page 100 (No. 157).

SiO_2	73.28
Al_2O_3	11.83
Fe_2O_3	4.61
FeO	.56
CaO	1.04
MgO	.36
K_2O	4.50
Na_2O	1.66
H_2O	1.82
Total	99.66

Age. Cabotian; red-rock series. U. S. G.

No. 135. Apobsidian (?)

Opposite the fifth island east of Beaver Bay. Forms a bluff twenty to sixty feet high.

Ref. Annual Report, ix, page 34.

Meg. A reddish-brown, compact, aphanitic rock. Throughout the rock are minute, rarely as much as one-sixteenth of an inch in diameter, rounded spots of a whitish material. Frequently these spots have a centre like the mass of the rock, and thus consist only of a narrow ring of the white material.

Mic. The mass of the rock is essentially like No. 127, and need not be redescribed. Throughout the section are small circular areas which are much clearer than the mass of the rock. These areas contain many minute black specks which seem to be *magnetite;* in some cases these are arranged in roughly concentric lines. The rest of each circular area is composed of a transparent fibrous mineral radially arranged. In the thinner part of the section these fibres have almost no effect on polarized light. Where the section is thicker an indistinct, fibrous, radial, or fan-like, structure is seen when viewed in polarized light. The extinction is practically parallel to the elongation of the fibres, which are optically positive.

The exact nature of this mineral in the circular areas is not known. Sometimes the quartz of the mass of the rock runs into these circular areas. It seems quite

probable that the rock here described represents a spherulitic glass, although the circular areas may possibly be gas cavities rather than old spheruliths.

One section.

Age. Cabotian; red-rock series. U. S. G.

No. 136. Basalt *(with acid inclusions).*

Opposite the fifth island east of Beaver bay.

Ref. Annual Report, ix, page 34; Annual Report, x, page 141; Bulletin ii, page 125; American Association for the Advancement of Science, vol. xxx, page 164.

Meg. A medium-grained, brown-green rock, with much quartz. The brown or brownish-red color is produced by a stain of the feldspathic ingredient. The green is confined to an amorphous green substance which is abundantly disseminated through the rock. The quartz is disseminated micro-pegmatitically amongst the feldspars and also occurs in the green substance. The feldspars are not wholly stained red, but the central portions are frequently white. They seem to be frequently twinned on the Carlsbad plan and occasionally the albite striation can be seen. There is also a considerable amount of amorphous red substance which cannot be called feldspar, though probably feldspathic.

Mic. The *feldspars* are permeated with impurities. They are largely or wholly of the plagioclase family, some of them being minutely twinned on the albite plan; yet, in some parts of the slide, they can hardly be separated from the reddish amorphous substance throughout which quartz is intergrown pegmatitically.

Quartz has a single orientation, sometimes, over considerable areas which also enclose portions of the amorphous green and red substances, as well as what appear to be altered phenocrysts of feldspar. It also ramifies in a branching and spreading manner through some of the feldspars having, in that case also, a single orientation. It is thus evident that it is of later date than any of these substances.

The red feldspathic substance is easily recognizable as that which makes up the largest part of the "red rocks" of the region. It gave rise to orthoclastic feldspars when it was allowed to cool slowly, and it may be the generator of the most of the Carlsbad twinned crystals in this section. At least it may be stated that it has a close alliance with the reddened feldspars of this rock, for sometimes it seems to pass insensibly into the crystalline feldspathic condition.

The green amorphous substance, in a like manner, shows evidence of having been the magma of a basic rock. It is the same that is seen in No. 133, but is here more abundant. It surrounds the feldspars, and sometimes small portions of it are included in them. It solidified later than they. It is now in the form of a chloritic mineral (pennine?), and occasionally it is cut favorably for showing its pleochroism.

Magnetite appears in distinct masses, and hematite is everywhere as a coloring substance.

One section examined.

Age. Cabotian.

Remark. This curious and interesting rock is but a local phase of contact between the basic and the acid magmas, which seems to have mingled without entire chemical union. The field notes (Annual Report, ix, page 34), show the confusion which prevails along the coast at this point and for some distance. The action of the great diabase sheet, commencing at Silver creek and extending continuously at least to this point, amongst the "red rocks" of the Cabotian, affected them profoundly, and produced in the acid rocks, in some places, a condition of fluidity, from which sometimes they crystallized into granites, but more frequently, perhaps, were left but slightly changed. (Compare No. 132A.) See Part III, for a further discussion of this subject.

Wadsworth's No. 136 (Bulletin ii, page 125) is not this rock, but is misprinted for No. 736. His No. 134 should read No. 734, and No. 153 should be No. 753.

N. H. W.

No. 137. DIABASE. *(Modified.)*

From the same place as No. 136, *i. e.*, near the centre of sec. 28, T. 56–7, but having the green and red colors in larger patches, and therefore more strongly contrasted.

Ref. Annual Report, ix, page 35; Bulletin ii, page 109.

Meg. The green portions of the rock have the appearance of a coarse diabase, in the interstices of which is seen a fine, green, amorphous substance, some of the patches of this substance being half an inch in diameter and excluding all the crystalline elements of the rock. The red portions have the appearance of a red granite in the interstices of which is seen an amorphous red substance which is more abundant in some places than in others. This red substance appears like the aporhyolitic magma of No. 140(7) and also like that of No. 140(2) and of several other of the red rocks that occur in the vicinity of Beaver bay. The only noticeable difference between this red substance and those mentioned consists in a brighter redness and more friable texture of this, making it approach more nearly the appearance of a powder of common ferric oxide. Quartz is seen in both portions of this rock, but it is more abundant in the red. Magnetite is abundant in the green and is not wanting in the red. In short, the chief cause of the difference in color between these parts of this rock seems to lie in the difference in the nature of the ferric oxide. This again seems to imply a difference in the degree of basicity. At the same time, in the absence of olivine, it would be allowable to attribute some part of this green element to the decay of that mineral.

Mic. The green portion of this rock consists of most of the essentials of a coarse diabase. It only lacks olivine. The feldspars are striated and frequently zoned, and sustain a curious relation to the pyroxene. The latter mineral is in general older

than the former, and is embraced by it. The small rounded pyroxenes are sometimes sprinkled through a single feldspar to the number of four or five independently oriented grains, but in some cases it appears that large pyroxenes were corroded to a mere skeleton, and were then embraced by the feldspars. Thus the orientation of many isolated small pyroxenes is the same. That they once were united in a single crystal is proved by the fact that they are often still connected in a series with narrower and narrower links between them till finally the link is entirely lost and only the common orientation remains to show their former continuity. When the pyroxenes are of different orientation it is evident that the corrosion went so far as to break up the crystal and disturb the relative positions of the parts.

These small, rounded pyroxenes, originating in this manner, suggest a possible cause of the "granulitic" phase of the gabbro. This phase is seen in its fully developed state, in Nos. 122 and 131, both of which are parts of the same diabase sheet as the basic rock, No. 137.*

The green substance, as stated, is probably derived from an alteration of the non-differentiated portion of the basic magma, while the red may have resulted from the inclusion of portions of the Cabotian rhyolyte.

Other sections, made by Marchand, afford some further data as to the nature of the pyroxene. When sections are favorably cut, *i. e.*, perpendicular to the prism, there are seen three coarse cleavages, one being parallel to the direction of the optic plane, and hence parallel to the side 010, which is a character distinguishing the cleavage of *diopside* from the fine cleavage of diallage, the latter being perpendicular to the optic plane in such a section. The aspect otherwise of this pyroxene is that of augite.

The sections also contain considerable *apatite*, some *sphene*, some *biotite*, and in the red portion of the rock, much *hematite*.

Four sections.

Age. Cabotian; Beaver Bay diabase. N. H. W.

No. 138. Aporhyolyte.

Top of the Great Palisades, 315 feet above the lake.

Ref. Annual Report, ix, page 35; Annual Report, x, pages 38, 141; Proceedings American Association for the Advancement of Science, vol. xxx, page 164.

Meg. An aphanitic brownish gray rock, with porphyritic crystals of quartz and of whitish decayed feldspar.

Mic. The groundmass of the rock under polarized light is of micropoikilitic quartz areas inclosing the other materials. The groundmass is similar to No. 68. Phenocrysts of *quartz*, with their angles more or less rounded, are rather common

*Compare W. S. Bayley. The peripheral phases of the great gabbro mass of northeastern Minnesota. *Journal of Geology*, vol. ii, page 814.

in the sections, but only two feldspars are seen. These are very small, and their character cannot be determined. A microchemical preparation, with hydrofluosilicic acid, of one of the feldspar phenocrysts showed large amounts of both soda and potash, with a very small amount of lime. The feldspar is probably *anorthoclase*.

Two sections.

Age. Cabotian.

Remark. This rock and those numbered 139 and 140 are from the Great Palisades. These rocks are all regarded as acid lavas which were once glassy; in fact, some of the specimens of No. 140 still contain glass, and some show distinct perlitic cracks. Some of these features are described under No. 140. Compare also Nos. 812 and 813. U. S. G.

No. 139. Aporhyolyte.

So taken as to express the character of the rock of the bulk of the Palisades; of the same character as No. 138.

Ref. Annual Report, ix, page 35; Annual Report, xiii, pages 100 (No. 158), 103; Bulletin viii, page xxxiii. (See No. 533.)

Meg. A reddish brown, aphanitic rock, containing small phenocrysts of quartz and feldspar, the latter pinkish to white in color. The rock is filled with irregular cracks and under the hammer breaks up into small irregular nodules. It is difficult to get a fresh fracture of large dimensions.

Mic. The groundmass of the rock is similar to that of Nos. 68 and 138. The particles of iron ore and the small cloudy feldspathic particles occur as in these rocks, but the poikilitic quartz of the groundmass is of much smaller size. The sections show distinct flowage structure, the lines of flow being brought out by streaks, which are more or less filled with the iron ore. The sections show only a few of the phenocrysts. The quartzes are small, angular or rounded, and one individual shows an embayment filled with the groundmass. The feldspars are clouded and altered. A microchemical preparation, with hydrofluosilicic acid, of these feldspar phenocrysts showed large amounts of soda and lime, and but little potash. The feldspar is thought to be oligoclase. From the analysis of the whole rock, given below, the amount of lime and soda, especially of the former, is seen to be very small in comparison with the potash, and for this reason we might expect a more acid feldspar, orthoclase or anorthoclase. It would seem, however, that the feldspars tested were some of those first formed and thus contained a large percentage of lime.

Two sections.

Chemical analysis. The following analysis was made by Prof. J. A. Dodge and was first published in the Thirteenth Annual Report, page 100 (No. 158):

SiO_2	76.68
Al_2O_3	12.14
Fe_2O_3	3.16
FeO	.52
CaO	.25
MgO	.26
K_2O	3.53
Na_2O	1.06
H_2O	1.66
Total	99.26

The analysis shows this rock to be higher in SiO_2 and lower in CaO than most of the acid rocks of the Cabotian, and the amount of K_2O, in reference to Na_2O, is greater than in many of these rocks, which frequently have a larger amount of Na_2O than of K_2O.

Age. Cabotian. U. S. G.

No. 140. Aporhyolyte.*

From the contorted and fluidal portions of the Great Palisades near the water level.

Ref. Annual Report, ix, pages 21, 35, 36; Annual Report, x, pages 38, 110; Annual Report, xiii, pages 100 (No. 159), 103; Bulletin viii, page xxxiii; figure A of plate 44, Bulletin cl, U. S. Geol. Survey, was made from No. 140(1).

Meg. The rock here has been twisted and recurved so as to defy description. Large hardened masses or concretions occur in the fluidal portion. The whole of it contains the translucent crystals common in the bulk of the rock above, and also one or more species of feldspar. Some of it is red, some green, some brown, some dirty white, or buff; some is laminated, and some is massive, with a conchoidal fracture. The matrix of the crystals and the parts between the translucent laminæ are not crystalline, but seem to have been perfectly molten, though probably cooled rather suddenly. These laminated parts, and other (brownish) streaked portions, appear to have been drawn out in a streamed structure. The most careful examination was made of No. 140(7), but all the specimens numbered 140 bear a general resemblance. The green rock, associated with No. 140, is described under Nos. 136 and 137. Rock No. 140 is the same as Irving's No. 876. (U. S. Geol. Survey, Monograph v, page 109. Compare, also, Nos. 812 and 813; also, No. 162.)

Mic. No. 140(1) is *light red and gray*, and is laminated by a distinct fluidal structure, the thinnest laminæ being less than a thirty-second part of an inch in thickness, and some of the red, amorphous rock being simply striped with a translucent layering, or with a buff-white substance which appears more abundantly in some places, as in No. 140(12). The fluidal structure curves round the feldspar and quartz phenocrysts, and sometimes presents a perlitic structure, as represented in No. 140(7). The quartzes are corroded, and the reddened magma enters them some-

*As collected the specimens bearing this number represent a varied lithology, and for the purposes of description they are here further designated by subordinate numbers in parentheses.

times beyond the centre of the crystal. A vitreous feldspar is cut approximately perpendicular to the axis n_g and affords extinction at $3\frac{1}{2}°$, indicating andesine-oligoclase or oligoclase. The quartz of the matrix is micro-granitic, not poikilitic. A section made perpendicular to the fluidal lamination presents a perlitic structure throughout (plate I, figure 5), but in one parallel to it this structure is barely visible.

Three sections.

Mic. No. 140(2). *This seems to be identical with No. 140(7)*, except that the lamination is less regular. Brick red.

Two poor sections.

Mic. No. 140(3). *Brick red, similar to No. 140(2)*, contains quartz and a glassy feldspar.

Three poor sections.

Mic. No. 140(4). *Dark brown*, laminated in a manner similar to No. 140(1), contains quartz and feldspar phenocrysts in the midst of a perlitic fluidal structure.

Two poor sections.

Mic. No. 140(5). *Brown, or brownish gray*, resembling in general aspect the rock of the bulk of the Great Palisades, but still having a finely laminated fluidal structure, which is generally not evident in that rock. It is crossed by veinings of coarser secondary quartz.

One section.

Mic. No. 140(6). *Brown, but fading through light brown to reddish brown and to a dirty buff white*, like No. 140(12), the colors being irregularly distributed, but governed by the fluidal lamination whenever it is preserved. The specimen, however, appears to show that when plastic the magma had been folded and perhaps broken, and molded upon itself. The rock contains quartz and opaque feldspar, but not the glassy feldspar.

