UNIVERSITY OF MINNESOTA.

A REPORT

ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA;
MADE IN PURSUANCE OF AN ACT OF THE LEGISLATURE
OF THE STATE, APPROVED MARCH 1,
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VOLUME V

LETTER OF N. H. WINCHELL, STATE GEOLOGIST.

UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, September 1, 1899.

Hon. John S. Pillsbury, President of the Board of Regents:

MY DEAR SIR: The last volume of the final report of the Geological and Natural History Survey of the state, which is herewith tendered for publication, contains the results of long-continued investigation of the mineralogy and petrology of the state. A large portion of this volume was already prepared when volume iv was presented,—indeed, the conclusions given in that volume were based on the investigations which are given in more detail in this. It is hoped that this volume will add something to the science of the crystalline rocks.

Respectfully submitted,

N. H. WINCHELL,
State Geologist.

LETTER OF HON. JOHN S. PILLSBURY.

MINNEAPOLIS, MINN., September 4, 1899.

Professor N. H. Winchell, State Geologist, City:

DEAR SIR: I take pleasure in acknowledging receipt of your favor tendering for publication volume v of the final report of the Geological and Natural History Survey. It will go to the printer at once, as a contract for the same has already been executed.

Very respectfully,

J. S. PILLSBURY,
President of the Board of Regents.

THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
N. H. WINCHELL, State Geologist.

1898—1900.

THE

GEOLOGY OF MINNESOTA.

VOL. V OF THE FINAL REPORT.

STRUCTURAL AND PETROGRAPHIC GEOLOGY OF THE TACONIC AND ARCHEAN.

By N. H. WINCHELL,

Assisted by U. S. GRANT.

Submitted September 1, 1899, and published under the direction of the Board of Regents of the University.

ILLUSTRATED BY SIX PLATES AND FIFTY-FIVE FIGURES.

ST. PAUL, MINN.
THE PIONEER PRESS CO., PRINTERS.
1900.

TABLE OF CONTENTS.

ANALYTICAL KEY

TO THE

PETROGRAPHICAL DESCRIPTIONS.

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(1) MINERALS.

[REFERENCES ARE TO THE ROCK NUMBERS.]

(2) ROCKS.

[REFERENCES ARE TO THE ROCK NUMBERS.]

PREFACE.

It would have been probably a more logical order of publication to have issued the contents of this volume before the final conclusions and mapping contained in volume iv. Still in the main this volume was so far along that it was warrantable to make brief summaries of the main structural and petrological conclusions in the preface of volume iv, with reference to the discussions contained in this. In the course of the final revision of the manuscript of this volume but one point of importance has been discovered in which it is necessary to depart from the views presented in volume iv. That relates to the origin of the Mesabi iron-bearing rocks, which will be found fully presented in Part III.

In the final systematic discussion (Part III) of the facts embraced in Part II (petrographic descriptions) it was found that in order to limit the size of the book to reasonable bounds some considerations must be omitted and all must be abridged. Hence, the most important and fundamental results only are given. These embrace therefore only the discussion of the rock-forming minerals* and a synoptical treatment of the rock groups. There remains material enough in our field-notes and in the drawers containing our samples to carry forward researches into the geology and genesis of the crystalline rocks through the space of another volume equal in size to this. Such investigation would pertain to the nature and extent of the original rocks that now carry the Mesabi iron ores. We have carried the research far enough simply to reach the main conclusion. The application and scope of that result are yet to be considered. Such additional research would also involve the "red rocks" of northeastern Minnesota and would lead to the inquiry as to how much of that group of rocks can be attributed to actual acid eruption and how much to alteration of basic eruption in submarine conditions. It would also lead to an investigation of the tectonic relation of such supposed altered basic rocks to the gabbro of the Cabotian, and of the Cabotian to the iron-bearing rocks of the Mesabi Iron range. Such investigation also would lead to the microscopical examination of the Animikie strata with view to ascertain whether an igneous debris is not more widely disseminated in them than has been supposed. There is also a large chapter yet in the future relating to the visible effects of progressive metamorphism of clastic sediments. The threshold only of this subject has been trod incidentally in the lines of this book.

*It had been intended originally to include in the final report of the survey an annotated list of all the minerals of the state.

The data are much more numerous and are in need of definition and classification. From our study we have been able, as in the case of the Mesabi iron ore, only to reach a warrantable conclusion. Such conclusion must yet be pursued to its legitimate results, not alone theoretically, but through an inspection of other positive data and the interpretation and application of many minor steps and collateral issues.

Unfortunately, however, these and other questions must, for the present be left unsolved. It is the nature of all geological research to continually open up new fields. These, however inviting, must, in the case of the present survey, be relinquished with only a mention of their existence, in order that one or two, which have been sufficiently explored, may be described and thus preserved within the scope of positive geology.

The reader will find in this volume some conclusions as to the geology of the Archean which, while not entirely new, having been proposed in the main by others, sometimes on imperfect data and at other times with only partial apprehension of their scope, yet are not everywhere accepted as valid tenets of Archean geology. It may be well to succinctly mention some of these.

1. The Archean began with the crust of the earth a basic rock—greenstone. This crust, on cooling sufficiently to allow the condensation of water, was covered with chemical, detrital and volcanic sediments.

2. The metamorphism of these sediments produced later the schists and gneisses and the fusion of them by the combined action of heat and moisture gave rise to acid igneous rocks.

3. At the bottom of this series of sediments is a great mass of clastic greenstone which varies to acid rock, by chemical precipitation and by detrital accretion. The metamorphism and fusion of this, and other, intermediate rocks, gave rise to the intermediate schists and igneous rocks.

4. The basic igneous rocks, gabbro, diabase and their allies, are, in like manner, the result of the same forces acting on the basic rocks (greenstone) whether of the original crust or of the clastic series.

5. From the most basic to the most acid of the igneous rocks, therefore, there is an unbroken series of minute gradations, both chemical and petrographic, corresponding primarily to similar gradations in the clastic rocks, by reason of which it is impossible to establish definite classes or groups separated by constant characters.

6. Hence all igneous rocks of the Archean, after the first greenstone, are in one heterogeneous family, interlocked in different directions, and incapable of separation. Every rock sample has its own characters or combination of characters, but these are shared variously with its neighbors, or with its congeners from more distant localities, in almost an infinite series of differences and shades of variation, by reason

of which it is impossible to uniquely define any single group. The extremes and the mean are easily apprehended, and that is about all the classification that can be given. The history and the multiplicity of petrographical nomenclature verify this conclusion.

7. The igneous rocks of the Archean are not derived one from the other by any process of differentiation of magma.

8. The rocks of the Archean are not unstable, but fixed. Their Archean composition and characters have come down to the present without showing, normally, the least alteration.

9. There have been epochs of intense metamorphism, of folding, crushing and fusion, but these were local as to time and place and their effects were wrought out in Archean time—with the probable exception that in Taconic time similar revolutions produced similar effects on the Archean rocks adjacent.

10. The weather effects, which are superficial and have been removed by glaciation, the accidental location of oxidizable sulphides or carbonates so as to intensify locally the changes in the adjacent rocks, and the rare instances of post-Archean fracture and mountain-forming, are the abnormal conditions that may be appealed to to justify the idea that the crystalline rocks are *as changeable as an organic body!* But these conditions are exceptions to the normal state of the Archean rocks, and can hardly be said to establish a great principle which contravenes the general history and the verdict of the normal condition of the great mass of those rocks.

11. The Archean in Minnesota was fully crystalline and brought to vertical attitude before the deposition of the Taconic, and there was certainly a long time interval between the Archean and the Taconic not represented in Minnesota by any rocks, during which in other parts of the country there may have been formed other rocks, both fragmental and igneous.

12. As the Archean igneous rocks are derivable from Archean earlier rocks by metamorphism and fusion, so later igneous rocks may have been produced by similar alteration of later clastic rocks, and these would introduce a great many additional varieties and peculiarities into petrographical nomenclature.

13. But, whenever the basic original crust has been reached by such action, the resultant rock has been a *diabase,* whose constancy of composition vouches for the constancy and universality of its source.

Diagrammatic scheme of the Archean in Minnesota.

For the purpose of conforming to a conventional practice, and in order to make somewhat clearer the composition and order of the Archean and Taconic in Minnesota, as described in this report, the following structural scheme is given. Such schemes are liable to convey error by their exactness of definition and the meagerness of data they embody. Nothing is more plain to the practical geologist than that structural changes in the Archean are seldom abrupt and evident, and that even from one rock species to another there are usually intermediate transitions which sometimes baffle reasonable interpretation. This scheme, therefore, must be understood to present only the broader features of the rock succession.

TACONIC.	*Upper Cambrian.*		The *St. Croix* and *Hinckley* sandstones of the Upper Mississippi valley, or the western "Potsdam." Seen at Fond du Lac. The lower portion interstratified with trap, and thus passing to the Keweenawan.	
TACONIC.	Lower (and probably *Middle*) *Cambrian.*	Keweenawan.	*Potsdam* (clastic) and *Manitou* (igneous) rocks. *Puckwunge* conglomerate at the base. The *Potsdam* at Potsdam, N. Y., but not at Saratoga.	
		Keweenawan.	NON-CONFORMITY.	
		Keweenawan.	*Cabotian* (igneous). Gabbro and cotemporary surface eruptives.	
		Animikie.	Slates, quartzytes; conglomerate at the bottom of the clastic rocks; but sometimes without a basal conglomerate. Numerous dikes and sills of the age of the Keweenawan. The *Mesabi* Iron ores, probably derived from original basic eruptives, are at or very near the bottom of the Animikie.	
			NON-CONFORMITY.	
ARCHEAN	*Upper Keewatin.*		Quartz-porphyry, Volcanic tuff, Flint, Quartzyte, Sericite schist, Jaspilyte, Argillyte, Graywacke, Greenwacke, Greenstone (clastic), Ogishke conglomerate,	Metamorphosed and fused, producing mica schist, hornblende schist, gneiss, granite of various kinds, dioryte, syenyte, etc.; also muscovadyte and gabbro.
			NON-CONFORMITY.	
ARCHEAN	*Lower Keewatin.*		Quartzyte, Graywacke, Flint, Volcanic tuff, Argillyte, *Kawishiwin.*: Greenstone (clastic), Jaspilyte, Quartz-porphyry, Greenstone conglomerate, Greenstone (igneous), oldest known rock,	Metamorphosed and fused, producing mica schists, gneiss, hornblendic schist, dioryte, syenyte, granite and their modifications; also magnetic ore, muscovadyte, noryte and gabbro with their modifications.

The reader will find in Part I a description of these formations, and in Part III a discussion of their genetic relations.

The term Norian is replaced by Cabotian because of its original application to a Mesozoic formation of the Alps, as shown by Renevier.*

ROCKS LEFT AT PARIS.

In order that European geologists may examine the rocks discussed in this volume, and thus be enabled to review the petrographic conclusions, a series of 118

* Ambiguité du term Norien, et son inadmissibilité dans la classification internationale. *Eclogae geologicae, vol. 5, p. 356.*

of the type rocks was deposited in the Museum d'Histoire Naturelle, at Paris, in the possession of Prof. A. Lacroix, consisting of the following:

Nos. 1, 5, 68, 119, 129, 140, 158, 187, 200, 270, 443, 449, 450, 470, 473, 488, 514, 518, 520, 526, 528, 533, 536, 543, 544, 549, 550, 554, 555, 557, 563, 571, 598, 603, 607, 620, 624, 625, 627, 637, 638, 682, 695, 699, 744, 746, 754, 797, 799, 801, 805, 828, 835, 854, 864, 865, 866, 867, 868, 869, 871, 872, 873, 874, 877, 879, 882, 883, 890, 892, 903, 911, 916, 921, 923, 936, 947, 950, 954, 958, 960, 963, 979, 983, 989, 991, 1044, 1049, 1050, 1059, 1061, 1062, 1068, 1073, 1074, 1094, 1098, 1100, 1109, 1128, 1129, 1136, 1137, 1277, 1278, 1283, 1312, 1318, 1340, 1409, 1428, 1436, 1518, 1797, 1838, 1843, 66G.

An analytical key of the petrographical descriptions of this volume will be found after the Table of Contents.

NOTE. It is recognized that the criterion by which diopside has been determined (cleavage 010) is not alone reliable; but usually diopside has been identified further by its elongated form, its light color, and its association with acid and alkali minerals, and by its occurrence in secondary rocks.

The reader will please note the following corrigenda:
On p. 169, line 12, for magnetite read magnesite.
On p. 180, line 10, for LABRADORITE read LABRADORYTE.
On p. 209, line 24, add the words: See Nos. 132A and 667.
On p. 309, line 25, add the words: Plate V, figure 9.
On p. 313, line 18, add the words: Plate VI.
On p. 344, line 14, add the words: See No. 884.
On p. 350, line 24, after crystals, add: and coarser ones of tourmaline.
On p. 456, line 3 from the bottom, add: Plate II, figure 1.
On p. 464, read LABRADORYTE and THOMSONITE.
On p. 473, line 6 from the bottom, add: Plate II, figure 2.
On p. 559, line 10, erase 1842.
On p. 644, line 18, for band read bond.
On p. 660, first line, for same read some.
On p. 735, line 25, add the words: Plate V, figure 7.
On p. 785, line 3, add the words: See note, p. 161, Twenty-first Annual Report.
On p. 844, line 18, add the words: Plate III, figure 5.

N. H. W.

PART I.

STRUCTURAL GEOLOGY.

By N. H. WINCHELL.

The following sketch is based on the field facts, which are given in volume iv, and on the petrographic descriptions that follow in this volume.

The Archean.

Definition of the term. As here employed the term Archean embraces that great series of crystalline and metamorphic rocks which lies below the Taconic or Lower Cambrian, and which is separated from the overlying rocks by a violent non-conformity. This horizon of separation is not known, nor presumed, to be immediately below the Olenellus horizon, as lately defined by the United States Geological survey; but it is probably considerably older than the Olenellus (or the Paradoxides*) horizon, although in strata probably conformable with strata of that horizon. These crystalline rocks, in whole or in part, have borne the names of Primary, Laurentian, Pre-Cambrian, Azoic, Eozoic and Fundamental Complex, but the term Archean, suggested by Dana, seems appropriate, and also is the most used.† As defined by him, it included Huronian and Laurentian. Owing to uncertainty as to the significance of the Canadian terms (Huronian and Laurentian) they are not employed in this discussion except for purposes of reference, although it now appears that the original Huronian embraced a part of the Taconic and a part of the Archean, while the Canadian Laurentian seems to consist largely of igneous rocks and of metamorphic clastics of different parts of the Archean. For the details the reader is referred to the plates and the special chapters accompanying them included in volume iv.

The fragmental rocks of the Archean.

Nature of these fragmentals. A large part of the fragmental debris that enters into the composition of the Archean, at least in its lower portions, is of volcanic character. It consists of fragments of minerals and of rocks that, even after more

*According to Prof. G. F. Matthew the Olenellus and the Paradoxides horizons are not always distinct, but probably blend in their stratigraphic and faunal characters. *American Geologist*, xix, 396, 1897.

†The recent restriction of the term Archean, by Van Hise and Bayley, in their monograph on the Marquette iron-bearing rocks, to the rocks supposed to be at the bottom of the "basement series" of Irving, *i. e.*, those that are without evidence of water deposition, introduces an element of confusion of which the reader should take note. It is a wide departure from Dana's definition of the term Archean.

or less alteration manifest their derivation from feldspars, from augite and from hornblende, or from an amorphous glassy substance. In the case of much of the greenstone of the Archean this debris is compacted and frequently recrystallized, giving it a striking outward resemblance to a massive rock. But it can sometimes be distinguished from a true igneous massive rock by the occurrence of clastic variations in the texture, and by the peculiar distribution of the crystals which compose it, and also sometimes by the existence of more or less globular, fine, pebble-like masses which become visible especially in the microscopic sections. In these the feldspars are distributed in a radial relation to the surrounding materials—the remnant of an original ophitic structure—while outside of these pebble-like areas the structure is that of a compact, fine, uniform clastic, though consisting essentially of the same elements. It is only rarely that augite is distinctly preserved amongst this debris, but feldspar is almost always distinctly preserved. The early augites, coming from some ferro-magnesian magma through the action of explosive ejection are apt to be converted to some form of hornblende, frequently actinolite, and this finely disseminated hornblendic mineral is the most potent cause of the prevalent green color of these rocks. The feldspars, which are more or less in fragments, usually have lost their original composition and crystalline purity, and are permeated by zoisite and calcite, and less frequently by quartz, epidote and chlorite, and at the same time are clouded by other indefinite, or kaolinic products of decay. On the other hand the feldspars are subject to another form of alteration by which their distinctness, even their outlines, are rendered almost imperceptible. This occurs in some of the later portions of the Archean, and especially in the rocks of the region of Ogishke Muncie lake. The original feldspar is replaced, in whole or in part, by a granular or micro-granulitic complex of quartz, or quartz and glassy feldspar. In some cases this substitution is so fine-grained that the shape outlined by it appears to be due to a grain of devitrified glass, or of aporhyolyte. It was found that this rearrangement of the feldspars of the Archean becomes coarser textured, and in that form is quite a prevalent mode of regeneration and of metamorphism, the significance of which is important, but which will be treated under the subtopic of "Metamorphism of the Archean Fragmentals."

Nearly always any thin section of one of these fragmental volcanic rocks discloses more or less of the iron ores. This ore may be pyrite, hematite, magnetite or ilmenite, and very often, in case of original ilmenite, this mineral is altered to leucoxene, and is accompanied by sphene.* In some instances notable amounts of nearly opaque leucoxene have been seen in these greenstones.

Epidote is quite common, and seems to have been generated in circumstances where alteration was slow and deep-seated, or was aided by other causes than simple

*Frequently in the vicinity of the iron mines more or less siderite and limonite also occur.

weathering. Various chloritic minerals, usually pennine, unite with hornblende and epidote in giving the characteristic colors. Where epidote is abundant the greenness verges toward yellow. Where the chloritic element prevails, the change has probably been due to weathering, and is carried a step further than when hornblende alone gives the green color. Quartz, which is not uncommon in these green clastic rocks, is plainly of two different sources, viz.: of fragmental origin, coeval with the rock, and of secondary origin, the result of alteration of the feldspars. Never in these rocks is there any trace of olivine, so far as observed, but this mineral, which must have been at first embraced in the debris, has been lost by alteration, and its elements divided between chlorite, actinolite and the iron ores.

As to structure, these greenstones, which, being fragmental, may bear the name *greenwackes*, are not distinctly stratiform, except in rare instances. They have a close structural relation, as well as a close mineral resemblance, to the igneous greenstones, their chief distinctions being petrographic, and mainly observable in microscopic thin sections. They acquire gradually detrital characters, *i. e.*, they become siliceous, lose their green color, and if fine grained might be denominated phyllyte, and when coarser grained they become graywackes.

At the same time it is apparent that the volcanic tuffaceous accumulation sometimes was accompanied by a copious oceanic precipitation of silica, and occasionally by iron oxide, these usually occurring somewhat sporadically in large quantities, but sometimes very continuously and very widely so as to sensibly change the composition and the color of the resultant rock. This chemical oceanic precipitation is most conspicuous in the fine-grained phases of the rock, the fine green schists sometimes becoming very siliceous and firm, or very siliceous and also reddened by hematite. When, under such a variation, the chemical elements are so abundant as to almost or quite exclude all other ingredients, the resultant rock is that which has been named jaspilyte by Wadsworth.* Frequently, however, the distinctly chemical precipitates are mingled with more or less of the cotemporary volcanic and other debris, and, in rare instances, the jaspilyte is charged with coarse fragmental materials.

Conglomeratic jaspilyte. A remarkable instance of a jaspilyte containing pebbles and even boulders of granite and other rocks occurs north of Moose lake, near the section line between secs. 20 and 21, T. 64–9. The question of the date and manner of origin of the rock termed jaspilyte was held as a debatable one until the discovery of this curious combination, although, in several of the annual reports, it was claimed to be of the nature of an oceanic precipitate.† Of this locality the following details are important:

*It is a question whether the term "jaspilyte" should be continued, inasmuch as Wadsworth's idea of the origin of this rock was very different. He described jaspilyte as a rock of igneous origin—a surface eruptive of the rhyolitic type.

† Compare, specially, *Bulletin vi*, pp. 55, 103–111.

On the portage trail from Moose lake to Wood (or Wind) lake, but near Moose lake, and near the section line between secs. 20 and 21, T. 64-9, is a very interesting locality. The country, at the time visited, had recently been burnt over and the rock was bare, showing its structure. There is a series of east-northeast and west-southwest ridges crossing the country parallel to the direction of the lake and of the islands, and on the portage trail they are quite conspicuous. At the lake is schist, quite fissile, as seen on some of the islands and the points, and argillyte, often green and falling down in large slabs, probably suitable for roofing slate. Immediately north of the portage landing rises a very singular and interesting ridge, which is steep on the south side and slants with the dip, and is somewhat more gradual on the north. The dip is 80° or 85° to the south.

This ridge is made up of conglomerate, in general terms, but shows interesting combinations.

1. It contains considerable deposits of jaspilyte, normal in all essential characters, rather magnetitic than hematitic, but considerably contorted and varying to a greenish siliceous jaspilyte and to dark slate.

2. This jaspilyte embraces rocks of different kinds as pebbles, and even occasionally as boulders, and the jaspilyte banding swings round and embraces them when large. The enclosed stones are of different sorts, but red granitic rock prevails. Such red granite boulders are also the prevalent pebble throughout that portion of this great conglomerate. Greenstone pebbles, hard, siliceous, greenish pebbles, and apparently pebbles of jaspilyte that is fiery red in color, are also included in the jaspilyte, yet, in the main, it is simply a banded jasper, nearly free from pebbles. Of one red granite boulder, about ten inches in diameter, a photograph was made (plate X, vol. iv). The jaspilyte is indigenous in the formation and its layers are frequently separated by fine green sediment, and sometimes by a coarser gritty green sediment. When the interleaved green sediment is fine and greenish it is sometimes also very siliceous, making a green flint. It is necessary to infer that the origin of the jaspilyte with its irony ingredient was cotemporary with a fragmental accumulation, the two processes operating simultaneously at the same point. No known agent is capable of such double process except oceanic water from which were being precipitated both iron and silica.

3. The conglomerate in its southern portion is characterized by a red weathering granite, but it also contains greenstone and jaspilyte and a siliceous, very fine rock like flint.

4. The jaspilyte itself occurs not only as large masses, but is strung out in small, lenticular, thin sheets, throughout the southern part of this conglomerate, and it fades out sometimes across the bedding into the general conglomerate, passing through a stage of siliceous, black or greenish slate.

5. Aside from the twisted and confused condition there is nothing further worthy of note in the southern belt, which is about thirty feet across.

On the south the rock, while plainly a part of a fragmental series, is a coarse irregular green schist containing much vitreous quartz in veins, running with the schist. This is visible only at the west end of the ridge. There is also some such quartz in irregular deposits throughout this conglomerate.

6. On the north side, while the conglomerate is continued in that direction, yet it consists wholly of greenstone debris, and is so consolidated that it looks like the massive greenstone of the lower formation. In some places it is so fine-grained and apparently siliceous, that it looks like the agglomeratic greenstone, although without the characteristic agglomeratic masses. It appears massive and uniform (No. 1821). There is another belt of jaspilyte further north, thirty or forty feet wide, and another further south about thirty feet wide, making a total thickness of about 100 feet of jaspilyte in 600 feet of conglomerate.