One thick section.

Mic. No. 140(7). *Brick red, laminated.*

The slide consists essentially of three distinctly separate portions:

1. Opaque, red, non-crystalline material.
2. Minutely crystalline substance, giving aggregate polarization.
3. Porphyritic crystals, clear and perfect.

The first shows a fluidal structure very beautifully streamed about the porphyritic crystals, but with this streamed structure is involved much of the minutely crystalline substance (2). In some cases No. 2 lies between the non-crystalline substance and the crystals, and in other cases the non-crystalline substance is in immediate contact with the crystals. The red substance is only a stained part of the slide, the color being hematite red. It makes up most of the rock, but the mineral which has

become stained is the same that is minutely crystalline in No. 2. The reddening ingredient is more or less abundant in the same structure throughout. When it becomes scant, the minutely crystalline mineral becomes apparent; when it is wanting, the minutely crystalline substance has its typical appearance. It looks as if these may have both been produced by an alteration of an original glass, the reddened aspect being due to the access of much ferric oxide.

But the minutely crystalline substance has two forms. One is streamed, and changes to opaque red by increase of ferric oxide. This gives a finely flecked polarization when it is clear, but in the main, between crossed nicols it is gray or nearly dark. The other part gives a minutely fibrous polarization, and has a yellowish tint. This second part has a close relationship with the porphyritic crystals, which it sometimes entirely surrounds in a series of undulatory concentric bands, thus excluding part No. 1 entirely from contact with the crystals. This undulatory surrounding is not always a fluidal structure, but a secondary growth. It occurs in many instances in isolated areas, without the presence of the crystal, and it is in all cases abruptly separated from the other minutely crystalline part. In the gross this second part of the minutely crystalline substance produces the evident magascopic fluidal form, but its minute structure is fibrous independently of that, and it has a preference for the proximity of the crystals. It is probably a segregation from the magma, later than the crystals, but not able to assume a crystalline form. Its fibres have a parallel extinction and a positive elongation.

The feldspar crystals are the most interesting portion. Some years ago the writer made an examination of these crystals and came to the conclusion that they were *adularia*, a form of orthoclase, and so published it. Subsequently, Prof. Irving declared them to be quartz, and without any further examination Irving's determination has been accepted. This rock, and the rock of the Great Palisades which immediately overlies it, really constituting one bluff, has usually passed for quartz-porphyry, on the authority of Prof. Irving. Pebbles from this rock constitute great conglomerates, being very durable, particularly on the south side of lake Superior.

A close inspection of these crystals with a common loop shows occasionally, though not usually, a cleavage parallel to one of the sides. The forms are not hexagonal, but this fact was presumed to be due to corrosion by the magma. Their sections in the slide are not hexagonal. They are of all shapes, such as a monoclinic crystal would give. They are never twinned, but simple, glassy, resembling quartz in having a conchoidal fracture and in the colors of polarization.

In one of the slides examined is a section perpendicular to n_g, quite characteristically manifested. It has an extinction angle with cleavage of 9°.

Three trials with hydrofluosilicic acid give chiefly characteristic crystallites of potassium by the Boricky method. Amongst these are also a few inclined crystals of fluosilicate of lime, and many smaller, less brilliant, hexagonal forms, indicating sodium.

A good cleavage grain, parallel to the easy cleavage 001, shows the cleavage 010 by reason of the rectilinear edges of the overlapped lamellæ 001; and the extinction here is 2.5° to 3.5°. Another grain parallel to 010 in like manner shows the cleavage trace of 001; here extinction is 9.5°. Specific gravity is 2.61, by Westphal balance, in iodide of methylene.

These characters agree in pointing to *anorthoclase* as the nature of the translucent crystals in the red fluidal base of the Great Palisades. (Fouqué, Bulletin de la Société de Minéralogie de France, vol. xvii, page 428.)

Below are the forms of some of these crystals as they appear in the section (figure 15):

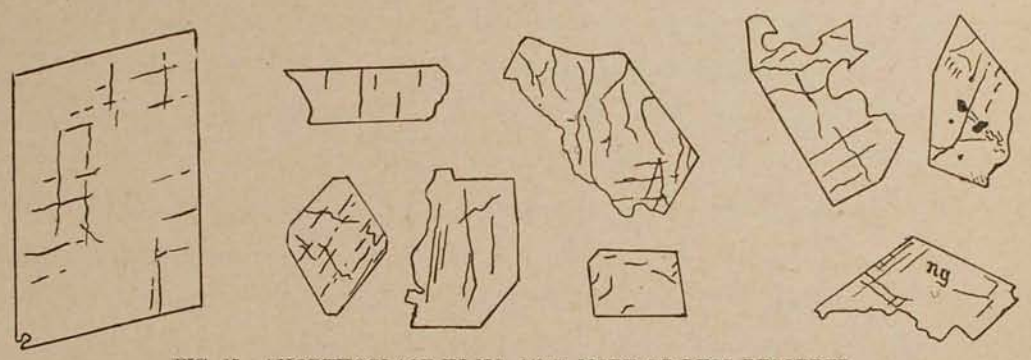


FIG. 15. ANORTHOCLASE IN NO. 140(7) MORE OR LESS RESORBED.

Still, there are other glassy crystals in the same rock, situated in the red matrix in a manner quite similar to the foregoing, which do not show plainly any regular cleavage. They are fractured along lines quite irregular and arbitrary, and they appear like quartz phenocrysts. One section is plainly uniaxial, having a hexagonal outline, and must be quartz. Several others cannot be distinguished from quartz, though they may be feldspar. The double refraction of quartz is so nearly that of anorthoclase, and of both it is so low, that they cannot be distinguished by the colors between the crossed nicols. In this rock they show clear and limpid, almost colorless sections of the thickness of .02 to .03 millimeters.

That Irving mistook these anorthoclases (which are the "adularia" referred to by the Ninth Annual Report, pages 21, 33, etc.) for quartz is evident from an examination of his report (Monograph v, U. S. Geol. Survey, Copper-bearing Rocks of Lake Superior, 1883, pages 95 to 112). He mentions, it is true, *orthoclase* as a porphyritic constituent of this felsyte, as well as *oligoclase*, and some little crystals are represented in figure 9 of plate XIII;* but in describing them he says:

*Op. cit.

"The porphyritic feldspars in the thin section are found to be either or both of orthoclase and oligoclase. *They are always turbid from decomposition, and are more commonly red-stained than not.* They have always crystalline outlines, or, when they have been eaten into by the still fluid matrix, as is not seldom found to have been the case, at least the remnants of such outlines."

The stained orthoclases are very distinct from these anorthoclases. They are a conspicuous feature of most of the rock of the Great Palisades. The anorthoclases are glassy and never stained by secondary changes. They are found to include particles of the glassy magma, now reddened by iron oxide, and thus to be opaque in small spots, but these inclusions are very distinctly different from the general staining or turbidness ascribed to the orthoclases by Irving. The determination of "adularia" by the writer was made by Wallaston's goniometer on the surface angles of some isolated crystals, and on some thin sections made for microscopic study. At the same time the fact that porphyritic quartz was also present in this rock was not detected, the evidence of the surface angles being applied inferentially to all the translucent crystals.

The reddened matrix shows distinctly a fluidal structure, viewed at large, and under the microscope it is apparent in the "streaming" which crowds round the corners of the crystals and which spreads out into fan-shaped and streaked areas. The whole section is occupied by such evidences of flowage. It is more evident here than in the bulk of the Palisades, and may be due to a second fusion superinduced by the intrusion of the great basic sill (?) of later date (?) which underlies the cliff, and which separated the Palisades from the similar rock appearing about a mile below the mouth of Baptism river.

There is, however, a more minute structure pervading the matrix of these crystals, which is to be ascribed to the contracting effect of the period of cooling. The rock being glassy or microfelsitic, it seems to have taken on various curved fissuring, by reason of which the peculiar ferritic circles and loops were afforded opportunity to locate themselves. There are also straight fissures, indicated now by the needle-shaped ferritic lines. There is sometimes a grouping of angular areas, each included between four or more straight reddened cracks, in each of which is a series of curled and non-connecting red lines. The curling is mainly in individual groups or areas, but sometimes the curves are crossed by the straight boundaries; rarely the straight lines themselves part and blend with the curved lines.

The second form of minutely polarizing substance in this rock, which gives the megascopic fludial or banded aspect, has also a unique microscopic fibrous structure. It shows but rarely, if ever, a distinctly fluidal arrangement, yet when, as frequently happens, one of the porphyritic crystals lies in this substance, there is sometimes a

striated or finely fluidal arrangement of the material parallel to its contours, and a crowded condition at its angles. Generally, however, this substance is isolated in the midst of the brick-red felsitic material. In both cases, when both nicols are used the fluidal structure disappears entirely and another crystalline structure stands out. In ordinary light the distribution of the impurities when not adjacent to the crystals gives the whole area the appearance of a summer cumulus cloud, the only colors being different shades of a yellowish brown, passing to yellowish white; but between crossed nicols a fibrous crystallization is apparent, standing radially perpendicular to the exterior surface. This is sometimes in layers or aggregations which correspond in general to the forms of the cumulus seen in ordinary light. These crystalline fibres may be of thalite, since the hardness of these areas is so low that they can be slightly crumbled into a floury powder under the thumb-nail and have the opaque, sub-resinous lustre of that mineral. The openings in which these crystalline fibres were thus arranged, somewhat in a botryoidal manner, were not caused by shrinkage, like the cracks that exhibit the perlitic structure, but are an incident of the flowage. The original substance was probably a form of the glassy magma, slightly different from the rest of the magma, such that in being devitrified it received the magnesian constituents of the glass and rejected the most of the iron oxide. Although generally elongated they have not the origin, nor the axiolitic structure described by Zirkel (Exploration of the Fortieth Parallel, vol. vi, page 166) in the western rhyolytes. (See, also, under No. 571.)

Three sections examined.

Remarks. The above described perlitic structure is a well known character of rhyolytes and glassy volcanic rocks. It is illustrated by the photograph seen in figure 6, plate I. The central portion of this figure also contains a view of one of the anorthoclases cut parallel to the brachypinacoid (010) with a corroded embayment in one corner. Figure 5, of plate I, shows the same structure, here embracing a quartz phenocryst with several embayments of the matrix.

Mic. No. 140(8). Identical with No. 140(7), except that the coarse laminated fluidal structure is wanting. The thin section, however, shows a micro-fluidal structure, which arranges itself about the phenocrysts.

Two sections.

Mic. No. 140(9). Dark brown, with lighter laminations along the fluidal partings, some of them being of quartz, some of the brick red substance composing the bulk of No. 140(7) and some of them of a lighter red felsyte; contains quartz and reddened feldspar phenocrysts. The sections show a minute fluidal structure.

Two sections.

No. 140(10). Similar to No. 140(9), but darker, yet spotted with a substance that is nearly white—like No. 140(12). These whitened spots are sometimes very

fine, and are sometimes distributed in the darker rock, somewhat as the spots described by Bayley in the slates and quartzytes of Pigeon point,* but in general the whiteness is coincident with certain of the laminations. It also surrounds the quartzes.

Two sections.

Mic. No. 140(11). Is almost identical with the general rock of the Great Palisades. Its only difference is in the existence of a megascopic fluidal structure, coincident with which are some lighter stripings. The feldspars are also not glassy but opaque, with red and white products of decay. It has evidently been broken and baked. Fine fracture-seams cross it. These are sometimes filled with quartz, but more frequently with a darker-brown cement. In other fissures there is evidence that the openings were the avenues of entrance of some decoloring foreign substance, for along the fissure on either side is a narrow film of light red, or of pink.

One section.

Mic. No. 140(12). White, buff-white, or pinkish white. This rock possesses all the characters, both megascopic and microscopic, of the others of this series, except the color. By some means the coloring matter (ferric oxide) has been removed. It constitutes but a small portion of the rock mass. It shows a coarse laminated structure, due to flowage, the laminæ being curved.

Chemical analysis. An analysis of this rock (No. 140) gave the following result:

SiO_2	69.66
Al_2O_3	11.49
Fe_2O_3	3.95
FeO	.60
CaO	2.64
MgO	.71
K_2O	1.08
Na_2O	1.15
H_2O	8.55
Total,	99.83

Age. Cabotian; red-rock series.

Remark. The whole of the specimens numbered 140, described above, are derivatives from No. 139. They show gradations from the normal rock to the most varied, of which probably 140(12) is the extreme. It is one of the most evident facts, all along this coast, that fragments from a "red rock" are included in a coarse diabase showing the later date of the diabase. The characters of the lowest visible portion of the face of the Great Palisades, as expressed in the above descriptions, agree with the field relations in pointing to the immediate subterposition of this diabase, and they all point to the earlier date of this rock than that of the diabase. In other words, the phenomena all warrant the supposition that the diabase itself refused the lower part of the "red rock" and imparted to it more evident fluidal characters. The age of the "red rock," here represented by No. 139, is hence considered Cabotian, and that of the diabase a later eruptive of the Cabotian, but perhaps nearly cotemporary.

N. H. W.

* *Bulletin cix.* The eruptive and sedimentary rocks of Pigeon point, p. 72.

No. 141. Diabase *(with olivine)*.

Dark green igneous rock, like No. 112, which holds the feldspar masses. This *seems* to lie under the Palisades, as it comes in at once on the coast east of Palisade creek, the rock of the Palisades suddenly disappearing with dip toward the lake; continues to near Baptism river.

Ref. Annual Report, ix, pages 36, 39; Annual Report, x, page 139; Proceedings American Association for the Advancement of Science, vol. xxx, page 162; Bulletin ii, pages 98, 99.

Meg. A dark grayish brown diabase of rather coarse grain. The weathered surface is filled with pits from which some mineral, probably olivine, has been removed.

Mic. *Plagioclase*, *augite* in large plates, and *magnetite*, constitute the most of the section. The rock is a diabase. Some areas of a green mineral, similar in position and character to that described in Nos. 136 and 137, are present. There are also dark brown, almost opaque, areas which are thought to represent original olivines, now altered to the brown *bowlingite* seen in No. 133. Dr. Wadsworth (Bulletin ii, page 99) says that this brown substance is closely like the hisingerite of the Ovifak basalt.

One section.

Age. Cabotian.

Remark. This rock is apparently part of the great mass which has been already described as holding fragments of the anorthosyte in the vicinity of Beaver bay.

U. S. G.

No. 142. Basalt.

Baptism river; N. W. ¼ N. E. ¼ sec. 4, T. 56–7 W.; 335 feet above lake Superior, and about thirty rods above the fourth falls of the river. About one-fourth of a mile above this the river, and country generally, undergoes a marked change, the former becoming slow and broad, and the latter level or undulating, without visible rock in either. The rocks here consist of alternations of trap, or basalt, with amygdaloid, similar to the layers of Agate bay, dipping N. W. 20°. The lower beds of basalt form shelving points and bars across the river, but the upper ones are in the bluff on the west side, which is thirty-five or fifty feet high. There are at least sixteen beds of basalt, more or less distinct, but they are not so thick as at Agate bay. Here they are from three to five feet thick, and all dip in the same direction. The fourth fall is made by one of these, more coarsely crystalline than the others.

Ref. Annual Report, ix, page 36.

Meg. A very fine-grained, compact, dark gray rock. It has a few areas, apparently amygdaloidal, of quartz and two smaller ones of a soft white substance.

Mic. The section is composed of *plagioclase* microliths, small grains of *augite*, *iron ore*, *chlorite* and confused, dirty, cloudy areas, which are in part at least alteration products of augite. *Quartz* is present in minute grains all through the rock, and is regarded as secondary.

One section.

Age. Cabotian.

Remark. As noted above in the field description, this rock is one of the basalt layers which alternate with amygdaloidal layers, as at Agate bay. The rocks here are regarded as of the same age as those at Agate bay (see Nos. 94 to 102). The dip to the northwest here seems to be anomalous. U. S. G.

No. 142A. Basalt. *(Amygdaloidal.)*

Evidently from one of the amygdaloidal layers mentioned under No. 142. But there is no mention of this number (142A) in the field notes in the Ninth Annual Report, page 36.

Meg. A very fine-grained, reddish-brown rock, filled with laumontite amygdules.

Mic. Small, lath-shaped *plagioclases*, more or less reddened, a little *augite*, *magnetite* and *hematite* constitute the slide (except the laumontite). The rock has been much altered. The *laumontite*, which fills the amygdules, has penetrated the whole rock and has replaced a large part of it.

Age. Cabotian.

Remark. This rock is similar in structure and occurrence to Nos. 95, 97, 99 and 101, at Agate bay. U. S. G.

No. 143. Diabase.

The rock which forms the fourth fall of Baptism river. The fall embraces the whole river in one narrow cleft and descends nearly perpendicularly. It is more crystalline than the others, and is very much more so than is No. 142. It resembles the great diabase Nos. 112, 141, etc.

Ref. Annual Report, ix, pages 36, 37.

Meg. A rather coarse-grained diabase, showing lustre mottling.

Mic. A usual section of coarse diabase, consisting of plagioclase, augite, magnetite and alteration products. Rock somewhat altered.

One section.

Age. Cabotian. U. S. G.

No. 144. Diabase *(at contact)*.

Baptism river. "The river bed is then filled with large boulders of No. 143 for some distance, and all dip and strike are lost. The next that appears is a closely-jointed dark rock, sometimes having red belts, and calcite seams, but mainly black. In this kind of rock is an abandoned exploration for copper, some distance above [below] the fourth fall. There are also in the river bed along this place, large detached masses of feldspar rock."

Ref. Annual Report, ix, page 37.

Meg. A dark-gray, compact, very fine-grained rock whose constituents cannot be distinguished, but which has the appearance of a very fine-grained diabase. Along seams the rock becomes brown. Another specimen, also marked No. 144, is a very fine-grained, red-brown, siliceous rock, looking like a vein rock, which contains some calcite. This probably represents the "red belts" spoken of above and is not represented by any section.

Mic. The section is composed of *plagioclase*, *pyroxene* and *magnetite*. The plagioclase is in microliths and in more or less allotriomorphic individuals which are frequently larger and of later date than the microliths. With this allotriomorphic feldspar is pyroxene in small, irregular grains, much charged with magnetite. The latter mineral is very abundant in the section. In general structure and composition this rock is very similar to No. 131, except that No. 144 is much finer grained than No. 131, and the pyroxenes are not so distinctly rounded as in No. 131.

One section.

Age. Cabotian. U. S. G.

Remark. Taken together, and considering the manner of association, the two rocks here described probably represent the great diabase sheet already mentioned (No. 143) near its contact with the "red rock" Cabotian, and included fragments of the "red rock." It is noteworthy, also, that the red rock here included is an apobsidian, rather than an aporhyolyte, thus agreeing with the character of the red rock known to exist near this place, viz., the pebbles in No. 149. N. H. W.

No. 145. Aporhyolyte.

Baptism river, third fall. This rock is somewhat finely amygdaloidal and weathers into rough slates, which are again cut by joints into lenticular pieces that present their sharp corners as their neighbors fall out. These slates have a dip north. Indeed, the rock No. 145, so far as it appears along the river here, has shown a dip northwardly, but only occasional exposures occur, generally low and water-covered. The rock here rises above the top of the falls about thirty feet, the whole hight being 105 feet.

Ref. Annual Report, ix, page 37.

Meg. An aphanitic, hard, pinkish-gray rock with numerous phenocrysts of quartz, and white, more or less decayed, feldspars. On a perfectly fresh fracture incipient cracks are noticeable and these are of a white color.

Mic. The groundmass of the rock is essentially like others of the aporhyolytes already described (see Nos. 138 and 68), and the areas of poikilitic *quartz* are quite large. The quartz phenocrysts are similar to those in the other specimens described (Nos. 138, 139, 140) and some of these crystals are distinctly bipyramidal. Frequently the quartz of the groundmass adjoining a quartz phenocryst has the same orientation as the phenocryst. The porphyritic *feldspars* are quite frequently partly replaced by *calcite*. Usually these feldspars break up into numerous small irregular areas of darker and lighter shades. This appearance is especially prominent when near the position of extinction. There seems to be in each crystal only two orientations for these patches, and they extinguish very nearly together. Occasionally a fine twinning, probably albite, is seen in parts of the feldspars, and in such cases the extinction is closely parallel to the twinning lamellæ. A grain which gave a positive bisectrix almost perpendicular had an extinction of about 5°, but such a result is not distinctive as an almost similar result could be gotten from orthoclase and oligoclase. The closely parallel extinction, the twinned grains and the presence of calcite as an alteration product would seem to point to oligoclase. It thus seems that we here have an intergrowth of *orthoclase* and *oligoclase*.

There are a few small areas, now filled with *magnetite*, *hematite* and *chlorite*, which seem to represent old phenocrysts of a ferro-magnesian mineral, but what it was is uncertain. One grain of *rutile* was seen.

Three sections.

Age. Cabotian.

Remark. The aporhyolyte at the third fall of Baptism river (No. 145) is evidently a part of the same mass that forms the Great Palisades (Nos. 138, 139, 140). U. S. G.

No. 146. Diabase *(with olivine)*.

Second fall of Baptism river. This fall is divided into two parts, and the samples are from the top of the first part of the fall. Dip northwest, but less than further up the river.

Ref. Annual Report, ix, page 37.

Meg. A medium-grained, brownish gray basic.

Mic. The minerals are evident and rather well preserved, though not intact, the thickness of the section being such that they are considerably obscured by the included impurities. In this respect the rock is more like an offshoot from the great Beaver Bay diabase than like the strata with which it is associated. The *olivine* is much affected by *magnetite* inclusions, but some of the grains still preserve their power to polarize light, a fact which has not yet been found to prevail in the older Cabotian effusives.

One section.

Age. Cabotian.

N. H. W.

No 147. Basalt.

One of the fine-grained alternating trap-sheets, lying between amygdaloidal sheets about one-fourth mile below the second fall of Baptism river. From the layer which slopes into the river from the left bank at an angle of about 15° toward the west, 15° north. Above this rises a bluff about eighty feet, composed of trap and amygdaloid beds.

Ref. Annual Report, ix, page 38.

Meg. This rock is hard, fine-grained, but somewhat amygdaloidal in places, with laumontite.

Mic. The augite and olivine are replaced by ferruginous impurities and can only be identified by their forms. The feldspar microliths cut through the groundmass in the usual independent manner.

One poor section.

Age. Cabotian.

N. H. W.

No. 148. Diabase *(with olivine)*.

At the first fall of Baptism river. There is an apparent anticlinal axis, and this rock is from the lowest stratum over which the other strata seem to pass, dipping in opposite directions. The dip changes here from northwest to southeast. This presents a somewhat basaltiform structure. Below the fall the bluffs are about 100 feet high.

Ref. Annual Report, ix, page 38.

Meg. A medium-grained, dark gray, heavy rock.

Mic. Presents the usual characters of an *olivine* diabase, but it also has the ophitic relation between the *plagioclase* and the *augite, i. e.,* it is lustre-mottled, the latter mineral embracing several crystals of the former.

Age. Cabotian.

Remark. This rock is probably the equivalent of Nos. 150 and 141. In the form of an offshoot it probably forms the dike represented by No. 152, and by means of a fault it is also raised to constitute the brink of the first fall of Baptism river, or

rock No. 143. It is the same great diabase which began first to be seen at Silver creek, and which is traceable to this place, and much further. For a detailed representation of the stratigraphy at Baptism river see Part III. N. H. W.

No. 149. Conglomerate. *(Red.)*

About one-half mile below the first falls of Baptism river. This rock appears on the east bank, dipping, with a synclinal bend, 10° south, by 10° east. It is isolated from all other outcrops and the dip of all strata seen further up the river would cause this to overlie them if there be no other irregularity. Runs twelve rods along the shore, the greatest exposure being eighteen feet; varies to a red sandstone, but the greater portion is full of pebbles. Some of the pebbles are six inches across, but generally they are smaller.

Ref. Annual Report, ix, page 38; Annual Report, xiii, pages 100 (No. 160), 103.

Meg. In addition to the field description, this rock may be said to be made up essentially of volcanic materials, evidently derived from the Cabotian eruptives of the region. The larger pebbles are of apobsidian and volcanic débris of the same, and the finer of the same and of softer elements. It is largely cemented by *calcite*. It has the appearance of the conglomerate at the Calumet and Hecla copper mine on Keweenaw point, but lacks, so far as known, metallic copper and quartz-porphyry. It is also somewhat less firm than that.

Mic. The composition of this conglomerate is almost exclusively of devitrified *glass* (with calcite cement), some of it being almost entirely of glass still. The pebbles show scattered small spherulitic growths, and a few indeterminable microliths, yet some of them are themselves composed of an earlier volcanic grit or tuff, in which the constituents are finer and angular, and embrace both quartz and plagioclase.

Two sections.

Chemical analysis. An analysis of this rock gave the following results:

SiO_2	66.72
Al_2O_3	7.41
Fe_2O_3	10.13
FeO	.69
CaO	3.10
MgO	4.06
K_2O	.42
Na_2O	.86
H_2O	5.32
Total	98.71

Age. Puckwunge; supposed base of the Potsdam.

Remark. This conglomerate is believed to be somewhat lower than that seen at Two Harbor bay, on the west (No. 817), but nearly the same as that seen again toward the east at the lake shore (Nos. 155 and 155A), and to be included in the base of the later division of the Keweenawan for this region, the red pebbles which it contains being derived from the Cabotian volcanic and red-rock series. N. H. W.

No. 150. Diabase.

Baptism river. Basaltic rock nearly in contact with No. 149, but so separated from it by débris of pebbles etc., that its stratigraphical relations to it cannot be seen.

Ref. Annual Report, ix, page 38.

Meg. A medium-grained, lustre-mottled diabase. Probably part of the great Beaver Bay sheet mentioned before (see, especially, remarks under No. 148).

No section.

Age. Cabotian; Beaver Bay diabase. U. S. G.

No. 151. Aporhyolyte.

Baptism river. A short distance below No. 150. Occupies the bed of the river at first, but gradually rises so as to form high bluffs.

Ref. Annual Report, ix, pages 38, 39.

Meg. A very fine-grained, pinkish-gray rock with phenocrysts of quartz and a gray to flesh-colored feldspar, some of which, at least, is plagioclase.

Mic. A good example of an aporhyolyte with poikilitic quartz in the groundmass. In this case, however, the feldspathic material of the groundmass is in larger grains than are common in the similar rocks already described. The *feldspar* phenocrysts are altered and clouded, but some still show two sets of twinning lamellæ crossing each other almost at right angles, and thus resembling *microcline*. A cleavage section parallel to the base of one of the fresher feldspar crystals gave an extinction angle of about 2.7°. This section shows very minute twinning lamellæ which, unless carefully examined under a high power, are easily mistaken for cleavage lines. The section also appears perpendicular to the optic plane. The latter fact, as well as the very minute twinning lamellæ, would indicate that the feldspar was *anorthoclase*, rather than oligoclase. A micro-chemical preparation, with hydrofluosilicic acid, showed large amounts of soda and a little potash.

Age. Cabotian; red-rock series.

Remark. Evidently this rock is the equivalent of the Great Palisade rock (Nos. 138 to 140) and of No. 145. Just below it, on the right bank, is an outcrop of rock like the aporhyolyte of Beaver bay (No. 127). U. S. G.

No. 152. Diabase.

Baptism river. Finely jointed, compact, basaltic, forming a precipitous high shore on either side of the river, letting the river down to the lake level. This is dike-like in character of rock, but confused and brecciated in outward aspect, forming irregular knobs and escarpments. This is found after an interval of non-exposure in the river bed, after (below) the last.

Ref. Annual Report, ix, page 38.

Meg. A very fine-grained, almost aphanitic, compact, heavy, dark-brown rock, looking like a fine diabase.

No section.

Age. Manitou (?) U. S. G.

No. 153. Aporhyolyte.

Baptism river. A contorted or brecciated, slaty, closely-jointed and laminated, reddish-brown rock, forming the "gate" by which the river enters the lake, rising in bluffs suddenly at the lake shore and shutting in a bayou in the river. This is also porphyritic, and has translucent, square crystals.

Ref. Annual Report, ix, pages 38, 39; Bulletin ii, page 128.