Conglomerates and graywackes. As already stated, this volcanic material grades imperceptibly into coarser, more siliceous and more detrital rock, forming slates, graywackes and conglomerates, whose stratification is perfectly evident. These detrital rocks are also very extensive, especially in the form of conglomerate. In these beds are fragments, well rounded, of many kinds of rocks, depending on the geographic position and the stratigraphic horizon. Probably the Ogishke and the Stuntz conglomerates are the most remarkable of these coarser beds, but between the localities denoted by these names, and especially in a wide belt at Moose lake and in the environs of Snowbank and Disappointment lakes, this conglomeratic terrane is very conspicuous and extensive. The color and composition depend on the nature of the underlying rock capable of furnishing an abundant detritus. The Stuntz conglomerate, at Vermilion lake and eastward, consists almost wholly of a gray quartz-porphyry, some of the rounded masses being a foot or more in diameter, whose source was unquestionably in some dikes of such rock which cut the older rocks of the vicinity. Eastward further this conglomerate is composed largely of greenstone debris, such as is seen on some of the islands in the southwestern part of Long lake. About Moose lake, especially on the south side, it is still coarse, but is partly of volcanic ejectamenta. The Ogishke conglomerate, which at Ogishke Muncie lake lies on the older greenstones, is largely composed of basic debris, and about Kekequabic lake embraces volcanic tuffs. Toward Saganaga lake this conglomerate changes to graywackes and slates, and at its immediate superposition on the Saganaga granite it is composed of debris from that granite, making a rock which, when firmly compacted, closely resembles the granite itself, but is distinguishable from the granite by its lacking the ferro-magnesian minerals.* One of the most remarkable phases of the coarser forms of the Archean fragmentals is to be seen at Zeta lake, which lies between Kekequabic and Ogishke Muncie lakes. The shores of this lake are almost wholly composed of a conglomerate in which appear conspicuous feldspar crystals, evidently also of fragmental origin, giving the rock the aspect of a porphyry. A similar composition is presented in the hills made of this conglomerate eastward from Moose lake (No. 2170), but here, in addition to crystals of feldspar, this conglomerate contains also fragmental crystals of hornblende (No. 2171). In numerous instances it has been observed that beds plainly of detrital origin alternate with those which contain such crystals of feldspar, indicating the proximity of volcanic vents and occasional explosive extrusion, accompanied by rapid oceanic assortment and stratification.

Origin of the fragmental rocks of the Archean. If we be allowed to infer the origin of these fragmental rocks from their nature, as given above, we are reduced to two methods of origin, viz.: volcanic ejection and ordinary erosion. Several geologists have already alluded to the probable volcanic source of much of the material which makes up the Keewatin of Canada and of Minnesota. We find that the Keewatin is separable into two parts, and that the volcanic materials are most abundant in the earlier or Lower Keewatin, while in the later Keewatin not only is there much less of distinctly volcanic debris, but also more of evident erosion and sedimentation.

The oldest detrital rocks are abundantly mingled with volcanic tuff of a basic nature. Indeed the fragmental greenstones of the Keewatin are so intimately associated with the massive greenstones that they cannot always be distinguished from them, whether in the field or in the microscopic thin section. Starting from the plainly igneous rocks, the characters gradually change by the loss of one feature after another and the acquirement of slightly different features, until finally the whole petrographic nature of the rock at one end of the series is so altered that it is not warrantable to class the rocks at both ends of the series in the same category. At one end of the series the rock considered is plainly an igneous one, and at the other it is plainly a fragmental one, and it is only by the most minute and painstaking comparisons that some of the steps in the series can be assigned to this or the other end of the scale. Without stopping at this place to specify these minute differences, or to indicate which characters are distinctly igneous and which are clastic, it is intended only to call attention to the significance of such an indefinite and gradual transition.

*The rock over which the short portage passes, from Saganaga lake to Oak lake, is a part of this conglomerate, but so closely resembles the original granite of Saganaga lake that several geologists have reported it as a part of the Saganaga granite.

In the first place, it is apparent that the supply of the basic debris, whether it was derived from erosion or from volcanic vents, was abundant and long continued; and if long continued it indicates that ordinary detrital action was limited or was excluded by the abundance of the supply. If ordinary detrital action had operated on these materials for a long period of time they would have received an indelible stamp of sedimentation and of assortment, such as is seen in the strata of later Keewatin time. It is allowable, therefore, to infer that the supply was not due so much to erosion of pre-existing rocks as to volcanic activity.

Since the larger part of these fragmentals consists of basic materials, it is apparent that the early, if not the earliest, magma was a ferro-magnesian one. Such materials, whether in a massive or in a fragmental condition, are, most of all rock substances, liable to alteration, and it is plain that in this case the fragmental and the massive have approximated each other in all outward characters.

Again, it is a legitimate inference, from the absence or rarity of plain sedimentary structures in much of these early tuffs, that they fell, not in the ocean, but on land surfaces. Such land surfaces, exempt from the action of organic matter, yet were subject to powerful atmospheric disintegration, by which the massive and the fragmental rocks, consisting of the same chemical elements and approximately the same minerals, would tend to a uniformity of texture and of structure.

These rocks, whether massive or fragmental, being the oldest known in the state, have been subjected to all the vicissitudes of subsequent geologic time. They have been pressed, depressed and upheaved and sheared. They have been heated by the ascending isogeotherms and permeated by subterranean mineralizers, and subsequently have been profoundly eroded. No actual volcanic vents have been certainly discovered, but the very evident tuffaceous character of the fragmentals has been met with in several places. These dynamic changes have also tended to unify these two classes of basic rock.

The plainly detrital rocks of the Archean lie higher, but the sedimentary stamp is also on some of the greenwackes which are described above. The true detrital rocks are graywackes, argillytes, quartzytes and conglomerates, usually quite siliceous. Some of these are in the Lower Keewatin and some are in the Upper. Those in the Lower Keewatin are, as a whole, finer grained than those of the Upper, and embrace argillitic slates, siliceous schists, quartzytes, arkoses and greenwackes, the last forming a link of transition to the older, underlying igneous rocks. Those in the Upper Keewatin are often remarkably conglomeratic and are of great thickness and extent. These occur in association with some argillytes, or black slates, and they also graduate into quartzytes and to sericitic schists.

All of the true detrital rocks of the Archean show the presence of oceanic waters, and the structure which oceanic distribution always implants on detrital rocks. But the coarseness of the debris, as well as the great thickness of the deposits, which in the Upper Keewatin reaches nearly two miles, attests the violence of the waves and currents which operated to produce and to transport the materials. In some places these materials are largely from the igneous rocks of the older formations, as in the Stuntz conglomerate, and in others they were derived from former clastic rocks. In some cases these fragments are coarse and angular, denoting powerful destructive agents but feeble transporting.

Distribution of the fragmentals of the Archean. The most important belt of the fragmentals of the Archean is found in the northeastern part of the state, extending northeastward, from Vermilion lake to Saganaga lake. It belongs to the Upper Keewatin and it lies non-conformably on the Lower Keewatin. Its materials everywhere contain fragments from the underlying, older strata. It occupies, apparently, the basin of an ancient syncline whose axis, in Minnesota, is traceable from Vermilion lake to the international boundary at Saganaga lake. The arms of the original syncline consist of granite and gneiss, and the origin of the fold probably dates from the appearance of the granite concerned. The northern arm comprises the granites and gneisses of the northern part of Vermilion lake, with the associated mica schists; these extend eastward by way of Bassimenan lake and enter Canada on the northern side of Hunter's island. Throughout some portions of this arm the igneous basic rocks, earlier than the granite, rise higher than the granite, and this is particularly the case on the southern side of Hunter's island. In like manner, the southern arm of this main synclinal valley consists of the early igneous Keewatin and its associated green schists and other schists, penetrated by a great range of granite which in its southwestern extension is known in part as the Giant's range. This granite belt, with its accompanying gneiss and mica schist, seems to come from far toward the southwest, but owing to the prevalence of the drift, it cannot be traced with certainty any further west than Pokegama falls, on the Upper Mississippi. Toward the northeast this arm sinks away and it is encroached on by the gabbro on the south, while the granite itself gives place to a characteristic massive greenstone along the north. In this way the axis of the depression has been shifted toward the south, and the overlying Upper Keewatin is brought, at Saganaga lake, immediately upon the granite itself, which further southwest constitutes the most of the southern rim of the basin. In this trough lie the rocks which, typically and specially, are herein designated Upper Keewatin. The rocks of the Lower Keewatin, mainly ferro-magnesian in character, whether massive or fragmental, and the later granite form the slopes and the summits of the rim. In general this expresses not only the distribution but the structure of the Archean lying to the north of the Cabotian gabbro and the Animikie, in the northeastern part of the state. There are ubtless other minor folds, and some of these are known to exist in the region tween Vermilion lake and Rainy lake, but the rest of the Archean portion of the ıte is so deeply buried under the drift sheet that it is impossible to indicate, even in ʒeneral way, the distribution of the Archean fragmentals. At certain points it is ıown that rocks of this character appear in other parts of the state. Much of the :chean in Carlton county is of this fragmental character, sometimes bearing a con-lerable proportion of volcanic debris. Similar rock underlies the western part of ɔrrison county, while the central and eastern parts of that county are underlain metamorphic conditions of the clastics as at Little Falls and by granite. The cks that appear along the Minnesota valley between New Ulm and Big Stone lake e also wholly crystalline, consisting of gneisses and schists, cut by granite and abase, but no sufficient examination has been made to warrant the statement that ıstic characters do not also occur. Such characters are most likely to remain in e rocks in outcrop farthest toward the southeast, the intensity of recrystallization ›parently increasing toward the northwest.

Metamorphism of the fragmentals of the Archean. It is not intended at this place enter upon the question of the dynamics and processes of metamorphism. That ıestion is more fully treated under the head of petrographic geology, parts ii and iii, to hich the reader may be referred for many details of the microscopic changes wrought the clastic rocks by dynamic forces and by mineralizing waters. It is only ›cessary here to call attention to such grand structural features as the state presents, ıich are dependent upon, and accompany, the principal belts of metamorphic change.

The centres of intense metamorphism are the points at which igneous rocks ,ve penetrated the strata, whether granite or gabbro. At the borders of the anitic bosses the clastics are converted to gneisses and mica schists. In general ch areas are more elevated than the non-metamorphic areas, but there are important ceptions. A glance at the geological map of the state shows the positions of these anitic and gneissic areas. In general they have a northeast and southwest direction, d between these hardened belts lie non-metamorphic rocks. It appears that very rly in the geological history of the state and of the northwest, a system of crustal lding was imprinted on the earliest rocks, and that this was attended by the appear-ce of igneous irruption at the fissure-lines which were produced at the upward xures. The rocks that were thus flexed and broken, so far as they appear by the ıdy which we have given to the state of Minnesota, consisted of greenstones, quartz-rphyry and their attendant clastics, of which the former may be assumed to repre-ıt the oldest rocks, and perhaps resulted in a large measure from the consolidation of ə surface of the molten globe. These rocks, especially the acid fragmental, have been bjected to earth-movements and widespread metamorphism which have given rise to a great series of gneisses and of mica schists, which in some of the annual reports has been designated by Lawson's term Coutchiching. They lie nearest the axes of upward flexure, and hence also nearest the large areas of granite. The crystallization produced in the Archean strata by this profound earth-movement is not wholly due to the act of contacting on the igneous rock, for it extends sometimes for a score or more of miles from the granitic area. It must be attributed rather to the general influence of a regional and uniform rise in the temperature of the earth's crust along those belts where this effect is seen, accompanied by an intensified action of heated water and vapor. It is apparent, therefore,—and this is in accord with observation,—that the mica schist and the gneiss may have resulted at any horizon in the early fragmentals, and that such rocks cannot from their mineral composition be taken to be older than other Keewatin rocks that do not show this metamorphism. In other words, the stratigraphic value of such a term as Coutchiching is nil, when it is applied to the general chronological scheme. It can only express a greater nearness to an accidental and local centre of metamorphism or to an igneous protrusion.

It is very true that Mr. Lawson, in his definition of the term Coutchiching* described that formation as lying non-conformably below a basal conglomerate of the Keewatin, which conglomerate, he thought, represented an important time interval and break in the Archean series. In Minnesota, however, no such conglomerate has been found at the point of transition from the Keewatin to the mica schists supposed to be Coutchiching, although careful examination and search were made with the special view of finding the break. Quite recently Mr. Coleman has shown that the conglomerate to which Mr. Lawson referred is not at the bottom of the Keewatin, but contains much Keewatin detritus and probably represents, as suggested by Mr. Coleman, a break in the Keewatin itself. It is therefore comparable with the break which is well known in Minnesota, and on the evidence of which the Keewatin is divided into upper and lower.†

The occurrence of the first grand folding may or may not have brought the flexed strata to verticality. The fact that both the earlier and the later beds are now in a vertical position rather indicates that the first folding which took place with the first granitic invasion was not sufficient to produce verticality. This uniformly vertical attitude of the Archean is one of its most marked characteristics. It implies, of course, that all the thicknesses are repeated, perhaps many times, in the measurement of any extensive traverse, the original sharp upward flexures having been denuded. In the case of the Upper Keewatin these flexures have not so universally been productive of metamorphism, and indeed have not usually been attended by granitic intrusion. The strata are compacted and in some measure a disintegrating kind of metasomatic change has passed over them. So far as known, however, they are not generally converted to gneiss and mica schist. The original minerals and rock fragments are distinctly preserved. Where, however, these Upper Keewatin strata are also penetrated by granitic dikes or by large bosses of granite, as in the region of Snowbank and Disappointment lakes, they are rendered micaceous and can often

*On the geology of the Rainy Lake region. *Geol. Sur. Canada*, vol. iii, report F, pp. 5–183 (for 1887–88), 1889.

†Report of the Bureau of Mines (Ontario), vol. vii, p. 153, 1898, "On the clastic Huronian rocks of western Ontario." *American Geologist*, xxi, pp. 222–229. "Some resemblances between the Archean of Minnesota and that of Finland."

correctly be called mica schist. In this case, however, the boulders and pebbles are still distinctly preserved, becoming more apparent on the weathered surfaces. One of the most perfect examples of the effect of metamorphism and granitic intrusion on the Upper Keewatin is to be seen about Snowbank and Disappointment lakes, and extending westward toward Moose lake. These beds are here penetrated by granite about Snowbank lake and the western confines of Disappointment lake, and by gabbro along the south side of Disappointment lake. The rocks resulting from these intrusions are quite different. The granite seems to have been accompanied by a wide regional metamorphism, and the gabbro by an intense contact metamorphism. The former permeated the conglomerate in such a manner as to form in general a rock that might be called mica schist, but the schist retains its perfect sedimentary structure, and shows multitudes of pebbles of various kinds, many of them of granite.. The gabbro formed a rock which has been styled frequently muscovadyte, but still retains boulders, though less distinctly than in the mica schist at Snowbank lake, and rendered the laminated, sedimentary structure much less evident. The ferro-magnesian element of the gabbro has been presumed to have been transferred by heated circulating water in some measure into the older rock, giving rise to hypersthene, biotite and sometimes olivine and enstatite. At the same time a secondary plagioclase is developed, ranging from andesine to labradorite, which embraces, in the same manner as the hypersthene and often as the magnetite, nearly all the other minerals poikilitically. But this hypothetical loss of ferro-magnesian minerals by the gabbro is subject to considerable difficulties, viz.: (a) The ferro-magnesian element in this modified rock is frequently equal to or exceeds the same that would be found in any normal gabbro; (b) The gabbro does not show any noticeable loss of these elements at the points of contact; (c) But rather possesses, as a rule, a greater abundance of these minerals.

Magnetite occurs in abundance locally in this metamorphosed rock. This is the case at Disappointment lake, where it has given rise to exploration for economic results. In some of the annual reports this iron ore was classed with the Animikie. It resembles the iron ores supposed to be Animikie where they have been affected by the gabbro, such as seen at the Gunflint Lake Iron company's works near Gunflint lake, and at Birch lake, but this resemblance is due apparently to the similarity of the original ores and the identity of the rock that caused the metamorphism. The two ores were hematite (occasionally magnetite) with silica as the principal impurity. The action of the gabbro has resulted in the re-formation of both substances, the resulting magnetite serving sometimes as a mesh or sponge in the spaces of which are found grains of secondary quartz and of nearly all the ferro-magnesian minerals of the muscovadyte. This deposit of iron, therefore, is to be parallelized with that existing north of Moose lake, already referred to, found in this conglomerate, rather than with the ore of the Animikie. In a similar manner magnetite belonging in the Lower Keewatin is produced in the green schists. This is found at Garden lake, on the north side of Long lake and near Tower. A belt of magnetite also occurs in the green schists at a couple of miles southwest from Ely. In each case the accompanying gangue rock is quartz in a finely-granular but compact state. It is only in contact with the gabbro that this ore is associated, so far as known, with the ferro-magnesian minerals mentioned at Disappointment lake.

It should be stated here that owing to the sameness of the result of the gabbro contacting on these different ore horizons, whether of the Animikie, the Upper Keewatin or the Lower Keewatin, it is impossible to distinguish them on lithological grounds. The structural environments and the nature of the associated rocks must be taken into account. There is a series of magnetite deposits extending from the vicinity of Iron lake (southwest from Birch lake) eastward as far as to the vicinity of Gunflint lake, which fall into this doubtful category. They occur on the north and south sides of Birch lake, the north side of Thomas lake, the north side of Fraser lake, N. W. ¼ sec. 20, T. 64-6 W., the south side of Gabimichigama lake, along the south side of the stream in the northern part of sec. 35, T. 65-5 W., at Paulson's lake (Gunflint Lake Iron company), and especially about a mile north of the Gunflint Lake Iron company's working, in section 28. The Animikie of the region of Gunflint lake extends unquestionably about two miles west from that lake, at which point it seems to swing southward, the strike of its lowest strata lying in the low, broad valley, which seems to be the northern continuation of the Cross River valley at the point where that river turns eastward to join Gunflint lake, Westward from that vicinity the iron ores above enumerated present ambiguous characters, and there are good reasons for considering some of them metamorphic conditions of lodes of jaspilyte that really belong in the Keewatin. The chief objection to their Animikie age is their intimate association with a rock (muscovadyte) which at Disappointment lake is found to be the product of metamorphism by the gabbro in contact with the Keewatin. These ores, however, in the chapters in volume iv, and on the geological plates, as in all the annual reports, have been represented as of Animikie age. They are as a class the ores which have sometimes been denominated "olivinitic iron ores."* Their accidental occurrence in the presumed line of strike of the base of the Animikie, which here also nearly coincides with the northern limit of the gabbro, was the initial cause of their being grouped with the Animikie. The absence of the black slate of the Animikie in any of its modifications, from the area extending from near Iron lake to within a few miles of Gunflint lake, has been attributed to the overwhelming volume of the gabbro, but it is more than possible that the Animikie never extended so far north, and that all the modified rocks that have been described in this belt, frequently called muscovadyte, as well as the iron ores mentioned, are parts of the Keewatin, chiefly of the greenstone phases. This remark is perhaps to be extended to include the crystalline limestone or breccia of flint embraced in limestone (No. 312), which has been described at Gunflint lake, but not the iron ores nor the horizontal flint seen on the north side of Gunflint lake.

Stratigraphic Structure of the Archean Fragmentals.

The structure of the Archean is made out by the occurrence of conglomerates which indicate stratigraphic breaks in the succession, inasmuch as they contain fragments from the older and not from the later strata. These conglomerates also strike across the structure features of the older series, and frequently dip in marked non-conformity with them. In addition to non-conformities, it has been observed that some of the granitic intrusions are earlier than others, and hence serve as guides in separating the Archean into grand divisions. It has not been found possible as yet to employ thus the ferro-magnesian or basic dikes and other forms of intrusion of the Archean of later date than the basal greenstones, but it is probable that structural and petrographic differences could be discovered to serve such a purpose if a sufficiently extended study and comparison of them should be undertaken.

* *Bulletin vi*, p. 117.

Nomenclature. The following summary sketch shows the succession and the structure of the Archean as made out by the field examinatious and corroborated by the petrographical studies. We find no use for the terms Laurentian and Coutchiching as stratigraphic divisions of the Archean, as they seem to be represented, the former by metamorphic and igneous rocks of the Archean, and hence of irregular stratigraphic occurrence, and the latter by metamorphic conditions which are also of different and uncertain horizons. We use the term Keewatin as applicable to all the clastic rocks here put in the Archean in the state of Minnesota, that term having been employed by Lawson for the region of the Lake of the Woods in his Canadian report published in 1886.* At the present time these rocks are all included by the Canadian survey, whether crystalline or fragmental, under the term *Huronian*, and that term would be employed here were it not for the objections brought forward by Lawson, chief of which is that the Huronian of the typical locality, as defined by Logan in his final description,† includes also the Animikie and excludes all mica schists and gneisses. To this may be added the fact that the original definition of the term Huronian embraced under that term also the Keweenawan.‡ By the United States Geological Survey the Archean, so far as it shows evidence of clastic origin, is included in the Algonkian. The crystalline rocks are divided between those which are palpably intrusive in the Algonkian clastics and those which are near the bottom, the latter only being put into the Archean. The term Algonkian might be used, but if due regard be paid to the law of priority it should give place to Keewatin. We divide the Keewatin into two non-conformable parts, separated by a great stratigraphic break. There may be a basal conglomerate at the contact of the fragmentals of the Lower Keewatin on the massive greenstones below, at least in some places, comparable to that which has been described on the south side of lake Superior, but it has not been well identified in Minnesota. Several conglomeratic contacts on the Lower Keewatin have been seen, but in all cases they have proved to be formed by the Upper Keewatin on the Lower.

The Lower Keewatin. The oldest rocks known in the state consist of greenstones. They constitute what has been designated, in some of the annual reports, the *Kawishiwin.* They are both massive and fragmental. As massives they seem to grade into some overlying greenstone beds which manifest clastic characters, the transition rarely having been seen to be that of an erosion interval marked by a basal conglomerate. The only place at which a conglomeratic structure has been identified at this horizon is that described in the Lake county chapter (volume iv, page 292), where a greenstone conglomerate 105 feet thick lies on the massive greenstone. The

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* Geological Survey of Canada, New Series, vol. i, 1886.

† Geology of Canada, 1863, pp. 50–57.

‡ *Esquisse Géologique du Canada pour servir à l'intelligence de la carte géologique et de la collection des minéraux économiques envoyées à l'exposition universelle de Paris*, 1855, par W. E. Logan et T. Sterry-Hunt.

transition seems rather to have been of the nature of a change from massives to surface lavas and volcanic ash, accompanied in some places by extensive oceanic distribution and sedimentation. These rocks extend east and west in two conspicuous belts. The southern belt begins in the vicinity of Gunflint lake and extends westward by way of Gabemichigamme lake, the Kawishiwi river and White Iron lake to Tower, and indefinitely westward. The greenstone hills, known as Twin peaks, south of Ogishke Muncie lake, are the highest summits of this range. Between Ely and Tower are numerous hills belonging to this range. The northern belt of greenstone enters the state from Hunter's island, appearing conspicuously at the south side of Bassimenan lake. At Pipestone rapids and Fall lake it widens southward and apparently unites at the surface with the southern belt, the overlying Upper Keewatin being absent for the distance of a few miles. But further west it is again divided by the Stuntz conglomerate, the northern arm running to the north of Vermilion lake, west of which its extension is unknown. In general these greenstone ranges constitute topographic elevations, the country being hilly or sub-mountainous, and this character is hightened when granitic intrusion has still further hardened this rock.

It is in the upper part of the Lower Keewatin that occur the iron deposits at Tower and at Ely. The enclosing rock is obscurely characterized, being in the main a greenstone which sometimes is distinctly fragmental, as at Tower, and sometimes hardly distinguishable from a massive igneous one, as at Ely. Owing to the structure and character of the ore, however, which is believed to be of the nature of an oceanic precipitate, it is quite certain that in all cases where this ore occurs the enclosing rock is a sedimentary one, although composed of the elements of a basic eruptive. This ore is common between Tower and Gunflint lake.

The fragmental, stratified portion of the Lower Keewatin becomes more important toward the west, while the plainly massive characters seem to fade away. The southern arm, for instance, of the Lower Keewatin, taking the form of more or less stratified greenwackes and finally of graywackes and argillytes, at Tower widens toward the south and continues apparently to the Giant's range of granite, by the advent of which it is changed to crystalline schists. Westward from Vermilion lake, while it is evident, from what is known of the region, that the Lower Keewatin extends as far as the Mississippi river and its northern tributaries and across the Bowstring river, the prevalence of the drift and the Cretaceous is such that nothing is known as to its divisions and geographic limits. Toward Rainy lake it is also apparent that a similar change takes place, *i. e.*, that the fragmental character prevails over the igneous. In this direction, further, a very extensive regional metamorphism has converted the Lower Keewatin into mica schists and gneisses, and this change has been accompanied by the intrusion of large volumes of granite. It is not possible to affirm that the Upper Keewatin occurs in Minnesota in the Rainy Lake region except at one point, viz., about the head of Jackfish bay, about six miles east of Koochiching. The gold deposits of Rainy lake are in the Lower Keewatin. Between Rainy lake and Kabetogama and Namekan lakes mica schists prevail.

This wide belt of recrystallized fragmentals of the Lower Keewatin probably underlies the most of the central and southwestern part of the state as far as to the Minnesota river, which they cross with a strike nearly at right angles and with a prevalent dip toward the southeast. They run below the later formations in the southwestern counties, but probably occupy, with more or less of intrusive granite, a wide patch in South Dakota. However, in this direction they become covered, both in South Dakota and in Minnesota, by beds of Cretaceous age.

On the south side of the Giant's range of granite, these rocks appear, and here they also carry the same kind of jaspilyte iron ore, but, as the gabbro of that part of the state and the Animikie strata hide them toward the east, and the drift deposits of the St. Louis valley toward the west, their characters and geographic boundaries are mostly unknown. They appear in the central and western portions of Carlton county where their line of separation from the Upper Keewatin is quite obscure. They extend southwestwardly to the central and western portions of Morrison county.

The basic Lower Keewatin or Kawishiwin series of rocks is presumed to be of very wide extent, and perhaps represents the universal original crust of the earth. Its modified clastics and the still later Lower Keewatin graywackes, etc., may be parallelized with some of the gneisses and mica schists which have been included under the terms Laurentian and Coutchiching.

The Lower Keewatin was terminated by an extensive folding and metamorphism, and this movement was accompanied by the oldest known granitic intrusions. These igneous rocks will be considered more in detail at another place, but it is germane to state here that these granitic areas rise as bosses in the midst of the older schists and also penetrate the later greenstones and their attendants as dikes. They vary from indefinite felsitic rocks to quartz-porphyry and to aplitic granite, as dikes, and to coarse granite in larger areas. There are also some indications that some basic rocks of igneous character and intrusive structure date from the Lower Keewatin. Such are certain altered gabbros. The only known occurrences of an Archean gabbro in Minnesota are at a few miles southwest from Motley, in Todd county, and at Little Falls, in Morrison county. There is also an important area of gabbro at Knife lake, on the international boundary, along the southeastern shore, but it is probably of more recent date than the Lower Keewatin. By far the larger part of the granites of the state date from the close of the Lower Keewatin. Such are the granites of Bassimenan lake, of Saganaga lake, a part at least of the Giant's range, and of the region of Rainy lake and the north shores of Vermilion lake. The granites of more southern localities, such as that at Ortonville, at St. Cloud and at Sauk Rapids and in the eastern part of Morrison county, are believed to belong to the same category, because of their association with large areas of highly altered and wholly recrystallized schists that bear the characters of altered northern Lower Keewatin schists. This of course is a character which is very unreliable for such an inference, but it is the only guide to the age of these southern granites which can be invoked.

Marble is also one of the constituents of the Lower Keewatin. It is seen at Ogishke Muncie lake, extending for about four miles conformably with the general structure. From this fact, and from the occurrence of microscopic debris of quartz, feldspar and green hornblende in this marble, it is believed to date from the origin of the rock, and was an oceanic chemical precipitate. A similar marble occurs in the staurolite mica schists at Pike rapids, on the Mississippi.

Upper Keewatin. The rocks which accumulated in the troughs after the folding of the Lower Keewatin consist very largely of conglomerates, but they also include graywackes, quartzytes, argillytes and jaspilytes. Jaspilyte, of the type seen in the Lower Keewatin, is the matrix of the conglomerate on the north side of Moose lake. In the same conglomerate are pebbles of a jaspilyte of an earlier date, and of granite and flint. In favorable locations, as at Ogishke Muncie lake, where this conglomerate lies on the Lower Keewatin, it also contains many boulder masses of diabase and of green and slaty rock similar to some seen in the Lower Keewatin. About Vermilion lake it embraces the Stuntz conglomerate, which is composed largely of pebbles of quartz-porphyry, whose source is probably from dikes of that rock cutting the Lower Keewatin in the near vicinity. At Tower this conglomerate undergoes sudden local variations. It is in some places composed largely of fine green schist, which gradually acquires fine clastic grains and pebbles of jaspilyte (figure 2, plate WW, vol. iv). In the near vicinity this schist is seen to surround larger and larger masses of jaspilyte which attain the dimensions of ten or twenty feet across; and it is very difficult, in such conditions, to distinguish this schist from the green schist underlying from which, as a debris, it has been obtained; and this difficulty is increased by the common folding, pressure and shearing to which they have both been subjected. Beautiful illustrations of this schist containing pebbles and large masses of jaspilyte are to be seen in the "South ridge" at a short distance from the city of Tower, while the original schist, containing the jaspilyte in its native places, can be seen conspicuously in the same ridge, and most prominently in the "North ridge." There is no known general order of succession in the composition of the Upper Keewatin. It can only be said that it is likely to be conglomeratic at the bottom; still that is not always the case, for at Saganaga lake the bottom of the formation is so much like the Saganaga granite (and is really a "recomposed granite") that it has been mistaken in the field for granite by nearly all who have seen it. In other places it appears that a very fine debris from the quartz-porphyries or from the greenstones of the Lower Keewatin has accumulated in the same quiet manner at the base of the Upper Keewatin, the coarser and even conglomeratic composition coming in at a higher horizon. This fact makes it very difficult to establish the precise base of the Upper Keewatin, except where this early fine debris was carried away and the conglomerate lies immediately on the older rock. The Upper Keewatin is cut by granite in the form of dikes and bosses. As it holds granite boulders there must have been an older granite. About Snowbank lake, and also about Moose and Disappointment lakes, it is changed to a mica schist by a regional metamorphism, but only at Snowbank lake is it seen to be penetrated extensively by intrusive dikes of granite. The two most notable masses of the Upper Keewatin are the Stuntz and the Ogishke conglomerates. These are believed to be substantially of the same age, although they are separated by an upward swell in the bottom of the great trough by reason of which they are in isolated areas.

The conditions of rock formation at the time of accumulation of the Upper Keewatin were the same as in Lower Keewatin time, but the detrital forces were much more powerful. It is evident that after the folding of the Lower Keewatin the igneous forces suffered a great abatement, though they did not cease. Isolated volcanic craters continued to throw out volcanic ash, and to charge the atmosphere with acid gases, and the ocean with the same chemical precipitates. This is evinced not only by the occurrence of much of the same volcanic greenstone ash in the rocks, but also by the existence of extensive deposits of jaspilyte in the later schists and conglomerates, as at Moose lake.

The Upper and Lower Keewatin have been subjected to another folding which had a general parallelism with the earlier folding. This pressure was so powerful and the folding so close that the Upper Keewatin lies in narrow synclines in the Lower Keewatin, and in nearly all places its attitude is nearly or quite vertical. With this general statement must be inserted some exceptions, viz., the strike of the bedding suffers sudden local changes. It runs north and south instead of northeast and southwest. Such an exception has been noted on the south shore of Vermilion lake, another on the east side of Disappointment lake (sec. 34, T. 64–8 W.), and still another southeast from Knife lake (secs. 7 and 8, T. 65–6 W). The strike sometimes is even 10° or more to the west of north. Such irregularities have, so far as observed, no systematic occurrence, but still, perhaps, indicate a pressure and a folding tendency oblique to the general direction. They may also be explained by the occurrence of local obstructions such as isolated bosses of the older formation round which, to some extent, the later strata tended to be warped within narrow limits.

This later folding was accompanied by metamorphism. The Upper Keewatin is converted to a micaceous rock about Snowbank and Moose lakes, and the Lower Keewatin (?) to a muscovadyte about the southern confines of Disappointment lake. These rocks are so similar to those produced by metamorphism of the Lower Keewatin that on petrographic grounds they cannot be distinguished. Still, it is plain that the rocks of the Upper Keewatin, in all known instances of such metamorphism, retain more of their clastic characters than do those of the Lower Keewatin.

[NOTE. There is an element of uncertainty in the assignment of rocks about Moose lake which contain the jaspilyte already noted to the Upper Keewatin; and this uncertainty is to be extended to the mica schists about Snowbank lake and the muscovadyte about Disappointment lake. The difference in metamorphism and the conglomeratic composition are features that might still inhere in the Lower Keewatin, and the general geographic position of these lakes rather favors the Lower Keewatin age of the surrounding schists and the jaspilytes. Their strongest Upper Keewatin character consists in the occurrence of pebbles of older jaspilyte and of granite in this conglomerate. This implies that some older terrane, probably the Lower Keewatin, had been formed, folded and cut by granite prior to the creation of these strata, for we know of no granite nor jaspilyte older than the Lower Keewatin.]

THE IGNEOUS ROCKS OF THE ARCHEAN.

Nature of the Archean igneous rocks. The igneous rocks of the Archean consist of two grand divisions, viz.: the massive greenstones and the granites, of which the greenstones are the older. With this grand distinction recognized, it is still true that there are a few intermediate rocks, but these are so small in amount that they are not worthy of class designation, and are so doubtful as to genesis that it is best not to include them in a fundamental classification. They will, however, be treated in a separate paragraph. There are also numerous dikes which are both granitic and diabasic. The former are included in the Archean, but of the diabasic dikes a considerable number are of later, probably Keweenawan, age.

The Archean greenstones show by their state of alteration that they are very old. Their original crystalline characters are much obscured, and sometimes quite obliterated. They are intimately associated with fragmental rocks that consist almost wholly of the same minerals as the greenstones, and these fragmental rocks have undergone such pressure and consolidation that in some instances they are very similar to the crushed massive greenstones, and the whole mass has frequently been classed as a unit under the designation Kawishiwin, a name derived from the Kawishiwi river, on which these rocks are well exposed. The petrographic characters of these rocks are given in another chapter, and their outward characters in the special chapters descriptive of the geological plates in volume iv.

That these rocks are older than the oldest known granite is shown by the apophyses from the granite which penetrate them. Such are to be seen wherever the two rocks approach each other, but may be specially mentioned at the northwest end of Birch lake, at the west side of White Iron lake, on the Kawishiwi river and at West Seagull lake. When the granite is in large masses the greenstones are metamorphosed by general and dynamic forces and converted to hornblende schists and amphibolytes. This alteration is not due so much to actual contact of the granite as to some deep-seated and widespread force acting on the older rocks over extended areas at the time of the granite intrusion. The older rocks seem to have been nearly at the same temperature as the intrusive rock, since the dikes do not generally show the structure due to chilling along their borders. When such dikes, however, are remote from the centres of metamorphism they are seen to be chilled at their borders.

As the greenstones merge into more and more clastic and siliceous rocks, as seen about the Twin peaks, and at the northwestern confines of Vermilion lake, and at Rainy lake, such widespread metamorphism gives rise to banded gneissic rocks of varying composition, sometimes quite hornblendic and sometimes quite siliceous, and in this form the upper part of the Kawishiwin has apparently been extensively altered into a group of rocks (gneisses, mica schists, etc.), which have very generally been taken to be the oldest known rocks of the earth's crust.

Besides these basal greenstones and their attendants, of the age of the Lower Keewatin, there are similar greenstones in the Upper Keewatin. These, however, differ from the older in being in general more plainly fragmental, and often in containing coarse fragmental debris. These fragmental beds are, in part at least, the rocks sometimes called "slate congomerates." They contain sometimes large pebbles of diabase and of granite, and often are distinctly bedded, making, when they become finer, graywackes, slates and quartzytes. That volcanic action was continuous into the Upper Keewatin, in northern Minnesota, is in harmony with all the structural and petrographic phenomena of the Upper Keewatin rocks, but exactly where the vents of volcanic ejection existed, it is at present impossible to state. It is probable that the volcanic areas of Lower Keewatin time would some of them be perpetuated into Upper Keewatin time, the intervening revolution not being sufficient to permanently obstruct the old ducts. It is hence also probable that it would be very difficult to divide the greenstones produced by such prolonged action in the near vicinity of such vent, into two epochs comparable to the two epochs into which the Keewatin fragmentals are divided. The region of the Twin peaks south from Ogishke Muncie lake is likely to be the seat of a long continued volcanic vent. Another seems to have existed about the northeastern confines of Kekequabic lake, and still another about the eastern end of Otter Track lake on the international boundary.

The granites of the Archean are well known. Several are described in later chapters in this volume, and their structural relations to the schists, gneisses and greenstones are given in the special chapters of volume iv. These granites are of at least two dates. As already stated, one series cuts the Lower Keewatin only, and the other cuts the Upper Keewatin. In numerous instances have been seen two series of granitic dikes, in the same rock, one series cutting the other. This occurs north of Vermilion lake, and at West Seagull lake. It is, of course, not known that these represent the two principal granitic epochs of the state, but it may be assumed.

The granites are more variable than the greenstones. They vary in texture and in composition; yet, as a whole, are better preserved than the greenstones. They very rarely show the effects of dynamic action, while the greenstones are frequently converted to schistose rocks by such action. The coarsest granites (aside from pegmatitic veins) are those of Saganaga lake, in which the quartzes are sometimes nearly half an inch in diameter, and are distributed evenly throughout the rock, and of Ortonville, in which the feldspars, orthoclase and microcline, are porphyritic, and sometimes are an inch and a half in larger dimension. A similar coarsely porphyritic granite occurs in Stearns county. The granites sometimes become gneissic. This word may be taken in two senses, viz.: the granite may become foliated by the occurrence of divisional planes, along which are a few more mica scales than elsewhere, but which do not affect the megascopic aspect, except on weathering. These divisional planes are separated from two to four inches. This rock, when quarried, appears massive and homogeneous. It is frequently seen at Bassimenan lake. Another form of igneous gneiss is that in which the minerals and even the mass of the rock are elongated uniformly in one direction, but in an interlocking mesh, making still a massive and nearly homogeneous rock, but on quarrying, having a distinct rift in one direction. These variations in the massive granites should not be confounded with the banding of the true gneisses derived from the metamorphism of sedimentary beds, which constitute probably seventy-five per cent of the gneissic rocks of the state.

The chemical composition varies in such a way that the alkali present is soda, as well as potash, making soda granites, or soda syenytes when the quartz is wanting. Frequently, also, the Archean granites contain some of the soda-lime feldspars, and they then pass into diorytes and to quartz diorytes. Rarely augite takes the place, in part, of hornblende, and still more rarely fluorite is found. Commensurate with these variations the rock takes different aspects, sometimes becoming quite dark with hornblende and biotite, and sometimes nearly white, because of the absence or scarcity of those minerals.

Distribution of the Archean granites. Owing to the fact that the granites graduate into gneisses, and that gneiss, which graduates into mica schist, may be of igneous or of aqueous origin, it is a priori impossible to indicate precisely the limits of the Archean granites. To this statement it should be added that no attempt has been made to outline the granites, either in the field-work or on the plates of vol. iv which show the areal geology. Considerable areas of the northern part of the state have not been traversed with sufficient frequency to furnish such information. It has only been ascertained that in such areas the rocks in general pertain to the crystalline series, and a single division has been made, viz.: into schists and gneisses, and the igneous granites have been included with the gneisses. In general, however, it is true that large areas of Archean igneous granitic rock cross the northern part of the state, trending with the grand features in a northeasterly direction. The Giant's range is the most southerly of these belts. This forms the most abrupt Archean hill-range in the state, running for the distance of fifty miles and maintaining the prominence and often the sharp outline which simulates that of a great protruding dike. Toward the north this granite spreads over the lower ground and disappears under a sheet of drift so effectually that its northern limit is wholly conjectural. This sudden change in topographic aspect suggests that the elevated belt is of a different date from the low ground granite, and is perhaps of later date. The Animikie lies in a tilted position on the southern slope of the Giant's range in its dike-like form, as if it had been uplifted by the intrusion of that granite.

Toward the northeast this belt of granite, after some interruption, is certainly, in part at least, of Lower Keewatin age, as it supplied debris to the Upper Keewatin conglomerates. This can be seen at the Kekequabic and Saganaga lakes, while at Snowbank lake the granite of the region cuts the Upper Keewatin.

The central islands and the southern shores of Bassimenan lake also consist of the earlier granite, which seems to be continuous with the granite of the northern shores of Burntside and Vermilion lakes, and with that of the international boundary at Lac la Croix and Kabetogama. About the southern confines of Rainy lake, granite gives place to much gneiss and schist. Granites are known in the central and southwestern counties, as in Morrison, Stearns, Benton, Todd, Big Stone, Nicollet, Redwood, etc., but the extent of these areas is unknown, owing to the prevalence of the drift.

Genesis of the Archean igneous rocks. The greenstones. The massive igneous portions of the Lower Keewatin, the oldest known rocks in the state, are believed to represent the first magma of the earth, and hence they are referable to the first cooled crust that enveloped the molten mass.

The question of the origin, as well as the order, of the Archean rocks has given birth to much discussion, for it is one of fundamental importance. Much of the diversity of opinion seems to have sprung from a defective and sometimes from an erroneous idea of the rocks themselves, and from differences in the usage of terms. The whole group of rock masses that lie below the basal conglomerate of the Taconic has been discussed as if it were a unit in structure and origin, as well as in date. Under the general term "crystalline rocks," they have been supposed to be due to original congealation of the surface of the earth, or to the crenitic action of water. At one time they have been assigned to a metamorphic origin, from sediments, and again considered as original precipitates in their present mineralogical constitution from a peculiar primeval ocean, a chaotic liquid which surrounded the globe, holding them as silicates in solution. By some extensive volcanic action has been invoked and by others specially excluded.

The following historic sketch of the progress of opinion is essentially condensed from T. Sterry Hunt,* the author of the "crenitic hypothesis," but with additions.

Newton, Descartes, Leibnitz, Buffon and others, seeing a resemblance between consolidated volcanic rocks and some of the crystalline rocks, and assuming a former molten condition of the globe, inferred that the crystalline rocks, whether massive or schistose, were the cooled and consolidated outer crust of the globe.

Lehmann (1756), called them "primitive," and regarded them as "parts of the original nucleus of the globe," which had not been altered since. Pallas and De Luc had the same opinion, though De Luc lastly admitted that they are due to "aqueous deposition." Pallas also regarded them as "due to the agency of water," and believed that volcanic phenomena were but "local accidents" (1777).

According to Werner (1785), "the crystalline rocks" were separated from the primeval ocean as chemical precipitates, and granite was the first laid down. This was followed by the gneisses and the mica schists. Thus Werner accounted also for basalt, and all the forms of the Archean. He saw no indications in these rocks of volcanic activity, or of subterranean heat. Actual volcanoes were by him explained as caused by internal combustion of carbonaceous deposits.

According to Hutton (1785), and Playfair, his interpreter (1802), who argued from injected granitic veins and from analogies with basalts and volcanic rocks, granite is of igneous origin, cooled from fusion. He supposed that quartz, feldspar, tourmaline and other minerals in granitic veins are formed from cooling from igneous fluidity. But Hutton considered granite of later date than the strata that lie on it, agreeing, however, with Werner that granite is the lowest known rock. Hutton, however, considered the gneisses and the schists as of different origin, viz.: detrital, distributed by water, consolidated by heat and by pressure, re-fused, injected in the strata, destroyed and again re-formed by the same process, in a ceaseless round, without beginning or end. He was attacked by theologians, and Werner's hypothesis, which began in chaos and invoked a universal ocean, was espoused by them. Wernerism, however, could not withstand the evidences of observation,

*HUNT. *Mineral Physiology and Physiography*, pp. 68-115.

showing that trappean and other rocks in a heated and fluid state had been injected, and Huttonianism prevailed largely.

De la Beche (1837) urged a modified neptunian (Wernerian) hypothesis, viz.: an unoxidized nucleus, a solid crust resting on a liquid interior, and a primeval ocean, gradually settling from the atmosphere as the crust became cool enough; and came to the conclusion that the stratified igneous rocks resulted from chemical precipitation from such an ocean. These would be mingled, more or less, with the products of direct igneous action, and often no lines of demarkation could be drawn between them.

Daubrée (1860) adopted and amplified the view of De la Beche and enforced it by experimental tests of crystallization of silicates under pressure in the presence of the vapor of water. Daubrée presumes that when the surface passed from the dominion of fire to that of water, it experienced a long series of chemical conditions promoting many decompositions and recompositions, aqueous action intervening with igneous, and again giving way before it, during which two principal products (structures) would be formed, one massive and the other sedimentary, passing into each other gradually. The crystallization of the silicates must have taken place in the presence of watery vapor. This vapor was under tension of 250 atmospheres, and a temperature of about 1330° centigrade "about that of redness." Thus Daubrée adjusted the Wernerian hypothesis to the theory of La Place of a fused and cooling globe, and supplied the "chaotic liquid," or universal ocean required by the Wernerian hypothesis.

In all these hypotheses the primeval rock is granite. Werner, Hutton, Macculloch and Elie de Beaumont supposed the first crystalline rock to have been that of granite, and Scrope imagined the whole earth to have separated from the sun as an irregular, granitic aerolite, on which were subsequently formed the gneisses and schists by the action of the primeval ocean, mainly through a process of disintegration and of regeneration. The process of sedimentation for the gneisses and schists though opposed by Saussure, was approved by Hutton, Boué and Naumann, and came to be generally believed.

Hence, when Lyell (1833) proposed the theory of metamorphism, giving origin to the hypogene metamorphic rocks (gneisses and schists) by a deep-seated change in the detritus from the first granitic crust, it was readily accepted, and has remained in vogue to the present time.