Meg. This is a brown, very fine-grained rock, laminated with narrow whitish bands, the latter being nearly as abundant as the brown parts of the rock. The laminæ, while preserving a general parallel direction, are at times bent and twisted. Sometimes the light-colored bands have a thin layer of quartz in the centre, in this respect resembling No. 127. The hand specimen shows no phenocrysts.

Mic. The rock is composed of *quartz* in poikilitic areas holding the usual impurities of these aporhyolytes and the feldspathic material. Much of this feldspar is in larger grains than is usual in these rocks, and in places there are micropegmatitic areas of quartz and feldspar. Some of the *feldspars*, which are probably *orthoclase* now much altered, have a tendency to exhibit crystal outlines. Scattered thickly through the rock are small, often curving and branching, and more or less disconnected, rods of *hematite*.

One section.

Age. Cabotian.

Remark. This again is probably the equivalent of the rock of the Great Palisades, and like much of that it shows distinct flowage structure—lamination. Some of the feldspar is regarded as original and not as a product of devitrification. In this respect the rock resembles those described under No. 140, which contain distinct feldspar crystals in the groundmass. U. S. G.

No. 154. Aporhyolyte.

From Palisade No. 2, a short distance east of the mouth of Baptism river.
Ref. Annual Report, ix, page 39.

Meg. Undistinguishable from the rock of the Great Palisades. This rock forms a small sharp point, and a high wall facing south; dips northeast.

Mic. Under the microscope it differs from the Great Palisades in presenting large areas of poikilitic quartz, these embracing not only the microlitic matrix, but the phenocrysts of *quartz*, with the latter of which they generally agree in optical orientation. There is an occasional phenocryst of *feldspar*, largely replaced by *quartz* and *calcite*.

Remark. This may not be from the same stratigraphic mass as the Great Palisades. This is indicated by the order of stratification. Under the Palisades is the great Beaver Bay diabase, while under this is a series of alternating trap and amygdaloid layers. N. H. W.

No. 155. Conglomerate. (*Red pebbles.*)

The rock of Palisade rock No. 2 continues easterly with irregular dip, and is seen to contain an intrusive sheet of diabase at about half a mile from the rocky sharp point formed by it. Then succeed, easterly, alternations of trap and amygdaloid, which continue to an exposure of this conglomerate, which dips north at an angle of 8° or 10°, the exposure being thirty feet high. The stones are occasionally a foot in diameter. Toward the east it is metamorphosed by intruded diabase.

Ref. Annual Report, ix, page 39; Annual Report, x, page 42.

Meg. Some of the pebbles are of brown-red amygdaloid, and some are of a grit-rock, made up of the same materials as the pebbles in No. 149, viz.: of clastic grains of apobsidian. The larger pebbles are of this latter sort. Indeed, the large majority of the pebbles are of a clastic rock, apparently a volcanic grit; a calcite cement runs through it. This conglomerate may have been accumulated by some abrasive agent operating on the upturned beds of alternating trap and amygdaloid, such as the Agate Bay series, since in the amygdaloids of that series, and in connection with other amygdaloids further west, a frequent ingredient is a clastic accumulation of devitrified glass. There is in No. 155, as collected, no evidence of the immediate presence of the Palisade rock itself, but the devitrified glass, apobsidian, has supplied a large ingredient in accord with the stratigraphic hypothesis under which the rocks of the lake Superior shore have been divided into Cabotian and Manitou, which requires that the quartz-porphyries, etc., be older than this break and should have furnished debris to such a conglomerate. (See No. 155A.)

No section.

Age. Puckwunge.

N. H. W.

No. 155A. Rhyolyte Conglomerate.

The eastern extremity of No. 155, where hardened and blackened by an intrusion of diabase. Were it not for the visible continuance of the lines of stratification from No. 155 into this it would not be noticed that this is really a conglomerate without close inspection.

Ref. Annual Report, ix, page 40.

Meg. The pebbles are drawn and flattened, but between them is a finer matrix of different composition. Some of the clastic elements are apparently from a fine shale, and one large one is a plain quartz-porphyry.

No section.

Age. Puckwunge.

N. H. W.

No. 156. Diabase.

East of Baptism river. A massive, heavy rock, with a considerable ingredient of red, with jointed and contorted lamination, or in heavy, massive beds. It has much amphibole and much magnetite. In other places it contains orthoclase and laumontite, the latter mineral causing an easy, natural disintegration. This is terminated eastwardly by a doleryte dike fifty feet wide. It seems to be partly derived from the igneous rocks themselves, mixed in eruption with fused portions of the sedimentaries.

Ref. Annual Report, ix, page 40; Bulletin ii, page 79.

Meg. There are two hand samples. The first is a coarse, crumbling rock composed of pinkish and gray feldspar and a dark mineral with glistening metallic

cleavage faces. The second is considerably finer grained and redder; it is composed of pink and white feldspars and smaller grains of black minerals. A few long acicular feldspars are also seen.

Mic. The section from the first hand sample shows a coarse diabase. The feldspars are mostly kaolinized; one of the fresher ones gave a negative bisectrix almost exactly perpendicular and an extinction angle of 61°, indicating *labradorite*. The feldspars are usually in short lath-shaped forms, and frequently several of these are grouped together with their long axes parallel. The *augite* is brownish, is in plates of considerable size, later than the feldspars, and is altering to an opaque mass composed largely of *magnetite* and *hematite*. The section from the second hand specimen shows a similar rock, with the feldspars more nearly allotriomorphic, much altered and reddened, and with less but more highly altered augite.

Three sections.

Chemical analysis. The following analysis was made by professors J. A. Dodge and C. F. Sidener:

SiO_2	50.86
Al_2O_3	15.72
Fe_2O_3	9.77
FeO	2.48
CaO	10.52
MgO	3.55
Na_2O	3.89
K_2O	.90
H_2O	2.53
Total	100.22

Age. Manitou (?) U. S. G.

No. 157. Granite.

Near the western side of the broad, shallow bay on sec. 30, T. 57–6 W. Forms a high bluff for ten rods, and is terminated by a dike. (See No. 636.)

Ref. Annual Report, ix, page 40; Annual Report, x, page 64.

Meg. A medium-grained granitic rock, composed of quartz and pinkish feldspar. Passing through the specimens are some small streaks of a fine-grained brown material which contains minute quartz grains.

Mic. The section shows *quartz*, cloudy *feldspar*, *magnetite* and *hematite*.

One section, which is too thick for study.

Age. Cabotian; red-rock series. U. S. G.

No. 158. Diabase. *(Amygdaloidal.)*

The rock first west of Little Marais; trap and amygdaloid, the latter having saponite (?) as a coating for the other amygdaloidal minerals, which are calcite, stilbite and apparently scolecite, as well as heulandite.

Ref. Annual Report, ix, page 41.

Meg. There are two hand samples. One is a fine-grained, dark-brown rock, looking like a diabase. It is permeated by a green substance, and is not amygdaloidal. The other sample is a fine-grained, almost aphanitic brown rock, containing

abundant amygdules of *saponite, calcite, stilbite, mesolite* and *heulandite*. While the saponite is usually soft, and coats the other amygdaloidal minerals, in the case of the mesolite it is intimately intermingled and becomes very hard (lintonite?) The mass of the rock has also been so permeated by decay that saponite is formed throughout it.

Age. Manitou.

N. H. W. AND U. S. G.

No. 158A. Stilbite, etc.

Same locality as No. 158.
Compare Nos. 630, etc.
Ref. Annual Report, ix, page 41.

Meg. The sample is like the amygdaloidal sample of No. 158, and contains one large mass of stilbite in the midst of which are also laumontite and mesolite. The last gelatinizes readily in hydrochloric acid, and fuses easily to a white porcellanous bleb.

N. H. W. AND U. S. G.

No. 159. Amygdaloid.

From the extreme east end of Little Marais bay, underlying No. 160, which forms the point on the east side of the bay.
Ref. Annual Report, ix, page 41.

Meg. Outwardly this amygdaloid in the field is associated with fragmental and brecciated material, being probably the upper surface of a lava flow, more or less worked over by atmospheric and aqueous agents.

Mic. The rock itself is porphyritic with feldspars of small dimensions, and shows many that are microscopic. It does not differ essentially from the basic amygdaloids which prevail along this part of the lake Superior shore, being closely allied to No. 158.

It contains two zeolites. One of them, having an easy, flat cleavage, affords a lot of thin flakes which, in convergent light, show n_g perpendicular to the cleavage. The acute angle of the optic axes seems to be small, as the whole interference figure is visible even without the use of methylene. A measurement by Lacroix's axial goniometer gives $2E=78° 46'$. This zeolite is evidently *heulandite*, its appearance also being quite similar, megascopically, to that found in No. 637.

Sometimes this mineral shows a shaded banding resembling a kind of albite twinning apparent in the thin flakes. When the flakes are thick the interference figure does not form a perfect dark cross at any time, but still exhibits characteristically the loci of the optic axes.

The other zeolite is *laumontite*, having a fibrous, yet occasionally a laminated, structure, the latter parallel to 010, and the axes n_m perpendicular to the face 010. Extinction makes an angle of 28° with the elongation which is parallel to the edge 100:010.

Two sections examined.

Age. Manitou.

N. H. W.

No. 160. Diabase.

"From the point that protects Little Marais from the east, and occupying, in the form of basaltic trap, the coast for two and a half miles further east, rising in some places about 100 feet, the conglomerate sometimes rising fifty feet above the lake, making a bold and dangerous strip of coast for small boats. The two interlock and blend in stratification, and the conglomeratic characters particularly become confused, and even lost, apparently passing into amygdaloid. The dip is toward the lake in the main, but there are spots where the dip is invisible. These extend to and beyond the Manitou river (see Nos. 628 and 629)." This has a conspicuous basaltic structure.

Ref. Annual Report, ix, page 41; Annual Report, x, pages 42, 61, 63, 139; Proceedings American Association for the Advancement of Science, vol. xxx, page 162.

Meg. A brownish, diabasic rock of rather fine grain, more or less permeated by reddish substance, appearing like a stain.

Mic. A diabase, composed of *plagioclase*, *augite*, *magnetite*, *hematite*, *chlorite* and a reddish alteration product which may represent *unindividualized magma*. There are some larger areas of feldspar which appear somewhat like porphyritic crystals, but without good crystal boundaries. Under polarized light these areas break up into aggregations of the usual feldspar laths.

One section.

Age. Manitou. U. S. G.

No. 161. Diabase.

From the shore at the town line between ranges 5 and 6 (on section 36), east of Pork bay. Apparently a layer in the midst of brecciated amygdaloid and conglomerate. Some of this breccia holds what appears like mesolite and thalite; other parts hold calcite and perhaps prehnite.

Ref. Annual Report, ix, page 42; Annual Report, x, page 140.

Meg. These parts are not evenly disseminated, but often are found in patches or lumps closely aggregated, the rest of the rock having less.

Mic. In general this is an ophitic diabase, much decayed, consisting of a plagioclase (probably *labradorite*) *diallage*, *magnetite* and *olivine*, with their products of decay. The change in the olivine has produced, generally, a hematitic red, amorphous, opaque substance. Disseminated abundantly throughout the rock, though not so abundant in the thin section examined, is the soft, greenish or grayish soapy mineral which was named *thalite* by Owen, but which is regarded by Dana as a form of *saponite*. It is a secondary product, and has gathered in the cracks of the rock. It has not the form of amygdaloidal filling, but is found finely distributed among the other minerals. From what mineral, or minerals, it is chiefly derived, is not evident, but it is highly probable that the olivine was largely instrumental in its formation. It is more fully discussed in connection with other numbers where it is more favorably exposed and occurs in larger quantity. (Compare Nos. 91B, 162 and 193.)

One thick section.

Age. Manitou. N. H. W.

No. 161A. Heulandite. *(Veins.)*

Veins from two to four inches wide, run irregularly in No. 161. Apparently these mark openings in No. 161 through which corrosive vapors or waters have passed, converting the rock on either side into a finely granular brown mass in which heulandite is the only identifiable mineral.

Ref. Annual Report, ix, page 42; Annual Report, xiii, pages 100 (No. 161), 103.

This brown rock was analyzed by Prof. J. A. Dodge with the following result (Annual Report, xiii, page 100):

SiO_2	50.31
Al_2O_3	14.17
Fe_2O_3	10.96
FeO	1.09
CaO	8.44
MgO	5.86
K_2O	0.46
Na_2O	0.90
Water	7.63
Total	99.72

Age. Manitou.

N. H. W.

No. 161B. Mesolite. *(Pebbles.)*

From the beach, supposed to be thomsonite when gathered. Derived from the top of No. 161.

Ref. Annual Report, ix, page 42.

Meg. This is a very hard and tough milky white, finely fibrous mineral, the pebbles sometimes being more than an inch in diameter. It is not conspicuously ornamented with the bands and cat's-eyes seen in the typical "thomsonite" of the region.

Mic. In a section made parallel to the fibrous structure, the fibres are seen to be very fine and short, interlocking and overlapping in a strong, dense, elongated, feathery network, which between crossed nicols is nearly opaque by reason of the overlapping of the fine fibres, giving only scattered acicular bright points, but amongst which are distributed many more minute light points. These acicular crystals have a negative elongation and show sometimes the terminal forms of monoclinic or triclinic crystals. They extinguish when nearly parallel with the axes of the nicols. They are frequently pointed at both ends, which is distinctly seen in polarized light, the rest of the field being dark. The polarization colors are very low or about that of quartz when viewed in this direction. It is evident that there is a banding, or zonal structure, which crosses the direction of the fibres at right angles. This is apparent on viewing the thin section with the naked eye.

Another section, made thinner, at right angles to the direction of the fibres, is still slightly fibrous, a few of the fibres apparently running nearly at right angles to the main structure of the mineral, but in general this section is divided into small angular areas which each represent the cross-section of one of the needles. There is not any noticeable difference in the power of double refraction. Gelatinizes with HCl. Fuses rather easily to a white enamel, apparently containing minute bubbles.

Micro-chemical tests by the Boricky method afford many magnificent crystalliths of lime, with hexagonal rods of soda. The hardness, the color, the structure and the

presence of lime and soda, along with the low power of double refraction, conspire to indicate that this is *mesolite*.