This theory, however, as it requires the destruction of a vast amount of the original granitic subcrust in order to form the 30,000 feet, more or less, of the gneisses and schists, met with a physical difficulty. It requires at once sufficient elevation of the granitic crust to bring it into contact with erosive agents, and a submergence below the ocean to allow of the enormous accumulations. This difficulty was met in part by Dana (1843), who introduced and amplified the idea of volcanic origin of much of the materials of the metamorphic rocks. He claimed that most of the crystalline igneous rocks could be formed also by the recrystallization of their debris, and that in the vicinity of volcanoes such debris was always abundant. According to Dana, pyroclastic material enters largely into the constitution of the "hypogene metamorphic rocks" of Lyell.

Clarence King (1878) recognized volcanic action as a source of oceanic debris, but showed that great depth alone (30,000 feet) is not a cause of metamorphism. He explained the origin of olivine rocks, magnesian silicates and serpentine, by the occurrence of volcanic olivine sand, etc. King also accounted for the variations seen in igneous rocks, by a process entirely novel. He assumed the downward increase in density of the mass of the earth, solid from pressure, and ascribed to removal of pressure the occurrence of fused areas or lakes of lava. As these were liable to occur at varying depths they would issue at the surface with the characters proper to their various densities, and would be local and temporary. By this, and by a presumed separation of such molten lakes through the action of gravity, into two parts or layers, the more dense at the bottom, all the varieties of igneous rock are explained.

Marr (1883) urged the volcanic source for the origin of the ancient crystalline rocks, *i. e.*, the gneisses and schists, and this element has been admitted more and more to the present day, except by T. Sterry Hunt.

Dr. Hunt proposed (1884) the "crenitic hypothesis," for the origin of granite, gneiss and all the other Archean rocks, including the schists, basalts and greenstones. This hypothesis conceives the crystalline rocks to have been derived, directly or indirectly, by solution from a primary stratum of basic rock, the last congealed and superficial portion of the cooling globe, through the intervention of circulating subterranean waters, by which the mineral elements were brought to the surface. This circulation is supposed to have been caused by heat from below and surface radiation. It is noteworthy that this hypothesis presumes a primeval basic layer, which is wholly lost by the crenitic process, originally not differing much from the composition of doleryte, and yet appeals to the "Huronian greenstones" as one of the products of the crenitic action, the last step in the process.

As metamorphism came to be recognized by most geologists as an essential element in this investigation, the question assumed two branches, viz.: the origin of the materials of the crystalline stratified rocks, and the origin of the differences in the igneous rocks. On the latter, recent investigation has been centered, under the terms segmentation or differentiation of magmas and their succession. At the same time much more accurate knowledge has been reached as to the nature and succession of all the parts of the crystalline rocks. The study of the igneous rocks proper since this division of the inquiry has been conducted by Rosenbusch, Teall, Iddings, Brögger, Michel Lévy, Geikie, Becke, La Croix, Lang, Lewinson-Lessing and others. The examination of the order of succession of the Archean rock masses has been carried on chiefly in the United States by the officers of the U. S. Geol. Survey, and of some of the state surveys.

On theoretical grounds, Dolomieu maintained, in the latter part of the last century, the existence, "beneath the granitic substratum, of a liquid layer which gives origin to basic rocks and lavas. A similar view was developed later by Phillips, Durocher, Bunsen and Streng, "who have imagined a separation of the liquid layer, or the matter at the surface of the cooling globe, into two layers, an upper acidic one corresponding to granites and trachytes, in which, besides alumina and an excess of silica, lime, magnesia and iron oxide are present in very small quantities, and potash and soda abound; and a lower basic one corresponding to doleryte and basalt, in which lime, magnesia and iron oxide abound with an excess of alumina, and but little alkali." These two constitute the trachytic and pyroxenic magmas of Bunsen, who derived his ideas (1851) from a prolonged study of the volcanoes of Iceland. Bunsen also believed that various intermediate rocks are produced by a mingling in different proportions of these two separated magmas.

Waltershausen (1853) criticised Bunsen's conclusions and maintained that while there is no distinct separation into basic and acidic magmas, there is still a gradual passage downward from acidic to basic, even increasing to a metallic interior with the metals and minerals arranged according to their densities. This was adopted and extended by Macfarlane (1864), and approved by Richthofen and by Zirkel (1866). According to this theory the earliest igneous eruptions were not of basic character, but came from near the exterior, and were feldspathic. Later igneous rocks became progressively more basic, coming from deeper and deeper reservoirs where the more basic elements reside, thus accounting for the basic nature of the late eruptions.

Von Cotta (1858) proposed the idea that below the siliceous crust, made up of granites, gneisses, etc., there exists a mass of more basic rock material mainly in the state of fusion, and that this sub-crust mass is the source of the basic eruptives. These eruptives become modified by the incorporation of more or less of the acid crust in the process of extrusion.

Durocher (1857) also shows the existence of two distinct magmas, one acid and one basic, and that intermediate rocks of eruptive origin are due to contact and mingling of these two magmas. Gravity determines the relative positions of these magmas, the basic being below the acidic.

Jukes on the other hand (1862) assumes a generally diffused uniform molten mass, from which, by a process of segregation, the basic rocks are extracted under certain conditions, and acid ones under others. This is essentially the idea of Iddings, which (1892) has been discussed by him under the topic of "Consanguinity" of igneous rocks.

Dutton (1880) assumed a primordial basic primitive crust, allied to basalt or doleryte, entirely homogeneous, and appealed to atmospheric forces to separate from it the more acid parts and form of them the quartzytes, granites and gneisses. The sedimentary products of erosion are heterogeneous, and by the rising of temperature within certain subterranean horizons, or perhaps by relief of pressure, the deeply buried materials are re-fused, to issue as igneous rock at the surface, with their recognized heterogeneous characters; or are reconsolidated *in situ*.

Under various theories for the cause of such differentiation, if it exist, this investigation has been carried on by Rosenburch (1889), who maintains that beneath the earth's solid crust the molten interior is separated naturally into certain reservoirs or "kerns" in which are gathered different magmas of which he distinguishes, on chemical grounds, five classes; by Brögger (1890), who believes that on account of the principle of Soret, certain silicates more basic than those with which they are associated are concentrated upon the borders of laccolitic masses, and hence are also the first to appear in cases of extrusion, followed by the magmas more acid; by Iddings (1892), who considers the differentiation to be caused by physico-chemical forces, largely inherent in the environment of the supposed primary or fundamental magma; by Geo. F. Becker (1897), who demonstrates that if such segmentations have occurred under the operation of physico-chemical forces, the time involved is inconceivably long, and the process so slow that fifty millions of years, or all the time elapsed since the close of the Archean, would be insufficient, and that the probable direction of the action of osmotic force would be to promote uniformity rather than heterogeneity; by Michel Lévy (1897), who, questioning the actuality of such differentiation and noting the opposing tendency of numerous observed facts, reaches the conclusion, from an exhaustive comparison of the chemical constitution of rocks having the "air of family," that but two magmas of permanent and fundamental importance can be recognized, viz., a basic or ferromagnesian one, and an alkaline one, represented respectively by diabase and granite. Of these, Michel Lévy finds the ferromagnesian was the earlier, and that from it, by a process similar to the "crenitic" of Hunt, the alkaline magma may have been produced, the basic lying below the alkaline. He, however, supposes the transformation took place in deep-seated reservoirs before solidification.*

*Classification des magmas des roches éruptives. *Bulletin Société Geologique de France*, xxv, 326, 1897.

It is a remarkable fact that, although several geologists have assumed a primordial ferro-magnesian rock as the earliest condition of solidified matter on the cooling globe, not one has been able to indicate a spot where it can be seen, but have assumed that the oldest known rock is a granitic or alkaline one. Hutton originally pointed out that this granite is younger than the strata that lie upon it, and Lawson has shown* conclusively that it breaks through the mica schists and the fragmental rocks of the Keewatin. As already fully stated, this is also the case in Minnesota, and it follows that the oldest rock at the surface cannot be these eruptive granites, whatever may have been their origin.

Those who have followed this chapter from the beginning will have learned that this granite is also more recent than that great greenstone series which plays so important a part in the geology of the Lake Superior region. They will also have noted that between the date of origin of the massive greenstones and the granitic intrusion there was formed an important series of detrital rocks, and that these detrital rocks, very largely composed of volcanic ash and to some extent of oceanic precipitates, such as silica, oxide of iron and lime, have been metamorphosed into the mica schists and gneisses which are cut by these granites. In other words, between the origination of the greenstones and the intrusion of the granite there was an immense lapse of time, which was characterized by a widespread, if not by a universal, scene of vulcanian activity. These volcanoes were, as indicated by the generally stratiform condition of these fragmentals, closely surrounded by the primeval ocean into which their ejectamenta fell,† and its erosion products must have mingled with the volcanic to constitute the cotemporary strata. Such strata would necessarily sometimes be acid and alkaline, and sometimes irony and magnesian, and would have embraced any oceanic chemical precipitates.

Origin of the Archean granites. Recent careful studies of the Archean granites have demonstrated several important facts respecting their nature and structural relations, showing their intimate connection with the gneisses, and thence with the mica schists. Before, however, mentioning these bonds of affinity, it will be best to refer briefly to some ideas that have lately been promulgated concerning their origin.

Relying on the result reached theoretically by numerous petrographers and upon the observed fact that, in Minnesota, the "greenstones" are the oldest of the Archean rocks, we are at once brought to the consideration of the question of the possible derivation of the granites from the greenstones by some process of alteration or differentiation.

*Geology of the Lake of the Woods. *Geological Survey of Canada*, 1886.

†The Kawishiwin agglomerate at Ely, Minn. *American Geologist*, vol. ix, pp. 359-368, 1892. In this paper, and in others written in the course of the prosecution of the geological survey, the greenstones were erroneously assumed to have been later than the granites and gneisses, following the order established by the Canadian Geological Survey.

It has been presumed by Hunt that by a long period of lixiviation by circulating waters the elements of the granite, as well as of all the other later crystalline rocks, were extracted from the early doleritic crust and brought to the surface and deposited in such form that they constituted, on consolidation, the rocks under consideration. By an extended series of chemical and mineralogical examinations he finds that all the minerals of the granite, etc., are derivable from the early ferro-magnesian crust, by the long-continued forces which he advocates. Recent researches by Michel Lévy also indicate that, starting with the ferro-magnesian scoria or outer magma of the earth, represented by some such rock as basalt, there may have been a profound transformation effected in that basic magma, in deep-seated reservoirs, through the action of mineralizing waters circulating through the surrounding rock walls. The end products of this transformation are the alkaline magmas which produce the granites, etc., while intermediate stages in the transformation give rise to igneous magmas of intermediate characters. Michel Lévy also allows for extensive other alteration of the igneous magmas by endomorphous metamorphism, *i. e.*, by the fusion and incorporation of material from the walls of the reservoirs and from the minor openings in the clastic rocks through which the molten masses may pass in their way to the surface.

Against such supposed change from a ferro-magnesian magma to an alkaline one there rises, however, an important obstacle, which appears to be insurmountable. It consists in the fundamental profound chemical difference that exists between these two magmas. It may be admitted, for the moment, that if a process of concentration of certain of the elements of the ferro-magnesian magma be long enough continued, accompanied by a slow extraction of other elements, there would be produced two magmas of contrasted characters. These two rocks, the end products of the supposed differentiation by whatever process, whether at the surface or in deep reservoirs, would contain all the elements of the original magma, and no others. If other elements are found they must be credited to some foreign source. If it be found again that the actual proportions existing between the elements in the derived rock be those that they could not possibly be supplied by the original magma, such excess of some of the elements must also be attributed to some foreign source. Allowing for these considerations, it appears at once that, while there is no potassium in the ferro-magnesian magma, it is the dominating base in the alkaline magma. It must hence have been derived from an extraneous source. It also appears that the amount of silicium present in the derived rock in proportion to that which could be supplied cotemporaneously with the needed quantity of the other elements, such as lime and alumina, is far too great. It is not necessary to enter into extensive or minute comparisons. The single fact that potash could not be supplied by the ferro-magnesian magma, and exists in large amount in the alkaline, is sufficient to warrant a serious doubt as to the actuality of any such transformation.

It has to be admitted that Hunt refers to the secondary occurrence of orthoclase in diabase in the Keweenawan rocks of the region of lake Superior. This he classes with the occurrence of zeolites, which are naturally produced by the first disintegration of the feldspars of the basic rock. Several occurrences of orthoclase and also of quartz in the Keweenawan diabases have been met with by the survey, but in all cases they have been supposed to be due to the inclusion of portions of the clastics within the diabase, or they are so far removed from the first disintegration that they are easily referable to foreign infiltration. Orthoclastic rock in patches is not an uncommon appearance in the Keweenawan diabases at certain points where the diabases are known to be near the clastics, and the inference is natural that where the clastic rock is not visible, the orthoclastic rock has been carried some distance from its source. The following is taken from the sixteenth report, page 16. The petrography of these occurrences is discussed elsewhere:

"It is apparently due to the enlargement and multiplying of the reddish felsitic amygdules (?) locally and the specialization of the mineral ingredients into macroscopical crystals that patches of red rock are produced in this greenstone [at Thessalon, Ont.] No. 1161 represents such red rock. Such patches are sometimes four and even eight feet square, scattered capriciously about, visible on the glaciated surface of the dark rock. This red rock consists apparently of quartz and orthoclase in distinct crystals, embracing in their interstices a greenish to black soft substance that, while finely foliated and resembling chlorite, yet does not seem to have served any other purpose than to occupy the vacancies between the other minerals as they assumed their crystalline shapes. Such nodules and veinings, if not such isolated large masses of reddish granulyte in trap rock, are not very uncommon. They occur at Taylor's Falls and at Duluth, and have been described by the writer at several places in northeastern Minnesota. Since the basic eruptives when in their normal state do not embrace the minerals here differentiated within them, it may be presumed that these exceptions are caused by the local and superficial mingling of small portions of the siliceous supercrust with the heated basic eruptive. On cooling and weathering the supercharge of siliceous matter is rejected from the mass to fill any convenient veins or amygdaloidal cavities that are within reach. When none such are found these crystals are formed within the greenstone, and are uniformly disseminated in it, causing the well known quartz dioryte and orthoclase gabbro."

Other isolated occurrences of orthoclase seem to be due to fumarole action, or at least to the introduction of potash by some later infiltration. On Isle Royale, at the Minong mine, it takes the form of adularia in small crystals implanted on copper (itself a filtration product) and on calcite. The total absence of potassium from normal diabase and hence the impossibility of orthoclase taking source from diabase, is the only point insisted on here. Leucite, which is a potash-bearing mineral of later basalts, has not been discovered in the Keweenawan eruptives nor in the Archean greenstones, nor have any potash-bearing zeolites been reported.

According to the researches of Pumpelly* on the paragenesis of copper and its associates in the lake Superior region, it appears that after the formation of a series of non-alkaline silicates, laumontnite, prehnite and epidote, followed by quartz, there was a concentration of copper in amygdaloidal and other cavities. After the copper and quartz the alkaline silicates appeared, such as analcite (?), apophyllite and ortho-

* *American Journal of Science*, vol. ii, September, October, November, 1871.

clase. If it be legitimate to infer, as has been done by Hunt in support of his crenitic hypothesis, that orthoclase is one of the products of lixiviation from diabase, it is also reasonable to ascribe metallic copper to the same source. On the other hand, it is quite easy to account for all these foreign substances by allowing the action of heated solutions circulating with fumarole activity through the rock long after it was solidified, during the process of cooling, or even at a much later date.*

If the original magma had been of intermediate character, as supposed by Iddings, such differentiation might, perhaps, have produced the contrasted magmas, but that would contravene the first term of the major hypothesis.

In the presence of this difficulty it is evident that some other source ought to be sought for the granitic magma, and for the igneous gneisses. This is not far to seek. Indeed, it is easily demonstrable from two different lines of evidence, viz., (1) Facts of field observation, (2) Facts of petrographic significance. After a brief statement of these two convergent lines of evidence, we shall consider the question of, (3) The source of the characteristic elements of the alkaline magma.

(*1*). *Facts of field observation.* Early in the study of the granitic rocks of Minnesota, the fact of the gradation of the Keewatin rocks such as graywackes, greenwackes, argillytes and sericitic schists, into mica schists, was impressed upon all the field geologists, and such gradation is affirmed in all the annual reports by all the assistant geologists whenever there was occasion to consider that question. Such transitions are found in nearly all cases where a considerable granitic area occurs, the crystalline condition gradually increasing toward the point of granitic intrusion. There are also very extensive areas of mica schists distant from any known granitic intrusion, which led to the conclusion that the crystalline transformation was due to some wider cause than mere contact of granite. Sometimes such mica schists are distinctly from rock originally clastic, containing still numerous boulder forms. This wider operating force has been supposed to be that which is expressed by the term regional metamorphism, and was attributed, in ultimate terms, to a general elevation of the temperature of crust throughout the region affected, either by the approach of large masses of the molten interior toward the surface, or by the heat generated by dynamic movements, or both. A local, temporary settling also might crystallize the fragmentals, by bringing them within the range of higher isotherms. Whatever the special and local cause, there is no question that such transformation is very widespread, and accounts for the greater part of the mica schists, and of the mica hornblende schists.

Equally early in the investigation of the crystalline rocks it was noted that the crystalline schists gradually pass into gneisses. At first a distinction was drawn

*Compare: The origin of the Archean igneous rocks. N. H. WINCHELL, *Amerierican Geologist*, vol. xxii, pp. 299-310, 1898.

between those gneisses which are plainly the result of a change in bedded fragmentals, and others which are nearly massive and homogeneous, but only present a gneissoid structure, *i. e.*, a prevailing direction of elongation of the constituent minerals. But it was found that such a distinction, while evident enough at the extremes, could not be maintained, and that the bedded structure gradually loses itself, under varying conditions, and passes into a simply gneissoid structure, the two being parallel and plainly different phases of the same fundamental transformation. In nearly all cases, where such a structural transition takes place it is observable also that there is a corresponding transition in the mineralogical composition, the mass of the rock becoming also more siliceous and alkaline. Indeed, there are considerable areas in the northern part of the state, occupied by crystalline rocks, which would be assigned in mapping by one geologist to the mica schists, and by another to the gneiss and granite, the last two rocks being grouped together according to our uniform practice. There is always evidence of more or less plasticity and of bodily movement of masses of the rock, and of streaming out of all the original structures, in the vicinity of transitions from the schist to igneous gneiss.

That the gneiss here referred to, *i. e.*, that which is massive, with only a mineralogical gneissoid structure or but rare and confused schistosity, is traceable into true granite, is a well-known fact of field observation, which has been repeated by numerous geologists. There is on this point very little, if any, difference of opinion.

When the crystallized fragmentals are dark colored, with larger amounts of mica and hornblende, the resultant gneiss or granite is also darker, but seems to differ in no way as to genesis and structure, from the lighter-colored crystalline rocks. They differ only in holding larger amounts of the dark minerals, and in their proportionate amount of quartz. In such instances the massive rock is rather dioryte than granite, and may be syenyte; and in some instances all stages of transition from one rock to the other can be collected within a comparatively small area.

(2). Facts of petrographic significance. As a group these rocks, from mica schist to granite, are characterized by much silica and varying amounts of alkaline feldspars. They rarely acquire hornblende or pyroxene and biotite in sufficient amount to warrant the adjective *basic.** When these minerals do exist in consider-

*The recent investigations of Dr. F. D. Adams on the chemical composition of certain gneisses of the province of Quebec,† have a bearing on this point. He has compared the chemical composition of several gneisses with that of a gneiss from Trembling mountain, and a granite from Carlingford, Ireland, these standards being assumed as normal igneous rocks. He finds that the gneisses investigated, while having a higher content of alumina than the assumed standards, a lower per cent of alkalies and a preponderance of magnesia over lime, have a chemical resemblance to certain clay slates and quartzytes. One of the gneisses of the series investigated has an intermediate character, its magnesia prevailing over its lime, so that it is "impossible to draw from its chemical composition any definite conclusions as to its origin. It might be an altered sediment or an altered igneous rock, or a sediment of the nature of a tuffaceous deposit." Dr. Adams concludes that the other gneisses of this series may be considered highly altered conditions of ancient sediments.

These are important results. It might be asked, however, what has determined the standard composition of an igneous rock, and whether the distinguishing chemical characters accepted by Adams will not be found to vanish when the comparison is extended so as to include undoubted igneous rocks from other localities. This seems quite possible from the fact that one of the selected gneisses of Dr. Adams' series is pyroxenic, and manifests such intermediate characters that it is to be considered as possibly "an altered igneous rock." The gneisses selected are interstratified in limestones and quartzytes so metamorphosed as

†Laurentian area to the north and west of St. Jerome. *Geological Survey of Canada*, vii, 1894 [1896], Report J, pp. 93-112.

able amount the massive rock acquires other names, such as amphibolyte, or eclogyte, and when free quartz disappears they vary to dioryte or syenyte; and as syenyte they still vary to laurvikyte when orthoclase is abundant and soda-bearing; to monzonyte when the feldspars are both alkaline and soda-lime-bearing and the rock contains augite; nordmarkyte when they contain more or less micropertbyte of orthoclase and oligoclase; quartz and small quantities of biotite, pyroxene, hornblende and ægirine; pulaskyte, which consists of orthoclase in kryptoperthyte forms, hornblende, biotite, diopside, eleolite, sodalite and accessory minerals; shonkinyte when they consist essentially of augite and orthoclase; and yogoyte when orthoclase and augite are in about equal amounts. When free quartz remains there has been a similar multiplication of nomenclature as the other ingredients vary. It is not necessary to enumerate these minor variations. They testify to constant fluctuation in the chemical composition, all implying a similar variation in the source from which they are derived. They point to the addition of potash and silica, in constantly varying amounts, to the elements already present in the ferro-magnesian rocks.

There are microscopical characters which should be noted, indicating a progressive crystallization in the fragmentals, leading up to structures that cannot be distinguished from those of massive granites. This is not intended as a general statement simply, for it is so well known that it need not be repeated; but as a fact of special and local observation in an individual rock mass, where the fragmental rock mass manifestly furnishes the material for the intrusive granite, which cuts it. In the field such relations are easily inferred from the study of the major structures* and such transitions have been tentatively assumed in some of the earlier publications. It was not until the rocks collected could be examined in detail that the petrographic transition could be seen to accompany and confirm the structural transitions. But one instance has been fully investigated. It is that of the granite of Kekequabic lake. The details of the petrographic examinations are included in the chapter devoted to the petrographic geology, and the field structures are presented in the chapters descriptive of plates 68 and 80. The evidence may be summarized as follows:

The Kekequabic granite. There is a small area of a reddish-gray gneissoid granite rising dome-like in the midst of the Keewatin. The clastic strata adjacent consist of a siliceous actinolitic schist, in general terms, but it varies in different ways. The hornblendic element becomes coarser and the rock assumes the character of a pecul-

to have no more clastic microscopical character than the gneisses themselves. It is not improbable that if a block analysis could be made of the whole mass, including both gneisses and evident fragmentals, the resulting composition would not vary strikingly from that of the gneiss of Trembling mountain, or from that of the granite of Carlingford. Indeed, if the whole seven analyses given by Dr. Adams, both slates and gneisses, be averaged, the result is: silica, 64.85; alumina, 15.74; lime, 1.55; magnesia, 2.94; soda, 1.39; potassa, 3.75, which does not vary much from a normal granite. If to these could be added the lime and quartz of the strata excluded by the selection of sedimentary gneisses only, the result would certainly not fall far from the composition of the normal igneous gneiss of Trembling mountain.

*Some new features in the Geology of Northeastern Minnesota. *American Geologist*, xx, July, 1897, pp. 41-51.

iar hornblende porphyry (No. 741). At other times the hornblende is partly replaced by augite, which is allied to ægyrine and in nearly all cases it can be seen to have been derived from augite by a uralitic (?) alteration. This derivation is evinced chiefly by a particolored polarization which sometimes represents exactly the original crystal form of idiomorphic augite, surrounded by fringes or external growths beyond the augite limits. When the augite grains were fragmentary, or were corroded before being enclosed in this rock, the hornblendic growths have exactly filled them out, the dark color of the polarization (or even the color seen in ordinary light) showing distinctly the original augitic outlines. Besides the conspicuous hornblendes sometimes this schist contains traces of feldspars, but usually feldspar is not evident. When feldspar is seen, the crystals often appear to have been altered into a microgranulitic mass of secondary grains which appear to be of quartz and feldspar. Sometimes pellet-like spots appears under the microscope, which are occupied by such granulation. By their assuming in thin section distinctly lighter and darker aspects four times in one revolution of the stage they are plainly due to a replacement of an old feldspar whose substance and crystalline integrity are not entirely lost. The "groundmass" containing these altered crystals is composed largely of finer condition of the same elements, but usually it embraces a notable amount of quartz. This quartz is in the form of free grains, of angular clastic shapes, or it is very fine and intimately interlocked with equally fine grains of feldspar.

This green schist is sometimes composed almost wholly of actinolite spicules. At other places it passes into a greenish graywacke. It is distinctly a fragmental rock, and shows a coarse, even pebbly, structure, the pebbles being usually of rock like itself, but finer grained. It is also distinctly bedded by sedimentation. It is considered to be largely of the nature of a volcanic tuff, and grades into the greenstones of the surrounding region supposed to be Upper Keewatin. This rock is represented by many numbers, of which the following may be mentioned: Nos. 1409, 1411, 1412, 1413, 1768, 1049, 1050, 1055, 1057, 1060.

This schist is part of a large sedimentary series, passing through greenwacke and graywacke into a pebbly conglomerate with which it intergrades. This conglomeratic condition is sometimes specked with coarse white feldspars, when it has been called *porphyrel*, and is well exposed in its perfect development at Zeta lake, east of Kekequabic lake. This "porphyritic" aspect, however, is widespread and sometimes appears in rock which is plainly fragmental though not conglomeratic, and has been noted especially in the region between Moose and Snowbank lakes.

The intrusive rock is sometimes a granite and forms distinct dikes cutting the schist and its associates, and sometimes is a porphyry, forming knobs of small dimensions that swell up rather fortuitously in the schists. As knobs this porphyry is known to occur beneath the schists and also superimposed on them, but it is not known, in this region, to occur as dikes in the schist, although it cuts some of the associated clastic strata. The granite also rises in domes though considerably larger. Geographically the porphyritic domes are so situated in relation to the granitic areas that they can be considered peripheral phases of the granite, projecting further amongst the clastics than the granite proper, but they were probably derived from slightly different sources.

Both the granite, which also passes into syenyte, and the porphyry, contain in places numerous pebbly or bouldery inclusions, and in the field have been noted several instances where megascopically the crystalline rock passes into the pebbly green schist already described, and into a granite which is charged with pebbles. These transitions seem to be in accord with microscopic transitions, as detailed below.

In the first place, it should be noted that there is a striking mineralogical affinity between the schist conglomerate and the crystalline rock, in that the augite in both is ægyrine, and that the feldspars of the schist-conglomerate, having very striking and unusual characters, are duplicated in the porphyry and in the granite, *i. e.*, the original feldspars are remarkably twinned and zoned. This statement as to the augite is not demonstrated, but rests on the concurrent evidence of other microscopic characters. It is evident that in such a schist it would be almost impossible to find augite retaining its crystalline form, for it readily changes to hornblende, that being indeed almost the first mineralogic change that takes place in a volcanic tuff of such age. But the augitic cores remain in the schist, sometimes as augite (No. 1060), and, on a still broader scale, the original forms of the augites are outlined in the resultant hornblendes by differences of absorption and of colors between the nicols. Exactly the same characters are seen in the augites of the porphyry where the preservation is sufficiently perfect to disclose the ægyrine characters of the original augite. As to the sameness of the feldspars, with their peculiarities, there is no question.

These two important characters ally these rocks in some way in a genetic bond, for the feldspars especially are wholly unlike any known elsewhere in the state. Chemical analysis points to anorthoclase, but the zoned structure, when analyzed by the microscope, indicates that the feldspars began as labradorite, passed to andesine, and sometimes at least terminated as albite, there having been a continual increase in the acidity of the material from which they were generated.

The general aspect of the granite (seen in thin section) along the south side of Kekequabic lake is suggestive, not of crystallization from a magma, but of simple induration of coarse debris. The feldspar grains do not interlock, except as they have been enlarged by a secondary growth, and in many sections examined they do not even come into contact, but are separated, very generally, by a space which is occupied by a fine interlocked secondary development of feldspar and quartz. The margins of the feldspars frequently are interlocked in this new growth. As this fine matrix increases in amount so the rock becomes porphyritic; as it increases in coarseness so the rock becomes granitic, but in all cases, or in nearly all, there is a distinct difference between the old feldspars and the new (compare rocks Nos. 1100 and 1101). Along with this generation of new feldspathic material is also the recrystallization of the quartz, thus making a truly granitic rock. The old feldspars, which, in the clastics proper, without metamorphism, have a tendency to disappear by a process of micro-granulitization into a fine mesh of secondary feldspar and quartz resembling the surrounding matrix, are by metamorphism regenerated by new borders and by micro-granitic growths of coarser grain, and by these new growths interlock about their margins. Occasionally the old feldspars embrace and surround idiomorphic small crystals of augite, having taken that relation in the magma in which they were generated, but the later feldspars do not enclose augite in that way. When the fragmental augites are not altered to hornblende, which alteration is usual, they are simply embraced between the newly developed feldspars. The old feldspars, as contrasted with the new, may be seen in Nos. 1046 and 1051. Indeed this distinction is observable with more or less certainty in nearly every thin section examined.

On a porphyry knob on the north side of the lake, at the corner of secs. 29, 30, 31 and 32, T. 65–6, there are, as observed in the field, transitions from the porphyry to the schist—at least to a green rock that contains the elements of the schist and nearly the same micro-structure, but yet has a petrographic alliance with the porphyry. Such intermediate rocks are found at several places, and in the field there is no line of distinction, the transition taking place in a few feet. These intermediate rocks of course have some origin. The microscope shows that the internal structures and composition are in accord with the major structures. In one direction the characters become more and more coarse and crystalline, and in the other more and more clastic, without the introduction of any new minerals. It appears as if the siliceous actinolite schist, losing locally its coarse feldspars, was converted into a dense green rock of hornblende, biotite, quartz and feldspar, in one direction, and in the other, with more or less preservation of the coarse feldspars that frequently characterize it, the same force had generated a lot of coarser quartz and secondary feldspar, and thus cemented the original debris into a granitic rock. Throughout the schist, even in its least metamorphic condition, there is a fine background of micro-granulitic quartz or of quartz and feldspar (No. 1047), which is ready, in case of the application of new forces, to take on new forms. The background matrix in the porphyry, as in the granite, is the same fine interlocked quartz, or quartz and feldspar. It is seen in the tuff in No. 1093, and in the granite in No. 1088. In the porphyry this fine matrix appears to be a micro-granulitized feldspathic debris, for numerous feldspars can be seen partially changed to such a micro-granulitized condition (No. 1093). Rock No. 1051 shows a link between the schist and the granite. It overlies green schist, and unites Nos. 1044, 1045 and 1046 to Nos. 1047–1051.

Still, under the hypothesis adopted it is not to be expected that very many actual transitions *in situ* from a plainly clastic rock to a plainly igneous one could be observed in the field. The moment a clastic rock becomes sufficiently plastic to move, under the pressure exerted upon it, it is likely to be dislodged and to enter any fissures that may exist in the firmer rocks surrounding it; and that gives it "igneous contacts" on the clastics. With these clastic rocks it would hence present not only contrasting structures, but also more or less petrographic differences. The porphyry here considered penetrates, in a few instances, the black slates associated with the green schists and with the graywackes, in the form of dikes, the slates being firm and refractory, affording most evident illustrations of intrusive action. In the area of the softer green schists, however, which are not brittle, but rather flexible, the same intrusive appears in the form of more or less round protuberances and blebs.

It is, however, with the conglomeratic condition of the sedimentaries that the most evident transitions occur to the granite. These are most evident in the field, and with the microscope the finer elements are seen to be simply compacted together, with but slight interstitial material. The crystals all being, as supposed, of the nature of volcanic ejecta, arranged somewhat by water, the elements of the rock embrace these with small amounts of erosion products, the latter increasing in amount with distance from the supposed volcanic source. One of the most evident and instructive instances of a granitized conglomerate is that seen along the south shore of the lake in sec. 31 T. 64–6. The fragmental character is most evident, and many of the pebbles are rounded. There is no short transition, but the whole rock over a wide belt acquires the granitic character. The appearance of the rock along this belt has been described as follows* by Dr. Grant:

On the northwest end of the little point in the S. W. ¼ of N. W. ¼ sec. 31, T. 65–6 (south side of the lake), there is a dark, medium grained diabase. And on the northeast corner of this point is a low outcrop of a fine grained, gray, apparently holocrystalline rock; the ground-mass is grayish and in it are small, black needles, probably of hornblende, and a few scattered, rather irregularly outlined, feldspar individuals. There are also a few rounded pebbles, up to those two inches in diameter, scattered through the rock. The specimens collected (No. 593G) show some of the pebble forms. Some of these pebbles are seen to be sub-angular, but most of them are rounded. They seem to be scattered irregularly through the rock and lie in no definite planes or layers; there is nothing in the rock to show any sedimentary lamination or bedding; it appears perfectly massive. This rock is seen in several outcrops in the N. E. ¼ of S. W. ¼ sec. 31, T. 65–6, and the shore is here usually lined with fragments of it. In the eastern part of this one-sixteenth section is quite an extensive exposure a short distance back from the shore. Here the pebbles, which have been steadily increasing in abundance eastward from the first mentioned outcrop, are very numerous. It would be almost impossible to find any surface a foot square in the rock at this place which would not contain one or more pebbles, and many areas of this size would include as

*_Twentieth Annual Report_, p. 76.

many as twenty. The rock is here represented by No. 594G, and pebbles from it by No. 594aG. This rock extends along the shore in a few outcrops nearly to the east line of section 31. The pebbles grow less abundant on going east from No. 594G. No. 595G shows a more highly crystalline condition of this rock from the S. E. ¼ N. E. ¼ sec. 31. The noticeable features of this rock are its sharply outlined, rounded and sub-angular pebbles and the few scattering, white, apparently porphyritic, feldspar crystals, sometimes a quarter of an inch in length. No bedding, lamination or definite arrangement of the pebbles could be seen in the rock. It seems that this rock is a metamorphosed conglomerate, and it strongly reminds one of certain facies of the Ogishke conglomerate.

In making, subsequently, a microscopic study of this rock it was classed as a hornblendic facies of the granite,* with the following note:

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

This rock (No. 595G) consists mostly of feldspar showing the usual characters, *i. e.*, much twinned with coarse and fine bands, often of tapering widths (albite and pericline), of hornblende, quartz and epidote. There is also a little biotite and magnetite. The hornblendes were at first augite, as shown by the central residua of greater absorptive power. The original feldspars were often nearly complete as crystals, but for the most part are fragments, and are clouded with fine epidote. They are cemented together by secondary deposition of fresh feldspar and of quartz. As grains they never interlock with one another.

A still more evident fragmental condition of a "porphyry," or porphyrel, is to be seen at Zeta lake, about a mile east of Kekequabic lake, where feldspar crystals as clastic elements are liberally mingled with pebbles of various kinds. There is, according to Dr. Grant, a traceable connection of this rock with the pebbly granite of the south shore of Kekequabic lake. In all respects, except in having a more evident fragmental composition, it is also a repetition of the porphyritic phase of the granite of Kekequabic lake (compare No. 1061, from Kekequabic lake with No. 1062 from Zeta lake). This porphyrel at Zeta lake has much the appearance of an igneous rock. It is in massive knobs that present a bold rounded outline quite similar to the porphyry at Kekequabic lake. It has a coarse jointage giving it a basaltic structure, and it was only after considerable field examination, and the consideration of the screened, though evident, pebbly structure that this rock was, in the field, recognized as a fragmental one. It is an obvious inference to unite this with the pebbly granite described by Dr. Grant, in a series which passes on to non-pebbly granite, and with the porphyry knobs at Kekequabic lake, which are less pebbly.

Order of generation of the new minerals. In the process of transformation from a clastic to a granite, at Kekequabic lake, the minerals appeared in the following order:

1. Actinolite, or hornblende, is formed, if it did not already exist, in the clastic rock. This was accompanied by a micro-granulation of the old feldspars, and by a

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* *Annual Report*, xxi, p. 40.

similar conversion of all finer feldspathic debris into a fine interlocking background.

2. Sometimes biotite occurs at this stage, but is more likely to be abundant under powerful metamorphosing action.

3. Epidote permeates the old feldspars and gathers independently.

4. Quartz and feldspar. Sometimes one and sometimes the other is plainly earlier, but usually they were about contemporary as to date of origin.

Therefore, in conclusion, there is reason, as has been shown also in several of the annual reports, for classing this rock, from the point of view of its intrusive action and crystalline texture, with the granites, and at the same time there is much evidence, from another point of view, both structural and petrographic, for classing it amongst the clastics metamorphosed by some force which has acted at least throughout the area of Kekequabic lake.

It is also reasonable to conclude that as an intrusive rock it is derived from the clastic beds *in situ*, and had no deep-seated source. As an intrusive it was at least plastic, probably rendered so by a combination of heat and moisture, and was probably at the same time under great pressure.

The action of aqueo-igneous fusion has recently been investigated by Crosby and Fuller,* and has been recognized by numerous geologists as an efficient cause in rendering plastic and even fluid the sedimentary materials when subjected to sufficient heat, moisture and pressure. When in that state the sedimentary materials would not only be recrystallized thoroughly but would act the part of intrusives on the strata adjacent or superjacent and they would necessarily exhibit the same chemical variations, within broad extremes, as the sedimentary strata themselves. This action of the clastics under pressure is well exhibited in the limestones of the Adirondacks, which according to numerous observers have been made to intrude the adjoining quartzytes and gneisses, and to surround isolated portions of them much in the same manner as igneous rocks. This fact led Emmons and some of the early geologists to class crystalline limestone amongst the igneous rocks. But this action is mutual—isolated pieces of limestone are included in the adjoining gneiss, indicating a common history and hence a similar origin.

If this source of the granitic rocks be admitted in the case of the Kekequabic lake granites, it is likely to have been equally efficient in other localities, and indeed it rises to the importance of a general cause, applicable, in the absence of other sufficient source, to all the granites of the state. Indeed the same facts, leading to the same conclusion, are observable at other places, and especially about Snowbank lake. The Kekequabic Lake granite, however, is a small isolated area, and the transitions

*Origin of Pegmatyte. *American Geologist*, vol. xix, 1897, pp. 147-180.

and all relations are to be seen within a small compass, affording better opportunity for study. At the same time the original clastic rock is one of marked peculiarities, different from most of the clastics of the Archean, in the possession of peculiar augites and feldspars which are probably of the nature of volcanic ejecta. This peculiarity is perpetuated in the resultant granite, which is a peculiar one, different from most of the granites of the state.

(3). *Source of the characteristic elements of the alkaline magma.* If it be true that the granites and other alkaline-acid igneous rocks of the Archean are the product of the aquo-igneous fusion of the fragmentals of the Archean itself, it becomes necessary to search for the cause of their characteristic chemical composition in the nature of those fragmentals. In a previous paragraph attention was called to the essential chemical differences between the alkaline magma and the ferro-magnesian. They consist in the presence, in the alkaline, of a noteworthy per cent of the alkalies, and of a large per cent of silica, a fact which precludes the derivation of the alkaline magma from the ferro-magnesian by any process of lixiviation, or "fermentation," or differentiation. It seems to be required, therefore, to find a satisfactory explanation of the existence in the fragmentals of the additional elements in excess of those amounts of the same which occur in the ferro-magnesian magma.

The nature and origin of those fragmentals immediately come into consideration. They are largely of volcanic origin, and contained originally not only the augite crystals from which has been derived their predominant hornblende, but also the olivine, the menaccanite and the soda-lime feldspars which characterize the ferro-magnesian rocks of the Kawishiwin. These original minerals were subjected to the manifold disintergration and final destruction which is incidental to oceanic action. Their soluble parts went into the oceanic waters, and their insoluble constituted the debris which went, so far as it was able, to form the sedimentary strata of the Archean. The ocean's waters must have been frequently heated by volcanic ejections, and locally charged with the gases and acids which characterize volcanic products. Such ejections would give rise to soluble chlorides and sulphates of the alkaline bases and of iron and would thus be able to take up silica from the decay of the rocks, and these substances would be distributed by currents to all parts of the globe. These salts would vary from time to time, and from place to place, sometimes reaching saturation. Precipitation would take place when the balance of their saturation point was broken by physical changes, such as lowering of temperature or an influx of currents bearing elements that caused a change in their chemical combinations. All these physical irregularities must have been due, in this early volcanic age, primarily to the movements set on foot by volcanic activity. It is impossible to state, and even to conceive, of the millions of fluctuating conditions in that primeval ocean, tending to work over the volcanic ejectamenta and the prior-formed ferro-magnesian crust. The essential inquiry, in this search, is to ascertain whether there was any source for potash and for an excess of silica, such that these could accumulate in the fragmentals in greater proportions than in the earlier rocks.

At ordinary temperatures, and under ordinary conditions, silica is quite insoluble, but in an alkaline water it is soluble and is carried from one place to another in the crust of the earth, in large amounts. In a heated alkaline water larger amounts may be held in solution. As it is known that throughout the Archean fragmental rocks there is a very large amount of microscopic silica, sometimes constituting important beds due to oceanic precipitation, as in the jaspilytes and other flinty deposits, the inference is natural that the ocean was in suitable chemical condition to hold in solution very large amounts of silica, and therefore that it must have been alkaline and probably heated.*

Such alkaline quality, residing in the ocean, could not have been derived, so far as it consisted of potassium, from the pre-existing rocks, for, as already shown, they contained no potassium. It must therefore have been resident in the ocean, from which it was precipitated, like the silica, and took its place, in form of such chemical combinations as its environment allowed, amongst the other sediments. Its ultimate origin might be further considered, but at this point it is necessary simply to call attention to the nature of the precipitate which would result from an alkaline ocean in which were numerous active volcanoes.

The acid exhalations of volcanoes are well known. They are sulphuric and hydrochloric acid, and also carbonic. But as the last may not have existed in the acid products of the Archean volcanoes, it may be omitted from this inquiry. These acids, mingling with the oceanic waters, would seize on the alkaline bases, liberating the silica. The soluble salts thus formed would be disseminated in the ocean, and it would result that the alkalinity would be locally intensified. In general, however, in case of the disturbance of the chemical equilibrium, there must have been a precipitation of silica and of an alkaline silicate, and even without any disturbance from the addition of volcanic acids, the ocean may have given everywhere a slow accumulation of such silicates. Owing to the avidity with which potassium seizes on oxygen, and the insolubility of the potash feldspars, it is apparent that the silicates of the alkaline feldspars would be immediately and perhaps copiously precipitated. This seems at least to have been the case. The Archean ocean, therefore, was unfit for animal life, and was characterized by the prevalence of the lightest of the alkaline bases (potassium) in some such way as, later, the Silurian was charged with lime and magnesia, and, as the present, with soda. It resulted that the world's great stock of

*On the precipitation of silica from solution in the Archean ocean the reader may consult—"On a possible chemical origin of the iron ores of the Keewatin in Minnesota." N. H. and H. V. WINCHELL. *American Geologist*, vol. iv, p. 291, 1889.

ım was stored up in the Archean sedimentary rocks, in the form of alkaline s, where it remains to the present.

he oldest quartz-porphyry. This oceanic source may be applied to the earliest porphyry. Not enough examination has been given to this quartz-porphyry :ant positive conclusions as to its source, but a few facts may be recalled here seem to be in consonance with this idea.

he oldest quartz-porphyry known is that which is in the Lower Keewatin, g a large mass southwestwardly from Snowbank lake. It is described in l terms in the twenty-fourth annual report (page 69). The following leading ıay be mentioned:

It lies between two greenstones, the older one being the massive portion of wishiwin and the later one the fragmental portion, and is perhaps 2,000 feet

Between it and the older, however, is a curious conglomerate, made up y of greenstone debris, but with a few fragments of jaspilyte.

It does not cut, so far as seen, the older greenstone, and at no place has any -porphyry been known to cut a greenstone of that date.

It has supplied many large fragments to the later greenstone, and its finer is scattered abundantly through the same (plate Z, vol. iv).

This quartz-porphyry varies. It does not generally show any sedimentary ıre, but occasionally it presents characters that are usually accredited to c origin. For instance, it becomes roughly schistose, in places, and ridged ıterrupted finer belts resembling siliceous argillyte. It holds pieces of green- ınd of slaty greenstone, varying in size from ten inches (rounded) downward an inch, also pieces of jaspilyte and rounded quartz. The slaty greenstone argillyte and runs usually with the structure, standing on edge. The rock ıs much quartz in grains usually less than a pea in size, but also as large as an diameter, the last being very rare, while other quartzes as if phenocrysts of ·porphyry, are abundantly disseminated.

In some places the bulk of the whole rock consists of more or less rounded ınts of orthoclase and quartz lying in a pellucid matrix which appears to be ally quartz of a kind like the so-called chalcedonic quartz seen in the te, mingled with equally fine feldspar.

This mass of quartz-porphyry occupies about the position of the great te lodes, *i. e.*, it is subsequent to the massive greenstone of the Kawishiwin.

may be inferred, from the fact that it succeeds immediately after the green- onglomerate lying on the agglomerated condition of the Kawishiwin, that, if ted from oceanic precipitation, it was formed at a time when the ocean was greatly agitated, and hence that chemical precipitations would have been profuse, such agitation probably being caused by local volcanic action.

If we allow the chemical precipitation of the silica of the jaspilyte in the midst of the greenstone Archean, or closely following the congealation of the earliest greenstone crust of the earth, thus producing the jaspilyte masses which everywhere occur in the greenstone, it is reasonable to presume that those conditions may have been prolonged in time and intensified in degree as well as extended in area, and that under favorable circumstances an enormous amount of siliceous mud, varying occasionally to pure silica, may have been produced. There have been noted repeated instances of the gradual passage, by inter-stratification, from jaspilyte to argillyte, and to a chloritic schist, as well as to iron ore. In one remarkable instance such banded jaspilyte has been seen to be at the same time a coarse conglomerate, showing that violent agitation as well as chemical precipitation was an attendant of the Archean ocean, both taking place, in some cases at least, at the same point and simultaneously.