Chemical analysis. This white mineral was analyzed by Sharpless and Winchell, with the following result, which is the average of three determinations (1):

	I	II
SiO_2	46.12	46.40
Al_2O_3	29.08	26.30
CaO	10.08	9.60
Na_2O	2.41	5.30
K_2O	....	....
H_2O	12.32	12.40
Total	100.00	100.00

In column II is shown the composition of mesolite given by Lacroix (Min. de France et de ses Colonies, vol. ii, page 278).

Age. Manitou.

Remark. This mineral has doubtless been taken for thomsonite at several points on the Lake Superior coast. This is found in the much decayed amygdaloids of the Manitou in the same manner as the thomsonites of the region. Mingled with this mineral, in mammillated spherulitic forms, is a finely fibrous form of silica which has a positive elongation to which, therefore, the name *quartzine* should be given rather than that of chalcedony. N. H. W.

No. 162. Amygdaloid.

From the same place as No. 161.
Ref. Annual Report, ix, page 42.

Meg. A brown amygdaloid, or at least with many original cavities now filled with a greenish soft substance (the thalite of Owen), much decayed. Some of the larger cavities contain mesolite which, about the circumference, is amorphous and has the dirty greenish color of thalite, but remains hard.

Mic. The *feldspars*, at least the larger ones, are completely filled with inclusions resulting from decay and afford only an aggregate polarization. The smaller feldspars have greater purity and more definite outward form, but still are considerably decayed. They are embraced ophitically in the *augite*.

The original *augite*, as well as the *olivine*, has given place to an opaque or brownish substance (in part *bowlingite?*), probably colored by oxide of iron. Some portions of these decayed and mostly opaque grains still polarize characteristically for augite, but for the most part the augite is lost. The *olivine* cannot be distinguished as such, but many of the opaque spots enclose central translucent areas which probably represent bowlingite or the remains of olivine grains. The brownish red mineral (bowlingite?) is apparently the same as seen in No. 133.

The green substance occupies places whose shapes were determined by the crystallization of the other minerals, and hence they are not round or amygdaloidal. These areas were not occupied by gas, but some substance must have filled them,

probably a portion of the glassy magma, and the present contents are the result of change from the magma. They have the cloudy or *cumulus* aspect of the minutely polarizing substance No. 2, in No. 140(7), and the hardness is about the same. They also have the minutely fibrous structure, arranged perpendicularly to the clouded banding, with extinction parallel with the fibres which are positive in elongation.

Three sections.

Remarks. There is a considerable quantity of this substance in the slide. Sometimes it forms a coating about the zeolitic nests, and is then minutely fibrous, as above described. In other cases it is massive, and completely fills some of the larger cavities. This cannot be affiliated easily with the brown mineral above mentioned as probably bowlingite, yet, according to the distinctions that have been made by Heddle and Lacroix, they are probably the same substance, and may have resulted from the alteration of olivine,* with contributions from the other minerals.

According to Michel Lévy olivine crystals in the basalts of Auvergne are sometimes peripherally and sometimes centrally transformed into a reddish-brown, highly refractive and doubly refractive mineral, having distinctly different optic properties from olivine, which, according to Lacroix, is goethite. This mineral is easily distinguishable from that under consideration, although they frequently have the same color. Bowlingite is less refractive and goethite more refractive than olivine.

In many of the diabases of the north shore of lake Superior olivine has changed partly into a similar brown mineral, first noted in No. 133, and partly into a finely fibrous, colorless mineral. In No. 162 both these conditions are found in the same changed olivine grain, the ferruginous brown mineral occupying the periphery, and the finely fibrous mineral the central area. In one non-fibrous grain a distinct cleavage is visible and can be traced from the brown into the colorless portion, indicating that the coloration is an accidental character. In some cases the central portion is not a clearly cleavable mineral, but a fibrous or a minutely scaly one. When it is fibrous its elongation is positive, but these fibres are in the midst of less fibrous and even of non-fibrous conditions of the same mineral. These conditions appear to belong to the same substance. Olivine is well known to be a favorite gathering place for magnetite whenever those changes take place which provoke its accumulation. In this case the ferruginous element seems to play the part simply of a coloring agent, and to fade out toward the centre of the original grain. It is highly probable that if it were abundant it would manifest distinctly the characters of goethite, as

*On this subject the student is referred to the following authorities:
HANNAY. *Mineralogical Magazine*, vol. i, p. 154, 1877.
HEDDLE. *Transactions of the Royal Society*, Edinburgh, vol. xxix, p. 91, 1879.
LACROIX. *Bulletin de la Société de Minéralogie de France*, vol. viii, p. 97, 1885.
MICHEL LÉVY. *Bulletin de la Société Geologique de France*, xviii, p. 831, 1890.
DANA. *System of Mineralogy*, 1892, p. 682.
IDDINGS. *Geology of the Eureka District, U. S. Geol. Survey*, Monograph, xx, p. 387, et seq.
LAWSON. *Bulletin of the University California*, vol. i, p. 31, 1893.
LACROIX. *Minéralogie de France*, vol. i, pp. 174, 442, 1895.

defined by Michel Lévy. But where it has not grown up in sufficient amount to replace the olivine crystal entirely, the other minerals, such as bowlingite and thalite, have simply been stained by it about their peripheral portions.

Throughout the decayed rock in which these two forms of bowlingite occur (*i. e.*, the crystalline cleaved variety and the fibrous), is an abundant dissemination of the mineral frequently known as saponite. This is a light-green, massive or finely fibrous, soft and soapy substance, whose fibres have a positive elongation, and which cannot be distinguished easily from the light-colored or greenish central areas of the changed olivines. It is the same substance (in part at least) that Dr. D. D. Owen named thalite (compare No. 91B). Between crossed nicols it is frequently nearly isotropic, a character which is due to its finely comminuted or massive structure, but in numerous instances also it is radiatedly and very finely fibrous. Careful examination has shown that its elongation in this condition is positive. There seems to be sufficient warrant for identifying it with the similar mineral which forms the central isotropic areas in the changed olivines, in the midst of which occasionally a positive fibrous elongation is apparent.

Although the crystalline, the fibrous and the massive conditions, whether greenish or brownish, seem to belong to the same mineral, only differing in the amount of iron oxide present as a coloring element, yet for the present it will be best to employ two terms, bowlingite and saponite [thalite], the former for the cleavable crystalline condition (whether iron stained or not) and the latter for the fibrous or massive, usually greenish, condition.

Wadsworth's reference of the brownish mineral in No. 141 to hisingerite, found in the basalt of Ovifak,* could hardly apply to the cleavable mineral here referred to bowlingite, since hisingerite is non-cleavable, black, or nearly black, and has a conchoidal fracture.

The mineral lately described by Lawson (iddingsite) is placed doubtfully, by Lacroix, under bowlingite, but he states that there are such divergences between them, as far as now known, that they cannot with certainty be identified. These consist chiefly in the greater specific gravity of iddingsite, which is given by Lawson at 2.839, whereas that of bowlingite is 2.300. See further respecting this mineral (bowlingite) No. 193.

Age. Manitou. N. H. W.

No. 163. Diabase. (*Amygdaloidal.*)

From Sugar Loaf point, S. E. ¼ sec. 21, T. 58-5.
Ref. Annual Report, ix, pages 42, 43, 44.

Meg. This number embraces two rocks of slightly different aspect, though closely associated in structural relations and origin. They both constitute parts of

* *Bulletin ii* (Minnesota Survey), p. 99.

the much-decayed, alternating trap and amygdaloid of the coast. The darker variety, which forms the upper part of the little peninsula of Sugar Loaf point, is but scantily amygdaloidal, and is permeated with green thalite. It is eighteen feet thick, and dips, with the underlying, 12° toward the south 10° east. The lower part of the rock of the point, about seven feet thick, is more loosely amygdaloidal with calcite, and is confusedly mingled as if in part made up of a breccia, or of breccia and conglomerate. It is probably the upper portion of a superficial lava flow, which was subsequently covered by the trap which constitutes the upper portion of the "loaf." The sample collected from this lower portion of the loaf is marked by pipe-like amygdaloidal cavities now filled with calcite. These pipes are, as preserved, two and a half or three inches in length, and doubtless ascended vertically through the rock, marking the avenues of escape of gases when the rock was cooling. They are round and about one-eighth to one-fourth of an inch in diameter. On the upper surface, on the area of a square inch, there would be, on an average, four or five of these openings. The rock is, besides, more or less permeated by saponite (thalite). This mineral also constitutes a thin first lining in the calcite-filled pipes. Along with calcite is also more or less of thomsonite (?) and chalcedony.

Mic. The thin section shows an ophitic structure and the olivine considerably changed to an opaque ferruginous bowlingite (?) around which can be seen an excess of iron oxide in the form of micaceous hematite, which spreads somewhat into the feldspars and gives a negative uniaxial interference figure. In these thin deposits this red mineral is laminated and pleochroic. A section of the rock of the lower portion of the loaf is finer grained, reddish brown by reason of the abundant dissemination of iron oxide, and carries nests of the thalite mentioned under No. 162.

Three sections.

Age. Manitou. N. H. W.

No. 163A. Thomsonite.

From No. 163. Large nests of a coarsely lamello-fibrous, radiated, white mineral occur in No. 163.

Meg. This mineral is hard, brittle and glassy, and in being extracted breaks into wedge or fan-shaped triangular pieces, coincident with the divergent fibres. It also has a cleavage or jointage by which it breaks easily, at irregular intervals, transversely to the fibrous grains. In the triangular pieces there is apparent a considerable variation, suggesting the possibility of two minerals intimately intergrown. The outer peripheries of the amygdaloidal masses are coarser than the central portions, and to that the foregoing applies. Toward the centre of each mass, as the fibres become almost insensibly finer, a pink tint comes on, and at last the mineral is massive rather than fibrous. There is an indistinct zigzag interlocking of the structure characteristic of the outer mineral into the structure exhibited by the

finer mineral, the pyramids of one fitting into the intra-pyramidal spaces of the other. This is not an evident structure, but, along with a close and somewhat confused fibrosity, the fractured surfaces sometimes reflect light in such a manner as to bring out such an oblique interlocking. Yet, notwithstanding this apparent difference between the centres and the peripheries of these masses, there are visible flat areas where no such structural contrast appears, and the two grade together with the most gradual and invisible variation. Hence it is necessary to conclude that there is really but one mineral.

Mic. Thin sections were made from the coarsely radiated portion, one perpendicular and one parallel to the macro-structure, from which it is quickly observed that the axial plane is perpendicular to the structure, and that n_g is perpendicular to the main cleavage. The elongation, hence, is sometimes positive and sometimes negative, n_g being the acute bisectrix. The section cut perpendicular to n_g gives no polarization colors, or very faint ones, but all others are colored, even in very thin sections. The section cut perpendicular to the structure is parallel to n_m, and gives the highest coloration. This section also proves, by the evident parallel lining, that the structure, at least in the coarser portions, is lamellar, rather than fibrous. It is evident, therefore, that toward the centres of the white masses, where they begin to show red and pink colors, the lamellar structure gives place more and more to a minute and densely fibrous structure. Extinction is parallel to elongation.

This mineral fuses readily to a porcellanous bead, and swells. With HCl, it gives flocculent silica which slowly gelatinizes.

With the Boricky test with hydrofluosilicic acid, the crystalliths that appear indicate lime and soda.

It is therefore *thomsonite*.

Three sections.

Age. Manitou. N. H. W.

No. 164. Diabase.

From one of the much altered traps, alternating with amygdaloid, similar to the series of Agate bay, between Sugar Loaf point and Two Island river, dipping toward the lake at an angle of about 12°; permeated with saponite.

Ref. Annual Report, ix, pages 43, 44.

Remark. The section numbered 164 is evidently not from this rock, but is from a rather fresh olivine and ophitic diabase, probably No. 165.

Age. Manitou. N. H. W.

No. 165. Diabase *(with olivine)*.

From the islands of Two Island river. The rock rises perpendicular from the water on the westerly side of these islands, basaltic, dipping southeast conformably with the rocks of the coast.

Ref. Annual Report, ix, pages 43, 44.

Meg. A dark-gray, or brown, medium-grained, homogeneous, rather fresh-looking rock; in that respect contrasting with the traps which form the coast series along here; scantily porphyritic with a gray feldspar.

Mic. The rock reveals an ophitic relation between the *augite* and the *feldspar*. The augite is clouded sometimes by a fine, fibrous alteration, but it is in general well preserved. The olivines are small, rounded, and frequently blackened by irony impurities, especially about their peripheries.

One section.

Age. Manitou(?)

Remark. The basaltiform structure, the good preservation and the isolation of this rock from the rotting trap of the series forming the shore are reasons for considering this sheet of later date than they, but the association of all these beds with the crumbling, soft, amygdaloidal conglomerates, as well as (further east) with sandstones, which are fragile, is an indication that they belong above the Baptism river basal conglomerate. N. H. W.

No. 166. Diabase.

"Heavy, dark trap, forming the gate to the amphitheater at Temperance river, from the top of the bluff, twenty-two to twenty-five feet."

Ref. Annual Report, ix, pages 45, 46.

Meg. A fine-grained, brownish, diabasic rock, permeated with thalite.

Mic. The section shows a fine-grained diabase consisting of laths of *feldspar*, *augite*, *hematite* and *magnetite*. The feldspar is twinned by the albite law and shows equal extinction angles as high as 30°. A section, which furnished a negative bisectrix almost but not quite perpendicular, gave an extinction angle of 60°. Both results show that the feldspar is *labradorite* approaching *bytownite*. The augite is mostly in plates of considerable size enclosing the feldspars. *Hematite* is abundant, and some of the hematite areas seem to represent original olivines. Saponite (thalite) is quite common, but the rock as a whole does not present as altered an appearance as would be indicated by the appearance of the hand sample. Both the augite and feldspar are comparatively fresh.

Two sections.

Age. Manitou. U. S. G.

No. 167. Shale. (*Red.*)

"Ochery, red, shaly beds of grit in a niche in the disturbed amygdaloid under the beds of No. 166, 0 to 3 feet; with fine argillaceous films."

Ref. Annual Report, ix, pages 45, 46.

Meg. A fine-grained, crumbling, often sandy, rather soft, reddish-brown shale. It shows fine, red, clayey films, and a few round blotches of a lighter shade. One of the samples holds part of an apparently rounded fragment of brown amygdaloid two and a half inches in diameter. The amygdules are of saponite and calcite. There

is also a mass, apparently filling a crack, of a mineral similar to one described under No. 163A. Cleavage flakes of this show a positive, biaxial interference figure, as does heulandite, but this mineral does not seem to have as perfect a cleavage as does heulandite. Some of this shale is made up of angular bits of similar shale embraced in a matrix which itself is coarser grained. No section.