Under conditions producing chemical precipitation of silica, if the Archean ocean was deep, and if the precipitation was rapid and abundant and the mass cooled slowly (for the Archean ocean at this time must be considered to have been heated), it might be that crystals of quartz of considerable size would be formed throughout the mass, and that all the quartzes of this porphyry may thus have originated, in some such manner as selenite, pyrite and other crystals form in a mud that holds the elements of those minerals in saturated solution. The general absence of a banded stratification, under this hypothesis, is the greatest obstacle; but if the precipitate accumulated rapidly, it must have been subject to the same forces, whatever they were, which excluded the banded structure from great thicknesses of fragmental greenstone, and from greater thicknesses of the Ogishke conglomerate, and from the Stuntz conglomerate. It is perhaps due to copious and quick accumulation that the sedimentary structure is not seen in some large and important fragmental terranes. A subsequent crystallization of the mass would also result in the obscuration, or the obliteration of the sedimentary structure, a fact seen in many great limestone strata of the Silurian.

If, however, as seems to be proved by the presence of orthoclase crystals in this porphyry, the precipitate was not wholly of silica, but included a considerable amount of potassa, the crystallization of such a deposit of alkaline mud would not only rearrange the molecular structure of the deposit throughout its whole thickness, but would still more effectually destroy whatever sedimentary structure the ocean may have stamped upon it. Elsewhere it has been shown by the writer that potassium was probably retained as an element of the atmosphere, after the solidification of the first crust, for a period long enough for the cooling of the crust and for the ocean to bring potassium within the bounds of possible condensation and precipitation.* This was an inference from the observed later introduction of acid-alkaline rocks in the Archean than the ferro-magnesian. It is a striking coincidence with that argument that, here, the oldest known acid rock not only shows signs of oceanic agency, but also embraces, along with phenocrysts of quartz, those of orthoclase, and that the fine matrix of these phenocrysts is both siliceous and alkaline, in a state of fine crystallization.

The heated waters of the Archean ocean had, at the date of this precipitation, been able to accumulate only a coarse "mud-conglomerate," a stratum seen at this place to have a thickness of about 105 feet, made up wholly of roundish and more or less squeezed greenish pebbles. This band sometimes has been designated a "greenstone conglomerate" from the nature of its pebbles, but in other cases it has been styled "mud conglomerate," from the fineness of their grain and the smoothness of their outlines, which also indicates an original plasticity. Under such conditions not only would the alkaline ocean hold in solution much silica, but such silica would, with alumina (also present as a product of decay and dissolution of the greenstone crust), necessarily unite to form such minerals as orthoclase. Hence would result, posssibly, from a supersaturated solution, a rock as an oceanic product which is usually considered a normal igneous rock resulting from fusion.

Even with this origin for the earliest acid rock, which is here a quartz-porphyry, this rock is not far removed from the same operations and the same agencies as those which are called igneous, for heat and moisture and plasticity are the essential conditions for the production of all acid igneous rocks, unless they be derived from some primordial magma. This explanation differs only in requiring a lower degree of heat (less than the boiling point of water), a longer period for crystallization and an enormous scale of operation, as contrasted with the restricted limits of normal volcanic action. It also implies the formation of the rock over broad expanses of the ocean's bed rather than in the reservoirs of the earth's crust; and as a corollary it points to the porphyritic rather than the granitic as the structure assumed by the earliest acid rocks.

Whence the Archean ocean obtained this large supply of potassium, it is not necessary to inquire. Whether it was imprisoned at greater depths within the earth, and for that reason did not appear in the ferro-magnesian earliest crust, but was thrown out by later volcanic action, and thus reached the sea, or was retained still in the atmosphere and was precipitated first into the ocean and later was thrown down as alkaline silicates as above indicated, is subject for legitimate further speculation, but it is not within the scope of this discussion. It might be added, however,

* The origin of the Archean igneous rocks. *American Geologist*, xxii, 299, 1898.

that there are weighty considerations, based on the chemical characteristics of potassium, its comparative specific gravity and its avidity for oxygen, that tend to indicate that potassium remained in the earth's atmosphere not only longer than the other alkalies or alkaline earths, but also during that long heated condition of the earliest crust occupied by the slow congealing, and finally the cooling of the first formed film before it was possible for the ocean to rest upon it.

The view above presented of the origin of the igneous rocks, especially those of the Archean, is essentially the same as that adopted by Hutton (1785), Keferstein (1834), Herschell (1836), Hunt (1858), Le Conte (1872), Dutton (1880) and numerous other geologists. But these geologists labored under the wrong idea that the oldest rock was essentially granitic, and much of their reasoning was vitiated by an attempt to explain the rock succession from the alkaline to the ferro-magnesian instead of the reverse.

The Taconic.

The detrital rock formations included under this term in Minnesota are separated from the Archean by a profound break in the stratification, as well as by difference in crystalline condition. They are divided between Animikie and Keweenawan, and are supposed to be the representative of the Lower and Middle Cambrian.

The base of the Taconic. The conglomerate which occurs at the base of the formation has been examined at various places in Minnesota, viz., at the south side of the Giant's range (No. 372H), S. W. ¼ N. W. ¼ sec. 32, T. 60–13, where it lies upon the granite of the Giant's range and embraces much debris from the granite. It is exposed to the depth of twelve or fifteen feet. At the top it contains considerable green uncrystallized material, with large feldspar fragments, and has an indistinct gneissic structure which seems to lie nearly horizontal, with a schistosity running northeast and southwest. At the top are some pebbles of quartz and green rock, some of them two inches long. In the field this conglomerate seems to grade into the granite.* A diamond drill section was made in N. W. ¼ S. W. ¼ sec. 27, T. 60–13, passing from black slates through quartzyte, ore, quartzyte, and conglomerate, into the Giant's range granite, the whole depth being 323 feet. The base of the Animikie here contained not only feldspars from the granite, and lavender-blue quartz grains from the same source, but also much green debris from the adjoining and underlying Keewatin. The coarsely conglomeratic portion of the Animikie here was only three or four feet in thickness. In some other drill sections the conglomerate was also quite thin, and in some instances the basal quartzyte was found to lie directly upon the granite with no apparent conglomerate. A thin conglomeratic

*Owing to the fact that the supposed Animikie is immediately in contact with granite on S. E. ¼ N. E. ¼ sec. 35, T. 61–12, and shows no conglomerate, as well as on account of the nature of the ore and of the conglomerate itself at the above locality, there is some uncertainty as to the Animikie age of the conglomerate. The granite may here be intrusive into the Upper Keewatin, and into the Lower Keewatin at other points in the vicinty. See *Seventeenth Report*, pp. 86, 94.

curs at the bottom of the Animikie further west, in the region where the onomic development of iron ore has taken place,* and at the falls of 'iver.

:egama quartzyte. The basal conglomerate of the Animikie soon graduates into quartzyte which is well developed at Pokegama falls on the Mississippi using the falls. From its favorable and conspicuous exposure at this place een named Pokegama quartzyte. The thickness of this quartzyte is not o exceed fifty feet, and it is sometimes less than twenty-five. It varies from ary quartzyte whose rounded grains are cemented by secondary silica into locking firm plexus of quartz, to a very fine-grained one which approaches ts texture. The finer portions prevail toward the east, and at Gunflint lake ıe flint is seen interstratified near the bottom of the Animikie. This flinty r is quite prominent at the base of the Animikie still further northeast, but artzyte this member is lacking at Gunflint lake. There is, however, at ; lake, some fragmental quartz in the bottom of the iron-bearing member.

e iron-bearing member exhibits a somewhat irregular manner of succession e quartzyte, and sometimes has an alternation with it in subordinate strata. case the quartzyte is very fine grained, and grades into the quartzyte which rough the iron-bearing member, becoming crypto-crystalline and non-ıtal. The ore is sparsely disseminated in isolated grains throughout these ing bands.† In the same manner the upper limit of the iron-bearing member : indefinite. The thickness of the iron-bearing member is several hundred l sometimes reaches nearly 1,000 feet. The ore is usually hematite on the Mesabi range and magnetite on the eastern. The original nature of the ring member is believed to have been a glauconitic sandrock, but at the time it consists almost wholly of silica and hematite, in secondary condition ting the iron ores of the Mesabi iron range. The alteration of the original ite is not entirely completed. Hence, by the examination of an extended specimens, the steps of the alteration, its causes and its final products, can d.‡ The great economic importance of this member of the Animikie has ed a more extended presentation in a special chapter on the iron ores of the l. iv).

nestone occurs just above the iron-bearing member. It is impure and usually ored, and can with difficulty be distinguished from the overlying black slates. t few feet in thickness. It extends, apparently, the whole length of the 'ange, but has been identified in place only at the extreme ends, viz.: sec. 7.

. SPURR. *Bulletin x*, p. 5.
. SPURR. *Bulletin x*, p. 229.
'ulletin x of the survey this subject has been fully discussed and illustrated by J. E. SPURR.

T. 58–17, and doubtfully on the shores of Gunflint lake. Boulder masses have been found, however, at one or two intermediate points, which are supposed to have been derived from this stratum. The thickness of this limestone does not probably exceed twenty feet, varying from place to place. It is essentially only the bottom phase of the black slates. It exhibits a fragmental structure, except when it has been subjected to the alteration incident to the formation of the iron ore deposits.

The upper or slaty member, with its siliceous variations, constitutes the bulk of the Animikie, and is probably several thousand feet in thickness. It has been more fully studied in the region of Gunflint lake, where it presents abundant outcrops in the perpendicular cliffs facing toward the north. Dr. Grant has there divided it into two parts: the lower part is composed largely of black slates, often very fissile and apparently carbonaceous, the lower portion being flinty, having a total thickness of 1,050 feet, of which about 100 feet represent the diabase sills; the upper part, or graywacke slate member, more firm, often a quartzyte, having a total thickness of 1,900 feet, of which about 250 feet are composed of diabase sills.

The Grand Portage graywacke. In the Indian Reservation at Grand Portage is a more fragile member of the Animikie. It outcrops at various places on the Grand Portage trail, especially toward the western end of the trail. This rock is greenish, gritty, rough and unevenly bedded, having a coarse conchoidal manner of disintegrating under frost and sun. It has suffered great denudation. It probably once rose to the summits of the great dikes that form prominent hill ranges crossing the country, but has been removed, leaving those dikes standing with sheer walls rising from 50 feet to 150 feet above the talus. This graywacke is supposed to overlie the quartzyte and slate of the black slate member, but its extent and stratigraphic position have not been satisfactorily established.

The summit of the Animikie has never been seen so as to be identified. Whether the fragmentals of the uppermost, graywacke member, probably represented by the Grand Portage graywacke, gave place suddenly to the next higher fragmental stratum, which is the Puckwunge conglomerate, the fragmental base of the Keweenawan, is not known. But as there was a period of great disturbance which witnessed the upheaval and the profound metamorphism, as well as the fusion of the Animikie before the accumulation of that conglomerate, it is reasonable to suppose that there were other rocks formed before the commencement of the conglomerate. The facts that are mentioned in the chapters devoted to the Duluth and the Pigeon River plates, and referred to in connection with the Lake County plate, show that there was more or less of eruptive activity prior to that conglomerate, and hence that there were probably agitated seas and coarse rapid detrital accumulation. These significant facts are as follows: (1) An amygdaloidal (?) trap (No. 1847) lies on the Animikie at the most southerly of the Lucille islands. This is supposed to be near the top of the Animikie. (2) The record of the deep well drilled at the Short Line park, near Duluth, shows a series of trap layers resembling those seen at Duluth below the quartzose conglomerate exposed in the St. Louis valley near Fond du Lac. This conglomerate is supposed to be the western representative of the Puckwunge conglomerate. (3) In the vicinity of Beaver bay, where the Beaver Bay diabase is charged with masses of feldspar rock, there is seen to be a loose red conglomerate and a diabase basalt below the Beaver Bay diabase. If there be equivalence of date between the Beaver Bay diabase and the parent mass of gabbro, as supposed, then there must have been at least one and perhaps several surface lava flows anterior to the outbreak of the gabbro revolution. This superposition is seen at the bite of the little bay (Two Harbor bay of the annual reports) sec. 12, T. 54–9, where the lower portion of the great diabase is a pudding-stone of feldspar masses. All this evidence, however, is still inconclusive and the nature of the top of the Animikie remains an unknown quantity. It may have blended gradually with volcanic ash and occasional lava sheets, but was terminated by the great revolution which gave origin to the gabbro and the red rock. The first recognizable and fixed datum, in the form of a clastic stratum, after the Animikie, is the Puckwunge conglomerate, and that is also posterior to at least some of the great dikes of Grand Portage, to the red rock and to the great gabbro mass.

The age of the Animikie is considered to be that of the Lower Cambian. It may be below the horizon of Olenellus, which sometimes restricts the downward extension of the Lower Cambrian, but as it is followed above by the sandstones which graduate upward into the Upper Cambrian, as seen on the south side of lake Superior, and in the valley of the St. Croix, it is at least in the proper place for the Lower Cambrian. According to the conclusion reached by Mr. Spurr that the iron ore of the Mesabi is derived from a glauconitic sandstone, there is reason to presume that large quantities of foraminiferal organisms once lived in the Animikie ocean. In the St. John group of New Brunswick, Mr. W. D. Matthew has shown* the existence of foraminiferal forms associated with noticeable amounts of iron ore. In the Animikie in the Thunder Bay region, Mr. G. F. Matthew has also described a Taonurus-like impression which he has named Medusichnites.† The Canadian geologists uniformly refer the Animikie of the Thunder Bay region to the Lower Cambrian.

Perhaps the strongest indication of the non-Archean age of the Animikie lies in the non-conformity at its base. All earlier strata are highly tilted, and usually nearly to verticality. The Animikie is rarely tilted as much as forty-five degrees from horizontality, and over large areas it is nearly level, lying on the vertical strata

* *Trans. N. Y. Acad. Sci.*, vol. xii, pp. 108–120, 1893.
† *Trans. Roy. Soc., Canada*, vol. viii, Sec. iv, p. 143, 1890.

of the Keewatin, this being its position also in Ontario. Such a break in stratigraphy implies a long epoch during which the folding of the Archean was produced. There is no geological horizon between the Upper Cambrian and the Archean which seems commensurate with these features except that which is usually put at the base of the Lower Cambrian.

Extent of the Animikie. Entering the state from the northeast at Pigeon point, this formation runs westwardly along the international boundary to the vicinity of Gunflint lake where it strikes into the state, to the vicinity of Chub (Akéley) lake where it disappears. The manner of disappearance is interesting and suggestive. It seems to separate into two parts for a short distance, one part leading into and under the gabbro which penetrates it in the form of dikes and sills finally overwhelming it, and the other running a few miles in an interrupted manner in a spur-like prolongation further north. This spur-like northern prolongation is last seen (No. 1896) near the working of the Gunflint Lake Iron company's exploration, S. W. ¼ sec. 21, T. 65–4 W., at half a mile north from the gabbro mass, separated from the gabbro mass by an intervening belt of Keewatin greenstone belonging to the great greenstone area of the region. It is known also to run eastward and to be the cause of several iron locations. The southern edge of the exposure, in S. W. ¼ sec. 21, shows a high dip north, and, indeed, it is vertical in many places along the southern borders of the mass. Then it bends, at lower levels, so as to be flat, and at favorable points of view it can be seen to change from a vertical or northward dip to a southward dip, there being a continuous swing between a southerly dip of 10° to 20° (extreme) through horizontality to verticality. The flexure is abrupt and on the southern side of the hill, the horizontal and southward dip being on the northern slopes. The appearance, where the mass stands vertical, is very much like some black jaspery outcrops in the Keewatin. The manner of superposition or contact on the greenstone at this point cannot be seen. While this northern spur has been considered a part of the Animikie, there are certain anomalous facts of position, structure and petrography which, not having been seen elsewhere in connection with undoubted Animikie, lead to the hypothesis that this part of the northern spur is a ferruginous belt belonging to the Keewatin, and that the real strike of the Animikie is along the southern spur mentioned, lost in the gabbro.

A series of similar ferruginous outcrops occurring southwestward further, beginning with and including the "mine" of the Gunflint Lake Iron company at the centre of sec. 28, T. 65–4 W., and extending along the stream westward from Akeley (Chub) lake to Gabimichigama lake, Fraser lake, Thomas lake and Birch lake, as far as to the appearance of undoubted Animikie in secs. 27 and 32, T. 60–13 W., fall into this uncertain category, with probability of Keewatin age for all of them. These ores are intimately associated with the large amounts of the rock muscovadyte which is not known to occur in connection with the Animikie and its ores, but which, in several places, has been observed to be derived from the Keewatin by metamorphism. Therefore, it appears that the Animikie is lost under and in the gabbro at a short distance from Gunflint lake, and reappears, with its own characters, only affected by contact metamorphism, on the west of the west side of the gabbro southwestward from Birch lake, and thence continues along the south side of the Giant's range, constituting the Mesabi Iron range* to Pokegama falls. Its extension south of the belt of iron mines, on the western Mesabi range, is unknown, owing to the heavy mantle of drift, but it is well known that the black slates of the Animikie overlie the iron ore horizon all along the mining belt.

What becomes of the Animikie, after its disappearance in and under the gabbro, has been one of the interesting geological problems of the survey. From preliminary field examinations it was stated by the writer, twenty years ago (1878), that the sedimentary rocks at various places along the shore of lake Superior, and notably on Pigeon point, at the Great Palisades and at Beaver bay, had been converted into crystalline rocks, and had been fused by contact with the basic igneous rocks. Nearly every year from that time to this has contributed in the progress of the survey to the verification and the extension of that truth. It has already been applied in the discussion of the Archean and its igneous rocks. In the Taconic are some of the most evident facts and the most convincing transformations tending to this result. They are recorded in some of the annual reports and in occasional papers, and are systematically summarized where they occur in some of the special chapters of this report. Therefore, at this place, in tracing out the extension of the Animikie, it may be assumed that, in general, the strike of the red rock shows the strike of the Animikie. But as there is reason to assume that the mass of the gabbro moved superficially toward the south, it is necessary to allow that the fused products of its intrusion partook in that movement. Indeed, it is certain that, in several iustances, the red rock formed lava flows which reached the latitude of the present shore line of lake Superior; and toward the western limit of the gabbro where it seems to have flowed farther as a great mass than toward the east, so the red rock is further displaced from the locus of its origin. It is not known that this red rock flow has no interruptions in surface extension from Lake county westward to Duluth, but it is highly probable that, with occasional variations and mutual overlapping with the cotemporary diabasic flows from the gabbro, its general continuity could be seen if the forest and the drift could be removed. It is seen at many places, as at Baptism

*It is the opinion of Dr. Grant that the Animikie continues, under disguised conditions, as formerly supposed, and as represented in the annual reports and in some of the chapters devoted to the Mesabi Iron range, all along the northern border of the gabbro. Facts mentioned by him in the chapter on the Akeley Lake plate are indicative of the Animikie age of the iron at Akeley lake, and that locality might be excepted from the hypothesis above expressed.

river and at Beaver bay, to be confusedly interlarded with and cut by basic trap, and also to appear as if intrusive in the gabbro and in the Beaver Bay diabase. Its physical relations to the gabbro and to the Keweenawan will be given in treating of the igneous rocks of the Taconic.

At the same time that the northern strike of the Animikie is westward along the south side of the Giant's range, there are points further south where it has been doubtfully identified. There are certain hardened and metamorphic rocks at Duluth which have been referred to the Animikie (Nos. 807, 1966), and the slates which appear at Thomson, and especially at the cuts by the Northern Pacific railroad southeast from Carlton, appear to belong to the Animikie. What may be the direction of strike and dip, and what the irregularities which the Animikie suffers in order to appear at these places, dipping southerly, while along the Giant's range fifty miles further north it also dips southerly, can only be conjectured. In this interval is the St. Louis valley, where not an outcrop occurs, and which is deeply buried under drift and perhaps under the Cretaceous. By reference to the chapter devoted to Carlton county (plate 56) it will be seen that only a portion of the rocks usually known as the Thomson slates are included in the Animikie, the rest being of the Keewatin.

Metamorphism of the Animikie. In St. Louis county, southwestward from Birch lake, in the angle between the granite of the Giant's range on the north and the northern line of the gabbro on the south, the Animikie appears in the form of a very fine-grained biotite mica schist with cordierite (Nos. 1708, 370H). The outcrops are not numerous, and it is impossible to define the limits of this metamorphism. The iron ore of the Animikie at the same place is converted to magnetite, accompanied by the generation of more or less actinolite and cummingtonite.

The mica schist at Little Falls, on the Mississippi, in Morrison county, also has some characters that suggest its Animikie age, viz.: its fine grain, its distinct sedimentary structure and its low angle of dip. There is also at Little Falls a massive igneous rock resembling gabbro (No. 1678), which increases the parallelism with the Animikie. At Little Falls the schist is garnetiferous and staurolitic, and at Pike Rapids embraces a bed of limestone (No. 1681).

The Puckwunge conglomerate. If the Animikie be separated from the Keweenawan on the basis of its fragmental rocks, this conglomerate would be the bottom of the Keweenawan; but if the earlier igneous rocks (compare the chapter on the Duluth plate, vol. iv) be included in the Keweenawan, that term will embrace an unknown interval of time and probably some of the latest clastics of the Animikie. This conglomerate expresses a profound and extensive non-conformity and erosion interval. It contains not only pebbles of quartz-porphyry and other forms of the red rock, but much debris from the Animikie slates, including the peculiar rock taconyte from the iron-bearing member of the Animikie (Nos. 852B and 852C). It is first seen in Minnesota in the valley of the Puckwunge, a small stream entering Pigeon river about a mile south of South Fowl lake (Nos. 1903 and 2069). The thickness here exposed, including the associated grit, amounts to 144 feet, with probability of as much more below the visible portion.

The dip is toward the S. W. by S. 12°, and is distinct. The rock is essentially a white quartz pebbly conglomerate, the coarsest stones being about six inches in diameter, rounded-lenticular and hard, altogether water-worn. There is very rarely a distinct banded red-jasper pebble, and some that are not banded, and more common a gray, siliceous pebble like basanyte. Some of the pebbles are reddish brown. The great majority of them are of vein quartz, but some appear of chalcedonic fineness of grain. The general character and appearance of the mass are like those of the quartz-pebble conglomerate seen in the St. Louis valley, a short distance above Fond du Lac.

In collecting pebbles (No. 2069) a special effort was made to obtain some that might prove to be characteristic of some earlier formation, and among these the rock taconyte was sought for. Thin sections made from some of these showed that the rock from which they were derived was of clastic structure, though now composed of secondary silica and hematite and identified with the taconyte of the Animikie, thus fixing the conglomerate later than the Animikie. One of the most common sorts of pebble is that of a gray, granular quartzyte, which is easily referable to the slaty quartzyte of the upper part of the Animikie.*

This conglomerate is known again at one mile southwest from Grand Portage village. described by Mr. Elftman as follows: It is in a high bluff facing the lake, appearing white as viewed with a glass from Grand Portage island. The rock making up this bluff is coarse, white quartzyte, becoming conglomeratic in places. Thin pebbles of slate are scattered throughout the rock. It is apparent that only the upper part of the formation is exposed here. Quite a distance intervenes between the conglomerate and the siliceous member of the Animikie, in which there are no outcrops. The exposed thickness is about 100 feet. The stratification of the sandstone is very plain. There is a diabase flow twenty feet thick, superposed on the conglomeratic quartzyte, fine grained and compact in its lower portion, and amygdaloidal in its upper. Small portions of the quartzyte are included in the diabase, which resembles that found on Grand Portage island. Above this diabase is a stratum of quartzyte varying from a few inches to two feet in thickness; and above this are successive layers of diabase with more or less of detrital matter between them. The successive layers of diabase, and all the quartzyte, are cut by a dike of diabase about vertical, running east and west, about ten feet in width. The general strike of the conglomerate seems to connect it with that seen in the Puckwunge valley and at Grand Portage island. The distinctions between the Animikie siliceous slate and the conglomerate or quartzyte are as follows:

Animikie quartzyte. Slaty, dull or earthy appearance, very fine grained, cut by Keweenawan dikes; also by post-Keweenawan dikes.