Age. Potsdam. U. S. G. AND N. H. W.

No. 168. Diabase. *(Amygdaloidal.)*

Temperance river. Same as No. 169, but taken higher in the beds.
Ref. Annual Report, ix, pages 45, 46.

Meg. A fine-grained, brown rock with numerous rather small amygdules. The amygdules are filled with *thalite*, *calcite* and *heulandite*. The first mineral is more abundant than the others, and it has also penetrated the mass of the rock. No section.

Age. Manitou. U. S. G.

No. 169. Amygdaloid.

From Temperance river, about a mile above its mouth. Upper surface of an amygdaloidal layer, rising like a dome near the water, and exposing three feet.
Ref. Annual Report, ix, pages 45, 46; Bulletin ii, page 117.

Meg. An amygdaloid similar to No. 168. The calcite amygdules are surrounded by thalite, which also permeates the rock. No section.

Age. Manitou. N. H. W.

No. 170. Diabase. *(Surface of lava flow, with zirkelyte.)*

Near the mouth of Temperance river.
Ref. Annual Report, ix, page 45. This rock was recorded as a museum specimen, with the No. 3581, and was so published.

Meg. The outward characters of this rock are best described by the following from the field description:

There is also a marking on the upper surfaces of some of the amygdaloidal beds which seems to show the effect of cooling from a molten condition. These marks or wrinkles are transverse to the direction of the dip. They are in a fine-grained rock, though on the upper surface of the amygdaloid layers, and seem to be of the same kind of rock, though redder, as the amygdaloid itself. They are seen at four different horizons, and overlie uniformly beds of a foot and a half up to three feet and a half of amygdaloidal trap, with which they are connected by slow changes into the same structure. They are themselves somewhat amygdaloidal, but with much finer and fewer amygdules. There is sometimes a thin belt or interrupted stratum of highly and coarsely vesicular and amygdaloidal rock immediately under the wrinkles, which causes the separation of sheets of the wrinkled finer rock from the rest of the bed. These wrinkled surfaces, which are transverse to the supposed flow of the molten rock toward the Lake Superior basin, may have been caused by the superficial cooling of a film of rock on the surface of the flowing lava. The lava

continuing to flow—toward the lake valley—the film was wrinkled by being obstructed by its own stiffness as cream is wrinkled transversely on the edge of a pan as the milk runs out below. * * * The crumpled layers are about an inch thick, but sometimes two or three are infolded upon each other, making a crumpled layer of three or four inches. They are much finer and denser in grain and structure than the beds on which they lie, and are of a redder color. The convex sides of the wrinkles are upward. * * * Sometimes embraced in these wrinkled layers are lenticular areas or patches half an inch to an inch and a half thick of red grit, resembling the red sandrock with which these traps are associated, and within the amphitheatre, near the water on the north side, is an irregular triangular patch of ferruginous, thin bedded shale (No. 167), lying under a layer of dark trap and over the beds that show these wrinkled surfaces. Five layers of alternating trap and amygdaloid are visible between the lake and the first fall, somewhat less than one-fourth of a mile up the river.

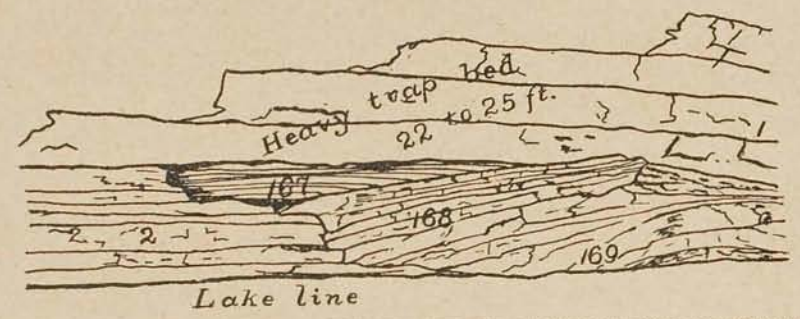


FIG. 16. SANDY, RED SHALE, NO. 167, BETWEEN LAVA SHEETS AT THE MOUTH OF TEMPERANCE RIVER.

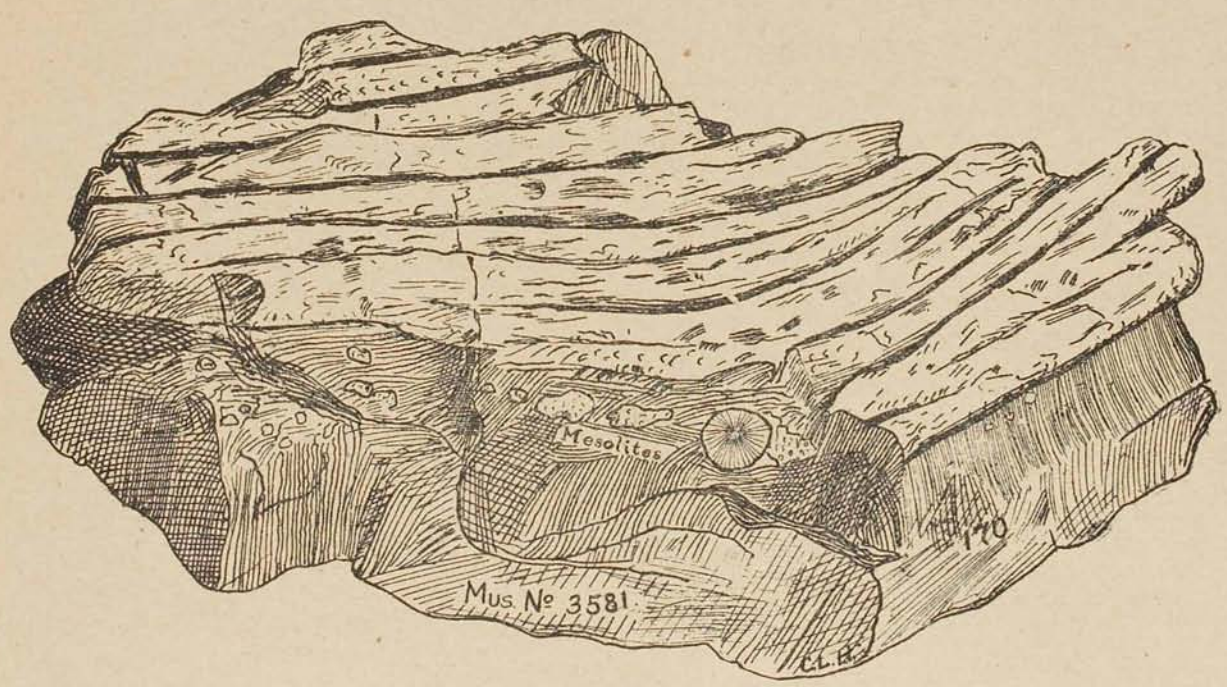


FIG. 17. ROPY WRINKLES ON THE LAVA FLOW OF ROCK NO. 170.

The above figures represent the manner of occurrence of the shaly and pebbly rock No. 167, and the wrinkles of the rock No. 170.

Mic. Section of the upper part of one of the wrinkles shows a finely microlitic, somewhat divergent crystallization of the *feldspar*, before which, however, there was a generation of small *olivines*. No augite is visible, but the intervening spaces are filled with a red substance which represents the poorly differentiated base. In this are *glass*, *hematite* spicules, and *magnetite* grains. The section between closed nicols is darkened by the prevalence of this residuum.

One section.

Age. Manitou. N. H. W.

No. 171. Diabase *(with olivine)*.

From the lowest layer exposed at the falls of Temperance river, about one mile from the lake. This fall is on the N. E. ¼ sec. 30, where a little creek joins the river from the northwest.

Ref. Annual Report, ix, page 45.

Meg. Rather dark-brown and heavy trap, somewhat amygdaloidal, much decayed, holding greenish-gray pseudamygdules apparently of thalite; also of calcite and of quartzine(?)

Mic. The rock is ophitic, the *olivine* is considerably altered to *bowlingite*, the *augite* rather fresh, and the *feldspars* are clear. The prevalence of *thalite* in this rock is an indication of great change, but the rock does not seem to show it except in the olivine.

Age. Manitou. N. H. W.

No. 172. Diabase *(with olivine)*.

"About three-fourths of a mile below the mouth of Temperance river; from a layer of trap that weathers green, is irregularly bedded and in spots is amygdaloidal. This is a little higher than No. 166, in the bedding, but at points further east, and particularly at a point about one-third of a mile east of Temperance river, seems to hold large globular masses, as if of boulders, and at other places seems to be conglomeritic in the same way."

Ref. Annual Report, ix, page 46.

Meg. A fine-grained, greenish-brown, diabasic rock, which has been permeated by a gray to green, soft mineral supposed to be thalite. The greenish color of the rock is due to the great abundance of this mineral.

Mic. A fine-grained diabase, holding *plagioclase*, *augite*, *magnetite*, *hematite*, *chlorite* and *thalite*. The last named mineral is common in small pseudamygdaloidal areas throughout the section. It is cloudy, and has a minutely fibrous radiating structure. There are also some areas which probably represent olivines, of an opaque substance, sometimes brown and semitransparent, which is perhaps *bowlingite*. The augite is not nearly as much altered as one would expect from an examination of the hand sample.

One section.

Age. Manitou. U. S. G.

No. 172A. Stilbite.

From No. 172.
Ref. Annual Report, ix, page 46.

Meg. A slickensided sheet of stilbite from a vein. The crystals stand out from the sides of the sheet, and along a cavity in the centre of the sheet show rough terminations. A little thalite and some small fragments of the adjacent rock are included in the specimen.

No section.

Age. Manitou. U. S. G.

No. 173. Diabase.

Northeast corner sec. 28, T. 59–4 W. In a little stony bay facing northeast. This bay is partly shut in by a projecting trap point running northeast, from which this number is obtained. It is an amygdaloidal trap containing heulandite, thalite, calcite, with some laumontite in amygdules and in nests and joints. The heulandite occupies the larger cavities, or lines them, the thalite being as filling to amygdules or in geodes of heulandite. The rock itself is roughly bedded, and dips toward the lake at an angle of about 10°.
Ref. Annual Report, ix, page 46.

Meg. A dark, brownish-gray, fine-grained, diabasic rock. Small, white, apparently pseudamygdaloidal areas are common. These contain calcite, thalite and heulandite (?), and the rock is more or less penetrated by very minute areas of these minerals.

Mic. The section shows a fine-grained diabase, similar in structure and composition to No. 172. There are a few *plagioclases* considerably larger than the usual feldspar laths, and these give a semi-porphyritic aspect to the section. In several areas is a very finely fibrous mineral, the elongation being in a negative direction. Commonly, in polarized light, there appear fine, dark, curving bands, on each side of which are radiating fibres. Occasionally these dark bands are double, with a narrow light band between them which extinguishes with the fibres on each side of the band. The double refraction is rather low, and the fibres rarely show colors higher than bright gray of the first order. The mineral is perhaps *chalcedony*. The feldspar is often much altered and is sometimes partially replaced by this fibrous mineral.

Running partly through the section is a vein of a very cloudy mineral with a low index of refraction and very low double refraction. The cloudiness is due, at least in part, to minute inclusions which are arranged with their long axes approximately parallel to an axis of elasticity, which is greater than the axis at right angles to these inclusions. This mineral is perhaps *stilbite*.

One section.

Age. Manitou. U. S. G.

No. 173A. Heulandite and Calcite.

From No. 173. A mass of crystals of heulandite two inches in thickness and about four inches wide.
Ref. Annual Report, ix, page 46.

Meg. It has the appearance, being broken, of having been at least six inches in diameter, and of a plano-convex form. In the central portion of this mass is an irregular crystalline form of calcite an inch and a half in greater dimension.

Mic. The axial angle about n_g in the heulandite is small and about 50°.

Remark. In the field this crystalline mass was taken for stilbite. N. H. W.

No. 173B. Mesolite.

From the beach in the bay on section 28, near No. 173.
Ref. Annual Report, ix, page 46.

Meg. A white, strongly-radiated mineral resembling that of No. 163A, but finer.

Mic. Double refraction very low; indeed, the fact of extinction can hardly be observed without mounting the powder in Canada balsam, when it is seen that the fibres extinguish parallel with the threads, and have a positive elongation. A microchemical test shows the presence of soda and lime. The mineral may be taken to be, therefore, *mesolite.*

Age. Manitou. N. H. W.

No. 174. Sandstone. *(Ferruginous.)*

Sec. 12, T. 59–4. Coast of lake Superior at five miles east of Temperance river.
Ref. Annual Report, ix, page 46.

Meg. A ferruginous and feldspathic sandstone, sprinkled with scattered small secondary crystals of laumontite. This sandstone is dispersed through a breccia or a conglomerate which resulted probably from the rapid disintegration of an eruptive of the prevalent kind, under the action of the ocean's waters on a lava flow. The associated trap, amygdaloid and sandstone are in bluffs that rise from twenty to forty feet.

Mic. Thin sections of the trap show a finely ophitic structure, the white plagioclase needles piercing the darker constituents in a beautiful and characteristic manner, the latter being ferrated. In the interstices is found also the same soft, radiated decomposition product as mentioned already in connection with No. 162, as well as coarser amygdaloids of the common zeolites.

One section of the associated diabase.

Age. Potsdam. N. H. W.

No. 175. Conglomerate.

About six miles east of Temperance river.
Ref. Annual Report, ix, pages 47, 48.

Meg. This rock is distinctly conglomeritic, containing lumps of brown amygdaloid, the amygdules being of laumontite and calcite. These lumps are contained in a ferruginous and aluminous red sandstone, which really constitutes less than one-half of the mass. These beds of conglomerate are about six feet thick,

and are overlain by a bed of trap undistinguishable from the trap that occurs frequently along here, and underlain by the next.

From Temperance river to this place, the rocks consist of the same series, viz.: a series of volcanic debris, making sandstones, resulting from the disintegration of lava flows, appearing as conglomerate and as amygdaloid, with occasional sheets of firmer trap. The amygdaloidal minerals are largely laumontite and calcite, but these are also in the sandstone in the form of small veins and otherwise.