The *Keweenawan conglomerate* contains flat pebbles of the Animikie slate and quartzyte. It is usually fresh and bright in appearance. It is cut only by the later dikes. On Grand Portage island it also contains red rock pebbles.

The structural conditions are expressed by the following diagram (figure 1), drawn by Mr. Elftman. In this diagram the supposed place of the Grand Portage graywacke is in the interval of "no outcrop."

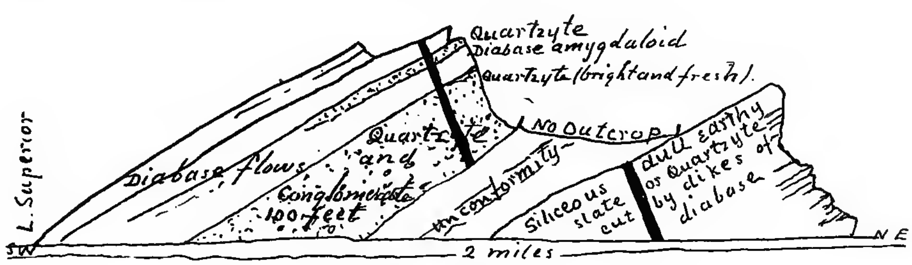

FIG. 1. CROSS SECTION AT GRAND PORTAGE.

The first point in the region of Grand Portage at which this conglomerate was observed was on Grand Portage island (No. 254), where it shows about twenty feet of

*Compare *Twenty-fourth Annual Report*, pp. 84-89, for the details of the stratigraphic relations of this conglomerate in the Puckwunge valley.

stratification, is cut by a dike nine feet wide and is covered with a surface diabase flow or a succession of flows. It here embraces distinctly quartz-porphyry and debris from the hardened clastics of the Animikie. The Animikie was therefore upturned by eruptive disturbance and the whole series of red rocks which appear as a result of fusion of the Animikie on the east flanks of mount Josephine and at the head of Wauswaugoning bay, and on Pigeon point, had been produced prior to the date of this conglomerate.*

From the region of Grand Portage this conglomerate extends eastward under the surface of lake Superior, reappearing at the southwestern end of Isle Royale, where it is coarse and quartzose, and where it is in like manner overlain first by some trap sheets (No. 562) and then by a hard sandstone.

Toward the southwest it is believed to be at first less developed. Its upper parts are apparently replaced by sandstones having a red color or by red laumontitic conglomerates. As such it appears a short distance up the Baptism river, while along the shore further east as far as to Little Marais and Manitou river are several conglomeratic bluffs at the lake shore, which are probably representatives of the same general horizon, separated by lava sheets and modified by an abundant supply of igneous basic debris.

The next that is known of it is in the valley of the St. Louis river, where it affords conspicuous exposures, as described and illustrated in the chapter devoted to Carlton county, and, according to the record of the deep well at Short Line park (Duluth plate), is separated from the Thomson slates by a series of igneous rocks having a thickness of ninety-one feet, although along the river it lies on those slates.

At New Ulm, but on the north side of the Minnesota river, is an unequivocal outcrop of the same conglomerate. It here lies on red granite, probably of the age of the red granite, or red rock, of the gabbro age, and its pebbles are coarse and varied, some of them being of the peculiar jasper called taconyte (Nos. 852B, 852C), a striking and unmistakable index of parallelism with the Puckwunge conglomerate of the northeastern part of the state.† It here lies below a large quartzyte formation which is well known, both in Minnesota and Wisconsin, in the latter state having been called Baraboo quartzyte, while it received from Dr. C. A. White, of the early Iowa survey, the name Sioux quartzyte.

In addition to these localities, Sweet has described it in T. 32-6 W., Wisconsin,

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*The reader is referred for a consecutive discussion of this interesting distinction to the following literature:

Tenth Annual Report, Minnesota Survey (for 1879) [1882] pp. 45, 46. Description of the rock section.

Copper-Bearing Rocks of lake Superior. *Mon. v, U. S. Geological Survey*, 1883, pp. 297, 367, 405, and figure 16 on p. 297. The conglomerate is referred to the Animikie by Irving.

Note on the Keweenawan Rocks of Grand Portage island, north coast of lake Superior. *American Geologist*, xiii, p. 437. Grant here shows that the conglomerate belongs in the Keweenawan, probably near the bottom.

The anorthosytes of the Minnesota shore of lake Superior, *Bulletin viii*, Minnesota Survey; and The Norian of the North-west, an introduction to the last. Here is emphasized the necessity of separating the gabbro from the rest of the Keweenawan, thus dividing the Keweenawan, as defined by Irving, into two parts.

The eruptive and sedimentary rocks of Pigeon Point, Minnesota. *Bulletin cix. U. S. Geol. Survey*, 1893. Bayley here shows that the quartz-porphyry and red rock are formed by fusion of the Animikie by the gabbro.

†A rational view of the Keweenawan. N. H. WINCHELL. *American Geologist*, vol. xvi, p. 150.

on the Chippewa river. Here it underlies a massive quartzyte, and reaches the thickness of 300 feet.* It has been fully described by the Wisconsin Geological survey.† It is probably the same as that described by Van Hise at the west of Agogebic lake, where it contains rolled pebbles of quartz-porphyry and certain phases of basic eruptives and debris from the Archean. ‡

The later Keweenawan fragmental rocks were at first interstratified with sheets of lava of diabasic nature. They are frequently conglomeratic, but consist largely of debris from the cotemporary trap. These beds of loose, fine, red conglomerate or of sandstone, are apt to be thickly sprinkled with crumbling laumontite, an additional circumstance which increases their friability. Hence, they are frequently seen along the lake shore, as at the mouth of Manitou river, and west from Little Marais, forming perpendicular cliffs capped with the next overlying lava sheet. Such conglomerate is to be seen in the St. Louis valley, above Fond du Lac, interstratified with red sandstone and red shale, these beds in the aggregate reaching a thickness of over 800 feet. Here no known trap-sheets are interbedded. However, in the record of the deep well at Short Line park, a series of trap flows separates the red sandstones and conglomerates from the basal, coarse Puckwunge conglomerate, reaching a thickness of 217 feet. The whole formation dips, at and above Fond du Lac, at an average angle of about six degrees toward the south-southeast. The uppermost layers become more siliceous and serve as a good building stone.

As the eruptive forces died out the sandstone became still purer, and indeed quite pure, forming first the Hinckley sandstone, quarried in the gorge of Kettle river in Pine county, and later the sandstones of the St. Croix valley, which are fossiliferous and alternate with magnesian shales and magnesian limestones, thus introducing gently the fauna of the Upper Cambrian.

During this later part of the Keweenawan in the northwest, both during the continuance of gentle or local eruption, and after its entire cessation, the whole region was undergoing a slow settling, bringing the oceanic waters over more extended areas of land,§ and burying under the later sandstones, not only the old Archean rocks, as seen in Carlton county (vol. iv, p. 16), but also concealing from sight the older beds of the Keweenawan itself, as exhibited at Taylor's Falls. It thus appears that the Manitou portion of the Keweenawan eruptive rocks are interjected in the midst of a period of sandstone accumulation. They would thus be expected to occur somewhat locally and at irregular intervals, and about the peripheries of the eruptive centre they would be found to diminish gradually as to thickness and to

* Notes on the *Geology of Wisconsin*. *Wisconsin Academy of Science and Arts*, vol. iii, p. 45.

† *Geology of Wisconsin*, vol. iv, p. 575.

‡ The Penokee iron-bearing series of Michigan and Wisconsin. *Mon. xix, U. S. Geol. Survey*, p. 461.

§ According to L. L. HUBBARD, state geologist of Michigan, this subsidence began early in the Keweenawan, and was continued during the accumulation of the 8,000 feet of coarse conglomerate on Keweenaw point. *Proceedings Lake Superior Mining Institute*, ii, p. 96, 1894.

disappear in some directions sooner than in others. There can be no doubt that under favorable conditions the surface eruptives flowed for many miles, and that in other conditions they were shut out, and a continuous series of fragmental strata was the result. The fine, red conglomerates and the red sandstones and shales were extended to great distances toward the southwest, and have been penetrated by deep wells at Minneapolis, Belle Plaine, Mankato, Hastings, Red Wing and other points, where they have been found in some instances, so thick that they constituted an effectual barrier against the further sinking of the wells.

Age of the Puckwunge conglomerate and sandstone. As in the eastern part of the United States, the term Potsdam has been applied, in the Northwest, to both of these sandstones, *i. e.*, to the quartzyte overlying the Puckwunge conglomerate, which has also had the names Sioux quartzyte, Baraboo quartzyte, Barron County quartzyte, and to the sandstones lying above the trap rocks, containing an Upper Cambian fauna which, in Minnesota, has been divided between Hinckley and St. Croix. From this circumstance considerable confusion of nomenclature has resulted. There is no doubt, however, that in the midst of what in some places is a continuous series of similar sandstone strata, the traps of the Manitou were interposed, thus affording an important character for dividing the sandstone into two parts. It also seems probable that even where no actual eruption occurred the cotemporary sandstone deposits were considerably affected in composition, and that, in others, the lower strata were hardened and cemented into quartzitic strata by the chemical action attending volcanic ejection in some adjoining portion of the ocean. If it be inquired what portion of this series is represented at Potsdam, N. Y., where the name was first applied to any part of this sandstone, there need be little hesitation in answering—to the earlier. Hence it is more in keeping with the practice of the best authority in geological nomenclature to restrict the term Potsdam to the quartzitic sandstone which, about lake Superior, underlies the traps of the Manitou eruptives and overlies the Puckwunge conglomerate, *i. e.*, to the sandstone seen at a mile west of Grand Portage village, and in Grand Portage island, to the quartzyte seen near New Ulm and in Cottonwood county, to the quartzyte in Pipestone county, and to the equivalents of this in the various deep wells. In some of the deep wells in the southern part of the state an enormous thickness of red shale and sandstone has been encountered, and this is supposed to be due to cotemporary volcanic action in such contiguity that the detrital and volcanic debris was colored by the ferruginous oxidation which rapidly pervades superficial volcanic ejections; but, owing to the occurrence of similar red shale in these lower quartzytes and sandstones, there must have been an earlier source for such sediment. There is here an indication of eruptive action in the central part of the state during the prevalence of what has been noted as the

Animikie revolution in the northeastern part of the state. Such sediments might constitute the transition link of the Animikie fragmentals in the central part of the state to the lower horizons of the Puckwunge (Potsdam). Still, it is at present impossible to refer this red sandstone and shale, as developed in several of the deep wells in the central part of the state, with certainty to either horizon.

The igneous rocks of the Taconic. The igneous rocks of the Taconic have been included *en masse* in the Keweenawan, and it is best to employ that designation with its original definition, rather than restrict its significance to include only the eruptives which accompanied and followed the clastic base of the Keweenawan.* But in order to avoid being misunderstood, and to insure definiteness to our desciptions, these eruptives will be divided into two general groups, with new names, viz.:

Cabotian: To include the gabbro and cotemporary accompanying red rock and their surface lavas and all their dikes and sills. These igneous rocks are associated with, but in date followed, the Animikie clastic rocks, and preceded the Puckwunge conglomerate, their debris being found in that conglomerate. This term is the designation given by Buchette to the mountain ranges on the north shore of lake Superior.†

Manitou: To include the cotemporary igneous rocks that accompanied and followed the Puckwunge conglomerate, whether surface flows, sills or dikes, extending to the top of the Keweenawan igneous rocks. This name is that of a river entering lake Superior in Minnesota.

The clastics that are associated with the Cabotian igneous rocks are of Animikie age, to the bottom of the Puckwunge conglomerate. Those which were cotemporary with the Manitou are of late Potsdam age. These graduate upward to sandstones free from igneous rocks, and to pure quartz sandstones, viz., the Hinckley and St. Croix sandstones.

Possible pre-gabbro eruptives. There are some reasons, mentioned under the paragraph which treats of the clastic strata of the Taconic, for believing there was some, probably gentle, eruptive action, after the substantial close of what we know of the Animikie, earlier than the convulsion which gave origin to the gabbro; and, further, that these eruptives were accompanied by some detrital accumulation. In the absence of definite facts that bear unmistakably on this point, it will be better to omit here further reference to these problematical eruptives, and to begin this description of the Cabotian igneous rocks with an account of the gabbro.

The Cabotian epoch of eruption. In superficial area, amounting to about 2,300 square miles within the state, in the associated problems of origin, date of intrusion, structural relations with older and also with more recent rocks, in variations of its

* This restriction was once suggested by the writer. *American Geologist*, xvi, 333, 1895.

† "During this distance the St. Louis river, a stream of prime magnitude, bursts through the high trap range of what Bouchette calls the Cabotian mountains, being a continuation of the upheavals of the north shore of lake Superior." SCHOOLCRAFT, in *Summany Narrative of an Exploratory Expedition to the Sources of the Mississippi River*, 1854, p. 110.

own internal structure and composition, as well as in the number of petrographic principles illustrated, the gabbro surpasses any other member of the Taconic, and perhaps equals in interest the granites of the Archean. Being an igneous rock of the opposite end of the magmatic scale it offers a new set of petrographical principles, and, with its attendant accidents of contact, exceptions and variations, it serves to add a large chapter to the petrographic geology of the state.

The numerous problems arising from the gabbro cannot all be considered as solved by the examinations the survey has given to them. There is a large uncropped field for the future student to enter upon. The structural discussion which follows is a tentative effort to set forth and to explain the leading facts of the gabbro on a general hypothesis, which is at the same time supported by all the special facts which are in our possession, or at least is not known to contravene them.

The extension of the gabbro toward the east. The eastern extension of the gabbro mass has sometimes been limited in the vicinity of East Greenwood lake, T. 64–2 E., and that approximately expresses the eastern limit of the continuous surface outcrop of the great body of the gabbro. At a short distance east of this lake it becomes covered by later diabasic flows, or loses itself in a series of sills and dikes that penetrate the Animikie. From Gunflint lake to Pigeon point the Animikie is thus affected. In some cases the body of the gabbro comes within a few hundred feet of the most southern mass of the Animikie bluffs, the Animikie having a dip southerly so as to throw it below the gabbro. This is particularly the case at Loon lake (south of Gunflint lake), where coarse characteristic gabbro is within 150 feet of the Animikie bluff, and the irresistible inference is that the great sills of diabase which are then seen in the Animikie at lower levels, and which are themselves sometimes intermediate petrographically between gabbro and diabase, are only apophyses from the gabbro. Such sills are of all dimensions, from one or two feet to fifty and more feet in thickness. Owing to the low dip of the Animikie, and to its easy removal by natural causes, it is seldom seen to persist on the tops of these mono-clinal hills, but almost everywhere the usual surface rock is that of one of these sills. This diabase-gabbro, therefore, might be said, in general, to extend much further east and north than the limit usually assigned to the gabbro itself. Indeed, it is very probable that even within the gabbro body, along the northern limit of surface continuity, there exists still intact much of the Animikie, and that such beds would be found on sinking a drill through the gabbro. Where these great sills constitute the representative of the gabbro, as at Rove lake, Mountain lake, Fowl lake and eastward into Canada, the country is generally very much broken, the mono-clinal hills and ridges rising steeply from 200 to 400 feet from the valleys on the north, but sloping more gently from their summits to the valleys on the south, the topography being due to the gentle slope of the Animikie dip but preserved by the greater endurance of the Logan sills, the latter still occupying by far the greater part of the superficies. It is in this portion of the northern border of the gabbro that the Animikie is very rigid and quartzose although slaty and easily removable by reason of its horizontal fissility and its frequent jointage. Into such a rock, undergoing upheaval and fracture, an igneous rock would farthest penetrate along planes of its easy parting, which, in this case, was along the sedimentary planes of slatiness. Some of the sills thus formed can be seen to be continuous occasionally for several miles, but generally they sink away and are replaced by others a little further north or south, after running less than two miles. As soon, however, as this quartzose and slaty member of the Animikie is replaced, at the point of intrusion of the gabbro, by the fragile Grand Portage graywacke, which breaks as easily in one direction as another, the form of the molten intrusion is changed into great vertical dikes, and these prevail in the Indian Reservation at Grand Portage. Such dikes form the mountainous features of the Grand Portage region. They are sometimes 100 or 200 feet wide, and they stand above the surrounding valleys 400 to 800 feet high, with sheer vertical walls of rock toward the top. By degradation of the enclosing graywacke the dikes have been uncovered and left bare. Mount Josephine, which stands near lake Superior and rises 703 feet above its surface, is a specimen of these dikes, but it is inclosed in the slates rather than in the graywacke.

The gabbro intrusion extends thus to Pigeon point, where it is shown to be of the same date as the great gabbro mass further west, by the effect it has on the Animikie, producing the red rock of Pigeon point, the crystalline debris from which is found in the Puckwunge conglomerate at the foot of Grand Portage island. The same red rock is visible in some of the hills near Grand Portage village, also at the east side of mount Josephine, and, according to Dr. J. G. Norwood, on the Pigeon river where these dikes are exposed by that stream.* How much further east this igneous intrusion extends, it is not at present possible to state. It is true, however, that the same kind of topography and the same kind of sills in the Animikie with occasional red rock areas, continue to Thunder bay and Silver islet. At the latter place red quartz-porphyry pebbles are found in the conglomerate at the bottom of the sandstone which lies non-conformably on the Animikie. Hence, it is reasonable to infer the existence of quartz-porphyry in that region produced by the same cause as at Pigeon point.

The extension of the gabbro toward the west. The western limit of the gabbro is represented, on our plates, to run southward across St. Louis county to the vicinity of Short Line park, a few miles west of Duluth. But that is a boundary that is

* Dr. Norwood's description and illustrations are on pages 407, 408, of Owen's report on the *Geology of Wisconsin, Iowa and Minnesota*, 1852.

wholly conjectural. It is simply the boundary of the most western line of outcropping. The rock disappears beneath the drift. The character of the rock at these western outcrops indicates that they are not "peripheral." The rock is coarse and rough. The gabbro may extend many miles further, underlying the whole Cloquet valley, which is also deeply buried under drift, and crossing the St. Louis valley north from Knife falls. It may even extend as far west as to include the gabbro which is seen in the northwestern part of Morrison county, for there is but one outcrop of the underlying formations between the Cloquet river and the Long Prairie river. That is a quartzyte, seen in Aitkin county, as described by Mr. Upham, and is probably of later date than the gabbro. If thus extended the gabbro belt would pass north of Knife falls, and the hills of gabbro seen at Short Line park would fall into the same category as the Sawteeth mountains, and could be classed with the Beaver Bay diabase, to which they show a general petrographic alliance, having characters indicative of surface flow. However, even with such a westward extension, the gabbro probably dies out in that direction in the same manner as toward the east, *i. e.*, by a diminishing series of dikes through the older rocks.

The southern limit of the gabbro. This has thus been described by Mr. Elftman:* "The southern boundary of the gabbro is irregular on account of the invasions of other members of the Keweenawan series. From the south side of East Greenwood lake the boundary passes westward for thirty miles and turns south and east through Brulé lake along the Brulé River valley to the east side of T. 63 N., R. 1 W. In the vicinity of Brulé mountain and Eagle mountain, the limit of the gabbro zigzags and finally follows a southwesterly course through sec. 6, T. 62 N., R. 2 W., and through sec. 15, T. 62 N., R. 4 W., on the east branch of the Temperance river; continuing westward it passes through the central part of T. 60 N., R. 6 W., between lakes Harriet and Bellissima; thence through the southeastern part of T. 60 N., R. 7 W., and between West Greenwood lake and Greenwood mountain, in T. 58 N., R. 10 W. At the last locality it turns sharply toward the south, passes near the northwest corner of sec. 19, T. 55 N., R. 11 W., and from there continues in a southwesterly direction to Duluth. These boundaries give the widest areal distribution of the gabbro. Within this area are other rocks, some of which are quite extensive and nearly all of later geologic age. The chief area of this kind is the region west and southwest of Brulé lake."

Along the northern and northwestern side of the great gabbro mass, the gabbro is plainly intrusive on the older formations, from the Animikie downward to the oldest of the Archean. On the southern and eastern border it is penetrated by and

* *American Geologist*, vol. xxii, p. 132, 1898.

penetrates in a confused manner the red rock, with which it alternates both structurally and areally. Large bosses and areas of the red rock, frequently granitic, penetrate the gabbro, and send dikes into it, the dikes sometimes running for several miles from the parent mass. According to Mr. Elftman, gabbro dikes are not known to cut the red rock, but this may be attributed, in a measure, to the assignment by him of such dikes to a supposed later intrusion of diabase, since the gabbro presents petrographic characters resembling those of diabase, when it acts as an intrusive in other rocks. The Beaver Bay diabase, which is considered to be the first great flow-stratum from the parent gabbro, carries isolated pieces of red rock, as shown in the chapter on Lake county. At Duluth, while the gabbro in the main lies under and involves the red rock, there are stringers and isolated red rock areas in the gabbro. The appearances, both at Duluth and at Beaver bay, are explicable by supposing the gabbro and the red rock were simultaneously in a state of mobility, allowing at the same time for the greater liquidity of a basic magma under complete fusion, and for the greater penetrating capacity of the acid magma, in a condition of aqueo-igneous fusion or plasticity.

The structural peculiarities of the gabbro. The Logan sills. Dr. A. C. Lawson gave this name to the great sills which, along the international boundary and thence to Thunder bay, lie in the bedding planes of the Animikie and greatly increase its aggregate thickness.* That these sills are cotemporary offshoots from the gabbro mass is sufficiently demonstrated by their mutual proximity and their similar petrographic characters. One of the greatest sills known is that of mount Reunion (No. 2064). It has a thickness of about 100 feet, and crowns the summit of a bluff of Animikie, facing north, which rises somewhat over 400 feet above the level of Rove lake. In this rock the augite is of two periods of development, a character not uncommon in the gabbro. The greater part of it is in rather small roundish grains that preceded the plagioclase, but there are a few larger grains that followed the plagioclase, since they embrace the plagioclase ophitically. Several instances occur of the inclusion of olivine in the augite. A little quartz, evidently of secondary origin, is in the angular spaces between the plagioclases, and also is in granophyric intergrowth with a feldspar which itself also appears to be of secondary origin. In several other instances (Nos. 296, 297, 300, 308, etc.) the same petrographic characters have been found in these greater sills, and in one or two of the great dikes that are probably cotemporary with the gabbro, at and near Carlton, at the extreme southwestern limit of the gabbro. Still, it appears that in many instances—and this seems to be the case when the dikes and sills are narrow—the augite is wholly later in date than the plagioclase, and displays only the ophitic relation. It is to be inferred,

* *Bulletin viii*, p. 48, 1893.

therefore, that when the gabbro magma consolidated in narrow dikes, or in large surface flows, there was some force that restrained the first generation of augite (contemporary with or earlier than the plagioclase) and only allowed it to form ophitically, after the generation of all the other minerals; but that in some cases the conditions were not sufficiently pronounced and uniform, and, as in many of the great sills, both generations of augite are seen. Hence, the characteristic diabasic structure is an incident of consolidation, and does not denote any difference in character, origin or date of the magma from which it resulted, by which the resultant rock can be differentiated, genetically or chronologically, from the gabbro. Most of the later eruptions of the Keweenawan coming probably from the same source as the sills of the Animikie, being of less volume, took the petrographic characters of diabase, as will be seen by examining the chapters devoted to petrography.