No section.

Age. Potsdam.

N. H. W.

No. 176. Basalt *(with olivine).*

Six miles east of Temperance river. Underlies a fragmental series of sandstone, shale and conglomerate. *Ref.* Annual Report, ix, pages 47, 48.

Meg. A tough, heavy, thin bedded rock, having a red mineral (heulandite?) separating its frequent joints, so as to appear blood-red on approach, or spotted blood-red. Its interior color is dark brown or black, and it is seamed with calcite and laumontite, the second including the former as between the walls of a vein, the veins being rarely more than one-fourth of an inch in thickness. It is scantily pseudamygdaloidal with the same minerals; twenty-two feet thick; resembles the Two Harbor rock (No. 117).

Mic. The groundmass is fine, and dark colored between the nicols, the feldspar microliths lying in the midst of a minutely granular mass. The *feldspar* had two periods of generation. The larger crystals have an extinction angle that ranges low, approaching *andesine.* They are of irregular forms, the separate twins not having uniform lengths nor widths. In a section which is perpendicular to an optic axis extinction occurs at from 6° to 10° in the lamella showing the optic axis, and the optic plane forms an angle of 22° with the brachypinacoid. This section is also perpendicular to the "plane of symmetry," as the term is used by Michel Lévy, *i. e.*, it is in the zone perpendicular to the edge 001:010. This is shown by its having four positions in a single rotation, at which the twinning bands are equally illuminated, and cannot be distinguished. Only *anorthite* can present these optic characters combined.* There are others of the larger crystals of the plagioclase that do not seem to be anorthite. One such cut perpendicular to the bisectrix n_g has extinction at about 16°, which according to Fouqué† can take place in a labradorite near andesine, or in an oligoclase near albite. If anorthite was crystallized from the magma, simultaneously with this, it is not likely that this differs from anorthite so widely as to be an oligoclase-albite. It is therefore more likely to be *labradorite-andesine.*

* Étude sur la détermination des feldspaths, plate VII.

† *Bulletin de la Société de Minéralogie de France*, vol. xvii, p. 428.

Augite appears in two generations. The older generation is represented by crystals of idiomorphic outlines, which preceded the feldspars, and which sometimes enclosed small quantities of the magma. The second generation is represented by a multitude of minute idiomorphic crystals, which lie within the nearly isotropic residuum.

The *olivines* are altered, for the most part, to bowlingite.

There are a few green and almost isotropic areas, but occasionally they show a fibrous structure, which allies them with the fibrous *saponite* (thalite) mentioned in No. 162.

In the feldspars is also a light green alteration mineral presumed to be *chlorite*. It shows a slight absorption. Other grains included in the feldspars, polarizing brightly, are probably *mica*.

Three sections.

Age. Manitou (?)

Remark. There is a substance *(glass)*, which, while not abundant, serves as a matrix for all the other materials. It might at first glance be taken for augite, since in natural light it has a brown color, but it is entirely destitute of cleavage, embraces opaque ferruginous impurities and remains dark on rotation between the nicols. That it is yet a translucent glass indicates the fixedness of mineral composition through the long history which the rock has suffered, and the necessity of attributing the prevalent alteration seen in these trap rocks below the natural surface to some other cause than ordinary weathering and length of exposure. It is allowable to refer the most of this alteration to gases and hot waters that penetrated the mass before it was cooled, after solidification. N. H. W.

No. 176A. Laumontite.

This number is not mentioned in the Ninth Annual Report, page 47, but it evidently represents the material of the red joints in No. 176.

Meg. Sheets of red to white laumontite, with some calcite. The section marked No. 176A was made from one of the rock fragments attached to the laumontite. This section is similar to No. 176, but more altered.

Age. Manitou. U. S. G.

No. 177. Shale *(with zeolitic amygdaloid)*.

Underlies No. 176. A bed eight feet thick. See No. 626.
Ref. Annual Report, ix, pages 47, 48; Annual Report, x, page 60.

Meg. There are two hand samples, one of the amygdaloid and the other of the shale. The former is a very fine-grained, almost aphanitic, rock, dark brown or almost black in color. It is thickly strewn with small amygdules of *laumontite*.

The shale is sandy and somewhat resembles No. 167, but contains a great deal of laumontite.

No section.

Age. Potsdam.

U. S. G.

No. 178. Amygdaloid.

Six miles east of Temperance river. "Shows four feet, but beyond at another bluff rises so as to show ten feet. It is a less amygdaloidal state of No. 177, and lies below No. 177. The last two numbers were got about fifty rods east of Nos. 175 and 176. There is an isolated pillar of No. 176 standing on a broad pedestal rising about twelve feet high, about forty feet from the shore.

"Round the next little point, about twenty rods further, these beds are broken and confused, the dip changing to the southwest. There are here broken upward bends, or domes, of soft amygdaloid that encroach on No. 176 so as by weathering to make deep purgatories with buttresses of No. 176 separating them. After a short interval the beds go back again, and retain the usual dip toward the lake. (Compare No. 626.)"

Ref. Annual Report, ix, page 47; Annual Report, x, page 60.

Meg. A brown, very fine-grained rock containing many amygdules of *heulandite*. The lining to the amygdaloidal areas is bright red, and the heulandite sometimes fills the whole amygdule and sometimes exists as crystals along the sides of the amygdule. There are also a few amygdules of *laumontite* and some small areas which seem to represent original, small, porphyritic feldspars now replaced by laumontite. The rock is permeated by a soft, green to grayish mineral, probably *thalite*. There is also present a dark-green, easily cleavable mineral in small areas; this is probably *chlorite*.

No section.

Age. Manitou.

U. S. G.

No. 179. Diabase *(with olivine)*.

"Comes in below these amygdaloids, at about a mile west of Poplar river; a greenish heavily bedded doleryte; rising about ten feet and returning near the water, as the coast line crosses the strike of the beds."

Ref. Annual Report, ix, page 48.

Meg. On a perfectly fresh fracture the rock is seen to have an oily lustre and to be composed of a greenish, semi-transparent substance (plagioclase), and a reddish or brownish material (augite). Scattered over the surface are small glistening faces, probably of augite. There are many rather irregular areas (pseudamygdules) of a soft green substance, probably *thalite*, and of a harder gray mineral with a radiating structure.

Mic. The rock is a fine-grained diabase, considerably altered, although much of the *feldspar* and *augite* are still preserved. There are some green areas (mostly *chlorite*) surrounded and penetrated by *hematite*, which seem to be the remains of olivines. The rock has been permeated with thalite, which is the most abundant secondary mineral, and there is also a little *thomsonite* in the usual radiating forms.

Two sections.

Age. Manitou.

U. S. G.

No. 180. Diabase.

From the middle island at the mouth of Poplar river.
Ref. Annual Report, ix, page 48.

Meg. A yellowish-brown, fine-grained, diabasic rock, permeated with a soft, yellow mineral (saponite). The abundance of this mineral gives the yellowish color to the hand sample. There are two small amygdules of calcite, and one corner of the specimen has a mass of calcite, heulandite and a black mineral.

Mic. The section shows a fine-grained diabase with abundant feldspar, which, by its extinction angles, is seen to be *labradorite*, a comparatively small amount of *augite* in small plates later than the feldspar, much *hematite*, some *magnetite*, and a very little *thalite*. The section contains very much less thalite than would be indicated by the hand specimen, and, contrary to expectation, the section shows a comparatively fresh rock.

One section.

Age. Manitou. U. S. G.

No. 181. Diabase.

"Underlies No. 180 and does not vary much from it, except in being more evenly and more thinly bedded; and in separating into closer joints, so as to disintegrate, leaving No. 180 to stand alone, and really causing its more rapid demolition. Nos. 180 and 181 form substantially one rock, and are both what has been styled trap along here. In weathering they become very rusty, when not under friction, and brick red, crumbling in little red globules. These beds are twenty-four feet thick."
Ref. Annual Report, ix, page 48.

Meg. The rock is a fine-grained, dark brown, diabase, with considerable disseminated yellow *saponite* (*thalite*), similar to that in No. 180, but not as abundant. There are a few small *calcite* amygdules, and some soft red areas, which perhaps represent altered *olivines*. Another specimen with the same number is of a similar rock stained red.

Mic. An ordinary diabase with the *plagioclase* and *augite* comparatively fresh, *magnetite* and abundant *hematite* in grains. The section is full of cracks which have been filled with *hematite*, and it is to this abundant hematite, both in grains and in the cracks, that the color of the red hand sample is due.

One section.

Age. Manitou. U. S. G.

No. 182. Shale. (*Red.*)

"Is directly under No. 181, and is a shaly, red, easily crumbling rock, apparently of not uniform thickness, but in one place is about eight feet thick; on the east of Poplar river associated with a red conglomerate."
Ref. Annual Report, ix, page 48.

Meg. A soft, red, sandy shale, with gray blotches (apparently of laumontite) in the cracks.

No section.

Age. Potsdam. U. S. G.

Conglomerate. Breccia. Stilbite, calcite, laumontite. Diabase.]

No. 183. Conglomerate *(with zeolites)*.

"A highly pseudamygdaloidal rock, exposed below No. 182, but ascending, at other places when exposed, so as to 'pinch' out No. 182, and almost uniting with No. 181. This crumbles and gets brick-red on weathering on the beach."

Ref. Annual Report, ix, page 48.

Meg. A soft, earthy, much decayed, brown conglomerate, containing much saponite. Some of the pebbles come out and on being broken are seen to be themselves highly vesicular.

No section.

Age. Potsdam. U. S. G.

No. 184. Breccia.

A vein of this about eighteen or twenty inches wide crosses the face of a crumbling, greenish trap. It runs N. 40° E. One-eighth of a mile east of Poplar river.

Ref. Annual Report, ix, page 48.

Meg. The hand specimen is a rough mass of breccia. The rock fragments are angular and appear to have been similar to No. 180 or 181, but have been largely replaced by the same minerals which form the cement. The cement is composed of *laumontite*, a soft gray mineral *(thalite?)* and *calcite*.

No section.

Age. Manitou. U. S. G.

No. 185. Stilbite, Calcite, Laumontite.

Three miles east of the mouth of Poplar river. Zeolite nests which occur in the rock No. 183, or approximately the same.

Ref. Annual Report, ix, page 49.

The material at hand consists almost wholly of *stilbite* in large cleavage plates, so twinned as to form more or less radiated and fan-shaped surfaces, with a few pieces of *calcite*. The stilbite, when separated parallel to its cleavages, and mounted in small fragments in Canada balsam, affords the image of the optic normal in convergent light.

Age. Manitou. N. H. W.

No. 186. Diabase *(weathered)*.

"A little further east [about three miles east of Poplar river], can be seen a very interesting instance of the manner of weathering of the trap beds. This is similar to what has been mentioned before, and styled globuliferous. The rock seems to decay to a considerable depth, and to assume a globular structure, the little globules being rough exteriorly, and generally about one-half inch across. This cannot be due wholly to any peculiarity of circumstance in exposure, since here we have an opportunity to see alternations of rough and globular weathering and of smooth weathering alternating in beds one above the other, the beds being otherwise outwardly undistinguishable. The rough and globular layers show these characters both near the water and also as they rise obliquely across the bluff, and the same is true of the smooth weathering layers. Samples show both."

Ref. Annual Report, ix, page 49.

Meg. There are two hand samples. One evidently represents the globular weathering part; it is a fine-grained, diabasic rock, very similar to Nos. 180 and 181, and it contains large amounts of yellowish thalite. Scattered through the rock are

areas, apparently pseudamygdules, of calcite and thalite. The other sample represents the smooth-weathering portion; it is similar to the first but contains no calcite and no, or comparatively little, thalite. It is, however, more or less permeated by a soft, green material.

Mic. The rock is a fine-grained diabase with large amounts of *hematite*. The *augite* and *plagioclase* are much less altered than would be expected in a rock of this character—in fact all of the diabases along this part of the coast from Manitou river eastward, except No. 176, appear considerably decayed in hand specimens, but in thin sections they are seen to be comparatively fresh. There are pseudamygdules of *thalite* scattered through the section. Another section, marked No. 186 (?), is of a similar rock and was perhaps made from the smooth weathering hand sample. Instead of having pseudamygdules of thalite this section has pseudamygdules of *chlorite*.

Two sections.

Age. Manitou. U. S. G.

No. 187. DIABASE. *(Amygdaloidal, with olivine.)*

Eclipse beach, sec. 26, T. 60–3 W.
Ref. Annual Report, ix, page 49; Annual Report, x, page 60.

Meg. A dark, brownish gray, fine-grained, diabasic rock, with amygdules of stilbite, a soft dark green mineral, a white radiating mineral, apparently similar to No. 163A, and calcite. Each of the first two minerals fill amygdules by themselves, while the last two are usually found associated with the green mineral. The rock contains one large crystal of feldspar which is apparently similar to the labradorite of the anorthosytes; this crystal is three-fourths of an inch across.

Mic. A fine-grained diabase, with the *augite* frequently in plates of considerable size. A large amount of *olivine*, now changed to brown *bowlingite* (?) and a green chloritic material, is also present. The section shows some of the *stilbite* amygdules and also the green mineral. The latter was called *delessite* in the field, and it is also here referred to that mineral; it occurs in minute fibres, which are elongated positively, radiating in bands from the sides of the amygdule; it is greenish in ordinary light, has very low double refraction and is hardly pleochroic.

Age. Manitou.

Remarks. This rock is similar to No. 625, and the radiating white mineral is similar to No. 625A. U. S. G.

No. 188. DIABASE *(with olivine)*.

Eclipse beach, sec. 26, T. 60–3 W. Occurs suddenly at first, on a point running northeast (Eclipse beach) and enclosing a little bay, being a bed of overflow of igneous rock, with corrugated upper surfaces like those seen at the mouth of Temperance river (figure 17), especially at points further east where it becomes closely

associated with No. 187, which it overlies. It seems to embrace parts of No. 187 and then to take its place. The corrugated surfaces are small, the wrinkles curving and being in various directions, sometimes like an inverted basin. (The equivalent of No. 623.)

Ref. Annual Report, ix, page 49.

Meg. A dark, medium-grained, ordinary diabase, which weathers softer, slippery and smooth, more or less permeated with a whitish saponite (?) substance.

Mic. Plates of *augite* embrace the *feldspars* and the *olivines*, the latter frequently altered to a brown *bowlingite*. The section also embraces several large geodic areas occupied by a greenish yellow, radiated, rather soft mineral, which is probably closely related to the saponite (thalite) of the region.

Age. Manitou.

Remark. This rock is typical of a large series of dark traps (with much amygdaloid), which, beginning at or near the mouth of Baptism river, are in contrast with reddish and laumontitic traps westward from that point. N. H. W.

No. 189. Diabase.

"Caribou point, S. W. ¼ sec. 10, T. 60–2. The rock of the point is represented by this number, and is of the same horizon as No. 188. On the east side of the point this rock is basaltic radiatingly, and shows a thickness of eight to twelve feet. The basaltic columns gradually give way to a bedded structure toward the north. In some places it is fine-textured, especially near the top, and there shows the corrugations of the surface that have been supposed to be old lava-crusts; but generally these are smoother than those seen at Temperance river. This dips toward the lake at an angle of about 10° and lies on the next."

Ref. Annual Report, ix, pages 49, 50.

Meg. This is a dark brownish, fine-grained, diabasic rock, with some thalite and calcite along seams and cracks.

Mic. An ordinary, fine-grained diabase, composed of plagioclase laths, augite, considerable iron ore (hematite and magnetite) and alteration products.

One thick section.

Age. Manitou. U. S. G.

No. 190. Sandstone.

"A brownish-red sandstone, or shale, so fragile as to fall to pieces by handling; within the bay inclosed by Caribou point. This has a cross-lamination, and toward its junction with No. 189 is much less siliceous, and more aluminous for a thickness of about twelve feet. Its dip causes it to disappear, and its fragile character to become covered, within four rods of its first appearance, under No. 189. It reappears slightly about fifteen rods within the bay, having the same dip. * * * It is plain that not much heat accompanied the overflow of No. 189, as it seems not to have affected No. 190, the transition being abrupt from one to the other."

Ref. Annual Report, ix, page 50.

Meg. A crumbling, poorly cemented, brownish-red sandstone of medium grain. Some of the grains are rounded and some angular, and most of them are coated with red iron oxide. The rock contains much *calcite*. The nature of all of the grains of this rock is not easily determined, but they seem to be composed of material derived immediately, without much transportation or abrasion, from basic amygdaloids.

No section.

Age. Potsdam. U. S. G.

No. 191. Diabase *(with olivine)*.

Cascade river. This rock first appears on the east of Cariboo bay, and continues to Cascade river, forming a low coast. It overlies No. 192.
Ref. Annual Report, ix, page 50.

Meg. Gray, mottled, coarse grained; evidently a normal diabase.

Mic. The ophitic relation between the *augite* and the *feldspars* is evident at a glance. The *olivines* are much changed to *bowlingite*. There is a considerable amount of a yellowish-green substance occupying positions that indicate that it formed after the other minerals, which probably represent altered remnants of the basic magma, never differentiated. A little *magnetite* is seen.

Two sections.

Age. Manitou. N. H. W.

No. 192. Basalt.

Right bank of Cascade river, at the lake shore; a low outcrop. Underlies No. 191.
Ref. Annual Report, ix, page 50; Annual Report, x, page 59.

Meg. Fine grained, brown, scantily amygdaloidal and pseudamygdaloidal with calcite and laumontite, the latter mineral also coating the joints.

Mic. The *feldspar* microliths are compactly embraced in an opaque matrix which was probably at first a *glassy* substance. A small amount of yellowish-green *thalite* is scattered throughout the rock. This rock was evidently from near the surface of a lava flow.

One section.

Age. Manitou. N. H. W.

No. 193. Diabase *(with mesolite and thomsonite)*.

From the very point which sharply encloses Good Harbor bay, *i. e.*, Terrace point.
Compare No. 535.
Ref. Annual Report, ix, page 51; Annual Report, x, page 42.

Meg. Dark, heavy, rather coarse amygdaloid.

Mic. The white *thomsonites* are intimately mingled with more or less reddish *mesolites*. These zeolites are closely intergrown in the same round cavities. The thomsonite is distinguished by its bright polarization in contrast with the very low or non-polarizing quality of the mesolite. A thick section of the finely fibrous mesolite gives no coloration, and in ordinary light it is clouded with fine hematitic or other dust. Sometimes, suddenly, in the midst of such an obscuration, other coarser, nearly parallel, lamellæ or fibres flash out with brilliant colors characteristic of thomsonite, while at the same time such coarser fibres are translucent and free from impurities in ordinary light. This intergrowth is also sometimes differently alternated. Even with the naked eye the centres of some of the broken amygdules can be seen to be coarser than the rest. It is plain that for some reason the cavities were partly filled

uniformly with mesolite and partly with thomsonite. Such intergrowth appears also in No. 163A.

Bowlingite in this rock manifests definite characters (See No. 162). There is, distributed amongst the other minerals of this rock in the manner of olivine, a mineral that has resulted from the alteration of olivine. It is idiomorphic and earlier than the augite or than the feldspar. It is sometimes surrounded entirely by the augite. When cut favorably it shows two cleavages, but usually only one, and it then is distinctly and rather strongly absorptive, the darker shade recurring when the cleavage is parallel with the principal section of the polarizer. There are also irregular coarser fissures. The ordinary color of the mineral is greenish brown, or yellowish, and it could be mistaken for chlorite when it is not well formed. In nearly every optic character it can be identified with the mineral described by Lawson as *iddingsite*. It is not fibrous, but distinctly cleaved parallel to definite chrystallographic characters. The optic plane is perpendicular to the easy cleavage, and the acute bisectrix (n_p) is shown in sections parallel to this cleavage, making the mineral negative. This axial angle is so small that its interference figure is almost a permanent black cross; but on rotation its arms are seen to fluctuate a little from perpendicularity to each other, the alternate angles becoming less or greater than 90°. The separation of the hyperbolas can hardly be observed. In sections transverse to the easy cleavage the direction of the cleavage lines is positive with respect to the axis (n_g) of the quartz plate. Its double refraction is about the same as that of augite, but its refraction is less.

Two sections.

Age. Manitou. N. H. W.

No. 194. Sandstone. *(Brown.)*

"Brown sandstone, from Good Harbor bay [sec. 34, T. 61–1 W.]; aluminous; by making measurement along the beach the outcrop is found to extend 1,400 feet, with an average dip of 8½° toward the lake; by trigonometrical calculation the thickness of the strata is ascertained to be 206.9 feet, as exposed, but the thickness must be considerably more, owing to the non-exposure of rock in an interval of nearly 1,000 feet before the underlying finer beds appear in the beach further north. This is probably the equivalent of the sandstone at Cariboo point, but may be another stratum. It is very frail and although sometimes a little slaty it will easily fall to pieces if taken in the hand."

Ref. Annual Report, ix, page 51.

Meg. A fine-grained, dark brown, rather poorly cemented sandstone. Some of the grains are seen to be rounded, while others are angular. All of the grains are coated with iron oxide. The rock effervesces with hydrochloric acid, showing considerable calcite in the cement. No section.

Age. Potsdam. U. S. G.

Remark. From general structural considerations this belt of sandstone seems to be distinct from that at Cariboo point, both being, however, in the Potsdam.

N. H. W.

No. 195. Basalt. *(Amygdaloidal.)*

From the north side of the first little creek in Good Harbor bay. Although not seen to immediately underlie No. 194, it is evident, from the remnants of No. 194 which fill the cracks in No. 195, that these rocks belong together.

Ref. Annual Report, ix, pages 51, 52.

Meg. This is apparently the upper surface of an amygdaloidal trap flow. Some of the cavities are flattened or roughly tubular, with their greater dimensions horizontal. Some are filled with quartz, some with laumontite, and some with a green fibro-lamellar mineral resembling delessite. Its own upper surface was apparently broken up, and its fragments were cemented again *in situ*. Its general color is brown, but the amygdaloidal minerals give it a spottedness. It is finely compact when not amygdaloidal.

No section.

Age. Manitou. N. H. W.

No. 196. Diabase. *(Amygdaloidal.)*

From the small rocky island off the point that encloses Good Harbor bay. In line of bearing of No. 193.

Ref. Annual Report, ix, page 51.

Meg. A fine-grained, gray rock, with numerous radiated flesh-red and white zeolitic hard minerals, which have been widely distributed as thomsonites.

Mic. Throughout the section is disseminated much of the glassy residuum, now mostly filled with feebly polarizing microliths.

There are *feldspars*, though they are small and imperfectly developed, and there are *augites* that separated early from the magma, and hold many inclusions. The rock is essentially the same in kind as No. 193, in which *bowlingite* is evident and abundant. In this rock, however, unlike that, there is much of the *thalite* stage or phase, mentioned under No. 162, as a possible alteration product from olivine. This is seen in the form of minutely radiated fibrous coatings that surround some of the areas, and frequently in the fillings of cavities of considerable size. In the latter condition, this substance is greenish, and although the general aspect is amorphous, and the polarization is that characteristic of a felted mass, yet on close inspection it is apparent that even the little scales or particles which make up these larger patches are occasionally fibrous and positive in elongation in the manner of those coatings in which the fibration is more coarse and more evident. In keeping with this fact is the light greenish alteration product of many minute *olivines*. These greenish grains are accompanied by much ferruginous coloring matter, which surrounds them and penetrates them irregularly as if accumulated along the former irregular fracture planes of olivine. These grains are plainly altered olivines. They are nearly dark during rotation between the nicols, but not wholly so. They exhibit no cleavage like that described under No. 193, nor any absorption. In other words,

they represent the thalite phase of alteration in these rocks, to which, evidently, olivine has contributed largely. The close alliance between this thalite stage and the bowlingite stage is evident from the fact that here they occur in the same mass, under similar physical conditions, but in rock which consolidated at different rates by reason of differences of cooling.

The amygdules in this rock are feebly translucent in the thin section, even in a very thin section. The section contains many. It is hardly possible that this feeble translucency can be attributed to the accidental orientation of all the fibres, of all the amygdules in the same position, and that position such that they uniformly present optic axes, and for that reason transmit little or no light. They are remarkably in contrast with the thomsonite of No. 163A, but they seem to represent the finely fibrous pink mineral associated with thomsonite in that rock. This fine mineral is the only one that is known to occur at Terrace point, varying to the characters assigned by Peckham and Hall to *lintonite*.* This mineral is *mesolite*. (See Nos. 535A, B and C.)

Age. Manitou. N. H. W.

No. 197. Porphyryte. *(Diabase.)*

"A reddish brown rock, closely jointed, and also breaking sharply with a conchoidal fracture; very rough exteriorly, *i. e.*, with sharp projecting angles that tear the boots, but not porous or open; forms the point and coast line first east of Good Harbor bay, east of No. 195."

Ref. Annual Report, ix, page 52.

Meg. A very fine-grained, compact, brownish rock, carrying a few scattered, gray plagioclase phenocrysts, which are less than one-eighth of an inch in length, and usually not more than half that length. There are also a few irregular areas of chlorite in the rock.

Mic. The small porphyritic *plagioclases* occur in a groundmass, the most evident crystals of which are plagioclase microliths. The phenocrysts are considerably altered, and, while no characteristics determining absolutely their species were found, there are indications that they are *labradorite*. The groundmass aside from the plagioclase microliths, is composed of feldspathic material, *chlorite*, *magnetite*, *hematite*, and a brownish material which perhaps represents *unindividualized magma*. There are also minute, brightly polarizing grains in the groundmass which are probably *augite*. A few *olivines* are present in the slide.

One section.

Age. Cabotian. U. S. G.

Remark. For reasons that are elsewhere given it is supposed that the stratigraphic horizon eastward from Good Harbor bay, at the lake shore, is that of the

* *American Journal of Science*, third series, vol. xix, p. 122, February, 1880. Republished in the *Eighth Annual Report of the Minnesota Survey*, p. 166.

Cabotian, and that the basal conglomerate of the Potsdam is beneath the Good Harbor sandstone. N. H. W.

No. 198. Diabase *(with olivine)*.

From near the mouth of Fall river, on the west side of the river, at the point illustrated in Norwood's report; apparently continues to Grand Marias; at one place overlies an amygdaloidal red rock.

Ref. Annual Report, ix, page 52.

Meg. This rock has a basaltiform structure and a coarse grain, and brownish-gray color.

Mic. Section showing a feldspar cut parallel to the brachypinacoid, has extinction at 38°, and the positive bisectrix (n_g) is also nearly perpendicular. This indicates *bytownite*. The field is largely occupied by *olivine* in broken and often small fragmental grains. The *augite*, which must have been of later generation, is much obscured by dark impurities. Indeed, in some cases, it appears never to have formed as augite. The magmatic remnant, after the magnetite, bytownite and the olivine had crystallized out, appears to have congealed without complete differentiation, yet it was not in the condition of glass at the time of solidification, since these obscure areas exhibit an imperfect double refraction, with recurring extinctions.

One section.

Age. A Cabotian flow from the main gabbro mass, analogous to the Beaver Bay diabase, of which it may be the equivalent. N. H. W.

No. 199. Diabase *(with olivine)*.

From the basaltic columns at Grand Marais (No. 536).

Ref. American Association for the Advancement of Science, xxx, page 163; Annual Report, ix, page 52; Annual Report, x, page 139.

Meg. Rather coarse, brown to black, basaltic.

Mic. The characters of this rock are almost identical with those already assigned to No. 198. It differs from that only in the possession of distinctly pure *augite*, which embraces the *feldspars* and the *olivines*, as well as non-differentiated remnants of the magma. The feldspar also appears zoned in one large crystal, in the centre of which is a large accumulation of chloritic impurities.

Two (thick) sections.

Age. Cabotian; perhaps the Beaver Bay diabase. N. H. W.

No. 200. Diabase *(with olivine and copper)*.

"Samples of copper-bearing greenstone (gabbro), from N. W. ¼ sec. 24, T. 61–1 W., up Fall river. This heavy-bedded rock has slickensided seams, or thin filling between layers. These seams contain much chloritic mineral (delessite?), some layers of it being one-half inch thick, with stilbite closely mixed with it, and also small quantities of calcite; the copper occurring in the massive, hard greenstone, or doleryte, in the form of thin spangling sheets once or twice the thickness of paper, or even one-quarter inch thick. The sheets sometimes embrace three or four square inches in area. This location was wrought by Johnson and Maguire in the sum-