The Logan sills were at first believed to be, like the surface flows of the Keweenawan, of the same date as the sedimentary strata between which they lie. This was the view of Bell, Irving, and, indeed, of all geologists until quite recently, the writer included; and it was for this reason that on seeing the gabbro occupying a position low down in the "Animikie" at Chub (Akeley) lake, the age of the gabbro in its commencement was said to be near the bottom of the Animikie.* Although the nature of some of these sills was recognized by a few geologists earlier, especially by Mr. E. D. Ingall, of the Canadian survey,† it was not till 1893 that their true age and geological significance were fully recognized. This was by Dr. Lawson, who stated as below, the evidence that these sills are intrusive within the slates.

I. The trap sheets associated with the Animikie strata are not volcanic flows, because of the combination of the following facts:

1. They are simple geological units, not a series of overlapping sheets.
2. They are flat, with uniform thickness over areas more than 100 square miles in extent, and, where inclined, the dip is due essentially to faulting and tilting.
3. There are no pyroclastic rocks associated with them.
4. They are never glassy.
5. They are never amygdaloidal.
6. They exhibit no flow structure.
7. They have no ropy or wrinkled surface.
8. They have no lava-breccia associated with them.
9. They came in contact with the slates after the latter were hard and brittle and had acquired their cleavage, yet they never repose upon a surface which has been exposed to sub-aerial weathering.

II. They are intrusive sills because of the combination of the following facts:

1. They are strictly analogous to the great dikes of the region: (*a*) In their general relations to the adjacent rocks and in their field aspect. (*b*) In that both the upper and lower sides of the sheets have the facies of a dense aphanitic rock, which grades towards the middle into a coarsely crystalline rock.
2. They have a practically uniform thickness over large areas.
3. The columnar structure extends from lower surface to upper surface, as it does from wall to wall in the dikes.
4. They intersected the strata above and below them after the latter had been hard and brittle.
5. They may be observed in direct continuity with dikes.

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* *Sixteenth Annual Report*, p. 85, 1887 [1888]. Notwithstanding this, the first description of an intrusive sill in the Animikie was penned by J. G. NORWOOD, in his report to D. D. OWEN, p. 404, who also gave an illustration. He also described and illustrated in the same report the connection between the dikes and the "crowning overflow." The writer described an Animikie sill in Wauswaugoning bay, in 1878. *Ninth Annual Report*, 1881, p. 63.

† Descriptive sketch of the *Physical Geography and Geology of Canada*, 1884, pp. 21, 22.

6. They pass from one horizon to another.
7. The bottom of the sedimentary strata above them, wherever it is observable, is a freshly ruptured surface.
8. Apophyses of the trap pass from the main sheet into the cracks of the slate above and below.
9. The trap sheets, particularly at the upper contact, hold included fragments of the overlying slates.
10. They locally alter the slates above and below them.

Besides the sills, which date from the gabbro, there may be others of later date, and to these will apply the argument of Lawson, that they are younger than the Keweenawan. But no data are as yet at hand to warrant an attempt to separate such sills from those of the age of the gabbro.

The Grand Portage dikes. There are at least two systems of dikes in the vicinity of Grand Portage. This is attested not only by the observations of this survey, but also by those of Norwood, who examined this region for the Owen survey. The general trend of the most of the great dikes is toward the northeast by east, but that which forms Hat point, culminating in mount Josephine, is nearly at right angles with that direction. Much of the rock in the mount Josephine hill, south from the summit, has a basaltic columnar structure, the columns standing vertical, indicating that a dike here is merged into a sill. Several of these great dikes, which are several hundred feet wide, and sometimes rise above the adjoining slates with vertical walls from 50 to 100 feet, are noticeably crossed by a series of smaller dikes running nearly at right angles to them.

The individual great dikes cannot be assigned to different dates except by some careful field examination more detailed than it has yet been possible to give the region. Yet it is evident from general considerations that some are older than the others, for they produced the red rock which has supplied debris to the Puckwunge conglomerate, while the younger cut some of the amygdaloids which lie upon that conglomerate. Some of the latter can be seen on Grand Portage island and on the points west from Grand Portage bay. There is an interesting problem connected with these dikes which must be left for the future student to solve. The petrographical study which has been given these dikes seems to afford no criterion for discriminating them, for some of the younger, as well as the older, present the augite cotemporary with or earlier than the plagioclase, a characteristic which is sometimes said to belong to gabbro.

Effect on the Animikie—the red rock. It has already been stated, in describing the strike of the Animikie rocks, that the Animikie formation is completely lost, as such, in the gabbro mass. Observations made on Pigeon Point peninsula at mount Josephine, on one of the islands of the Lucille group (south of Pigeon point), at Duluth, at Brulé lake, have now well demonstrated that the Animikie is converted into the "red rock," so called, which extends from the place at which the Animikie disappears in the "gabbro flood," with a nearly continuous surface band to Duluth.*

*The phenomena at Pigeon point have been discussed by W. S. Bayley in a bulletin of the U. S. Geol. Survey, viz., No. 109, 1893.

That this red rock is in some way dependent on the Keweenawan is indicated by its non-occurrence elsewhere than in connection with the Keweenawan. That in all its phases, which sometimes reach a crystalline condition equal to that of granite, it has resulted from the fusion of an acid rock, is a legitimate inference. It may hence be accepted as a fair illustration of the origin of granite. It is the same which Irving called augite-granite, although augite is a more rare mineral in its constitution than has been supposed. It is not to be presumed that the fusion of the Animikie was necessarily the only source of this late granite. The tremendous agitation which gave origin to the gabbro probably affected the rock on which the Animikie lies, and it may have been fused in like manner and its contribution to the fused mass, when acid, went to swell the volume of the red rock, and when basic may have been added to the gabbro.

Neither is it to be assumed that this fusion was a mere surface effect, due to the overlie and heat generated by the gabbro on the Animikie from above downward. Indeed, it is noteworthy that the bosses of the red rock, where they seem to be *in situ* of their formation, penetrate to greater depths and show by their behavior that their primitive seats are below the surfaces where they occur. Sometimes the red rock is struck, as at the mining shaft on the island south of Pigeon point, below a greater or less thickness of Animikie strata which are but slightly altered. When the red rock can be traced by successive steps of petrographic transition into the Animikie in place, the red rock concerned is not a granite, but a red quartz-porphyry, or keratophyre, as in the low red-rock knob on the south side of Pigeon point. The greater crystallization is not on the side toward the Animikie, but on those sides most remote. Most of the red rock dikes and the surface flows are to be considered, therefore, as peripheral manifestations of a greater volume, and as suddenly cooled portions escaping from a magma which, congealing slowly, gave source to the augite granite. Hence the Animikie was fused from below by the gabbro mass and not from above. The gabbro, as we see it, lies on and penetrates the Animikie, but the action of this intrusion, and the distribution of the red rock, show that the intensity of alteration was seated below all the Animikie of which we have knowledge, and hence that the bottom of the Animikie suffered the transformation before the top was involved. Therefore, while in the main contemporary with gabbro, sometimes penetrating it, sometimes penetrated by it and sometimes mixing with it so intimately as to constitute intermediate rocks, such as "orthoclase gabbro" of Irving, and "hornblende gabbro" of Streng,* and although at numerous points the dependent genetic relation which the red rock bears to the fusion of the Animikie can be shown by ocular demonstration, it must be allowed that both

* *Eleventh Annual Report, Minnesota Survey*, p. 51.

the source and the cause of the red rock may have been deep-seated, and may have involved other formations than the Animikie.

If this general conception of the origin and date of the red rock be admitted, the surface distribution which it shows in Minnesota, and, so far as known, all the special features of contact, flowage, intrusion and alternation with the gabbro and the cotemporary diabases, are easily apprehended.

In the main, the line of strike of the Animikie from Pigeon point to Duluth is represented by the red rock belt. It is certain that the undisturbed line of strike of the Animikie leaves the gabbro area and runs more westward, constituting the Mesabi iron range. It must therefore be understood that the strike of the red rock belt further south, so as to reach Duluth, marks a line of upheaval through the body of the Animikie area, really constituting another strike-line, or fracture line, dependent, not on the earlier existence of a shore line, but on the direction of a zone of dynamic fusion of later date. This red rock belt comprises the water divide. From it streams flow north and south—toward the north across the main gabbro area and on to the Archean, toward the south across the later diabases, etc., of the Keweenawan, into the area of the sandstones of the lake Superior valley. At Duluth the main gabbro area unites with and blends into the great Beaver Bay diabase, lying sometimes upon the red rock and sometimes on metamorphic rocks referred to the Animikie. It is probable that this relation occurs at other places toward the northeast, especially in St. Louis county, but they have not been observed, and therefore the red rock is considered as a continuous belt, while in many places it is known that the gabbro is separated from the Beaver Bay diabase by a wide tract of red rock.

The greater endurance of the red rock may be in part the cause of this greater elevation, and it may be in part due to a greater original elevation of the Animikie. The latter is indicated by the fact that toward the east this greater elevation blends in with the area of the Animikie, and its sills in Cook county, as the gabbro area becomes smaller and narrower. From the point at which the present water divide crosses the international boundary, between North and South lakes, the upper waters of Pigeon river, including the lakes of the international boundary, are turned eastward along the north side of this belt of greater elevation to the vicinity of South Fowl lake, below which point the Pigeon river begins its tumultuous descent to lake Superior, crossing the belt of elevation at its lowest (eroded) passage, and often running in a sharp preglacial gorge-like valley several hundred feet below the adjoining summits.

The Beaver Bay diabase. This term is not used in exactly the sense employed by Irving, although its rocks are embraced, in general, in Irving's Beaver Bay group. This diabase has an intimate connection with the red rock, and was apparently cotemporary with the gabbro and the red rock. It is believed to be due to the first (and the greatest) flow-movement from the gabbro mass toward the Lake Superior basin. If there were lavas that preceded it they were unimportant, and of the nature of volcanic ejections, superficial, local and easily removed or reincorporated when the general motion began. It contains many anorthosyte or feldspar masses, and a few of red rock. It is the matrix which encloses the boulders forming a great pudding-stone seen near Beaver bay at different points. Petrographically it is usually a diabase, in that its structure is ophitic, but this is not always the case. Its thickness is sometimes several hundred feet. In many places it has been called gabbro, as at Short Line park, near Duluth, where it not only shows the banded structure seen sometimes in the gabbro, and locally carries a notable amount of iron ore, but is also seen to be vesicular, like a surface flow.* It has an irregular and sometimes a gradational contact on the red rock, quite similar to that of the gabbro on the red rock. Such irregularities are common in the country about South Brulé lake and eastward. It was molten at about the same time as the red rock, as shown by an inspection of the relations of these two rocks about the shore of Beaver bay, yet it is cut by the red rock, and is the bearer of detached pieces of the same. The rock of the Great Palisades lies upon it, but it forms the crest of the Sawteeth mountains.

In moving from the area of the gabbro mass this sheet of diabase first encountered the Animikie, which is now represented by the red rock belt. If this rock occupied the prominence which it does at the present time, the diabase, once having surrounded it, would have flowed rapidly down the southern decline, leaving a comparatively thin covering over the red rock obstruction. If the movement continued long, as is probable, the action of the red rock was to form a kind of reef over which the diabase must have passed more quickly and in an attenuated volume, but further south, gathering in greater amount, was not only slower to solidify, but on complete solidification assumed more nearly the petrographic characters of the parent mass. Therefore, ascending the streams that enter lake Superior, such as Poplar river, or Temperance river, the observer comes upon coarse-grained conditions of this rock which are not distinguishable from the real gabbro, and such phases also appear at the shore line of lake Superior in the vicinity of Beaver bay, as well as at and near Duluth. During the lapse of the ages since this flow took place, the thin surface remnant which was left on the red rock belt has been destroyed and wholly removed, thus isolating the Beaver Bay diabase from its parent mass and constituting it the "great basal flow" of the Keweenawan defined by Irving.

*By Mr. Elftman this has been included in the later surface lavas of the Manitou series. *American Geologist*, vol. xxii, plate VII, September, 1898.

The removal of the superficial portion of the gabbro batholyth left exposed to atmospheric action the body of the gabbro mass. It is not probable that this movement took place within the crust below the surface. The effect of atmospheric contact is visible in many places on this diabase, and the crystallization of the red rock in nearly all cases is not that of deep-seated congealation. The fact that what is left of this great sheet seldom exhibits distinct superficial phenomena can be attributed to the denudation of its accessible upper portions, and the same probably applies to explain the present condition of the surface of the gabbro area itself.

The feldspar masses, or "anorthosyte." The former of these terms seems to be preferable to the latter, because the term anorthosyte is quite extensively applied to the gabbro mass itself; whereas, the objects here intended to be meant are quite distinct from the ordinary condition of that mass. These have excited the perplexed observation of several geologists. They have been considered as intrusive and later than the diabase, as transported blocks derived from a foreign source and as indigenous in the rock in which they lie, while by Lawson they have been supposed to belong to the Archean, on which the Keweenawan is supposed to rest. By the writer they have always been considered a part of the Keweenawan, but how they acquired their present forms and positions, and what their relations to the gabbro proper, have been points which remained unsatisfactorily explained until quite recently.

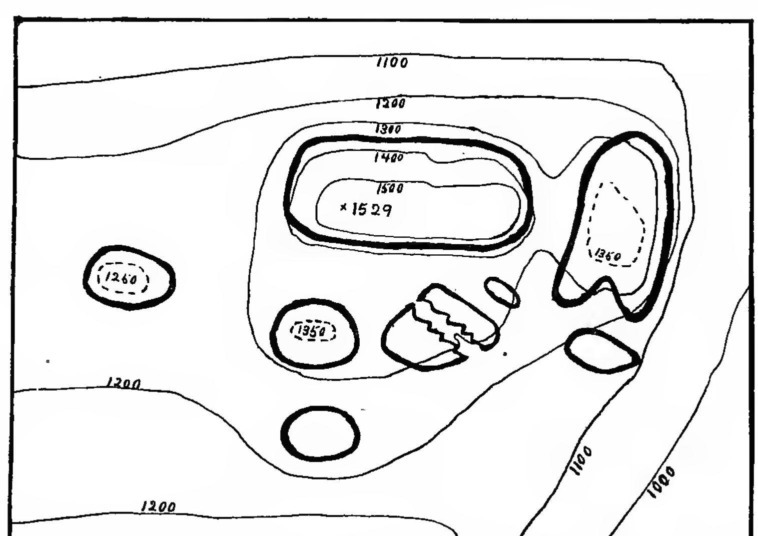

FIG. 2. DIAGRAM OF EXPOSURES FORMING THE TOP OF CARLTON PEAK.

Mr. Elftman's observations of Carlton peak are conclusive to show that at that place the feldspar masses were at first wholly surrounded by and now lie in and on the Beaver Bay diabase. At the shore of Beaver bay the diabase is about and over the feldspar masses. In the "pudding-stones" the feldspar masses are usually small and vary in mineral composition, and in the last case the diabase may have gathered up and transported masses of earlier cooled rock. Figure 2 is a contoured map of the summit of Carlton peak from Mr. Elftman's note book. The masses are isolated, and compose a small portion of the entire hill, some of them being 200 feet lower than others and separated by intervals of the ordinary diabase.

Within the main gabbro area are known several masses of similar rock, but they are not separable from the gabbro itself. They are phases of the formation resulting from a segregation and concentration of the feldspathic element. So far as observed they are not abruptly contrasted with the surrounding rock in a manner similar to the separation of the feldspar masses, but are associated about their peripheries with more or less of the ferro-magnesian minerals, and seem to grade into the general gabbro. At the same time the gabbro itself consists occasionally of nearly as pure feldspar as that of these isolated masses. When unweathered and coarsely crystalline, such areas do not attract attention, but are readily grouped with the general gabbro mass. The original habitat therefore of these feldspar masses may be assumed to be the gabbro itself. The manner of their formation was suggested to the writer by observing the accumulation of porphyritic crystals in a diabase at and westward from Gunflint lake. A coarsely porphyritic diabase forms a sill in the Animikie at the outlet of Gunflint lake. This sill is continuous westward, and is exposed along the Port Arthur, Duluth and Western railway. After a distance of about a mile toward the west, it was noticed that the feldspar crystals began to group themselves in couples, and in triplets, and then into irregular clusters. It was noted further that these clusters reached the size of a foot and more in diameter, and gave a blotched aspect to the diabase by reason of their lighter color. In traveling over the surface of this sill, which is denuded and at the same time much thickened, still larger areas of feldspar were seen, and it appeared as if numerous foreign masses were included in the diabase. These feldspar masses, however, were not sharply set off by rounded contours from the enclosing diabase, but presented angular projections and enlargements. It became apparent that it only required the continuation of such development in the ordinary diabase to reach the size and the purity of the masses seen at Beaver bay.*

If, then, it be admitted that these masses were indigenous in the gabbro, it remains only to account for their generally rounded contours and their greater number at Beaver bay. Generated in the gabbro mass before the Beaver Bay diabase left it, these masses must have had a tendency, on account of less specific gravity, to rise toward the top of the gabbro. It is quite reasonable to suppose that the minerals of that magma, as they took crystalline form, and if they became thus grouped, would, under unconstrained

* The generation of the feldspar masses from the general gabbro magma had previously been asserted by A. H. ELFTMAN. *Twenty-second Annual Report*, p. 178, 1893 [1894].

ons, tend to separate themselves according to their specific gravity. Those ons must have been most favorable at that period when the cooling had not far ed, but had reached the stage at which labradorite was generated and remained ; in the still molten mass. The cooling proceeded very slowly and must have place mainly after the severance of the Beaver Bay diabase. When that great on occurred it of course removed only the upper portion of the gabbro, and must rried along the major part of the feldspar masses. The inevitable result of such on must have been the collision of the feldspar masses upon each other and inding of their outlines. They seem to have been compressed and sometimes . They were, perhaps, not rigid at first, but still flexible, allowing the istment of the crystals, but also must have suffered numerous fractures and gs. Through the fractures the molten diabase entered, forming diabase dikes, f which still subsist, giving the impression of a later diabase intrusion. In w movement of the great molten sheet, the feldspar masses which it carried first encounter obstructions from the underlying older rock. Becoming lodged, arily or permanently, the still liquid magma would flow past them, thus ally removing them from contact with that particular part of the magma gave them birth, and increasing the petrographic contrast between them and base.

'uscovadyte. If the gabbro mass be considered as an individual, having phases tallization dependent on the stages of development, or as an epoch of geologic for that part of the state in which it is found, the muscovadyte and the osyte conditions occupy the extreme and opposite ends. One is so completely itiated that it can hardly be traced to its parent stock, and has been some lenied all relationship in origin and in time with the source from which it The other is so non-differentiated and complex that in like manner it has vorced from its offspring and has been assigned to an earlier geologic epoch other method of genesis.

iis rock presents protean characters, and its theoretical origin has had a and checkered history since the members of the survey began to study it. his rock was first encountered it was called "muscovado rock" without any its age and nature. Still, as it turns out, it had been examined earlier and eived the name "impure quartzyte." Again it was described as "noryte," one case it gave name to a point of land jutting into Gabimichigama lake, h at that place it is largely a fine-grained pyroxenic and biotite gneiss. It nd again to underlie, in form of angular fragments, a sheet of typical gabbro. 'ound to form a gradual transition into biotite mica schist. At this stage of estigation an effort was made to learn more definitely what distinctions were possible from a petrographic point of view. It became evident that the name had been applied to fragmental rocks and to igneous rocks, and that in the light of the close alliance of muscovadyte with the gabbro it would be best to restrict the term to a "peripheral phase" of the gabbro. With such interpretation Muscovado lake was named, which lies well within the gabbro area, because the most of its shores are composed of this rock. About this time the muscovadyte seen at Gabimichigama lake was traced through a slow gradation into the "greenstone" which occurs a few miles further east, and this transition has been observed since at other points. In several other cases the muscovadyte was noticed to be quite siliceous, and, acquiring a distinct sedimentary structure, was seen to change into ordinary greenwacke. Through greenwacke, therefore, it is linked with graywacke and the whole fragmental series. It was noted also, at numerous places, that, where the gabbro in bulk approached the eastern extension of the Animikie iron range, as that range was then understood and defined, the rock embracing the ore frequently was a form of muscovadyte, and that, in extreme metamorphism of the iron-bearing rock, the curious association was seen of the minerals olivine, quartz, magnetite. To these were added, usually in subordinate but varying proportions, biotite, diallage, augite, hypersthene and sometimes cummingtonite. Sometimes olivine was poikilitically related to quartz and magnetite, embracing both. Sometimes magnetite served the same office, and sometimes biotite, but usually hypersthene was latest to form, and hence surrounded all the other minerals in large crystals—and in favorable situations, as in vugs and veins, hypersthene reached the size of several inches. Prior to this the name Pewabic quartzyte was applied to the supposed base of the Animikie, where it exhibited this curious petrography; and under that name the supposed iron-bearing base of the Animikie was traced westward along the northern periphery of the gabbro to Birch lake and southwest from Birch lake to where the real Animikie appears. But the most interesting and important observation was made in the fall of 1897 at Disappointment lake. The iron ore, which occurs on the south shore and has been referred to the Animikie, is embraced in this rock muscovadyte. It is at this point and along the southwestern shores of the lake that had been observed the transition of muscovadyte into mica schist. This transition was again observed. This mica schist is conspicuously conglomeratic and occurs extensively about Snowbank lake, about a mile further northwest. The muscovadyte is also conglomeratic, losing this character, however, where it embraces the ore. There is hence a link which cannot be broken binding this ore with the older formation (Archean), and it hence bears exactly the same relation to the Keewatin as the jaspilyte seen in the conglomerate of the Upper Keewatin between Moose and Wood lakes. The gabbro is immediately adjacent and has an irregular superposition which resembles a tran-

;o the muscovadyte. It appears, therefore, that muscovadyte has alliances in ;e directions, and without questioning here the contention that it is a part gabbro, and that the Pewabic quartzyte represents a silicified condition gabbro incidental to its peripheral position, it is claimed only that it has also .able and direct connection with the Keewatin.

7ith this observation as a key a considerable revolution has latterly been made interpretation of the iron ores which are associated with muscovadyte further 7est, and they have been assigned to the Keewatin, rather than to the kie. Their peculiar petrography is due to the gabbro metamorphism, and ill be discussed under the heading

'o-called *peripheral phases of the gabbro.* There have been mentioned by nt geologists a series of modifications in the gabbro, the same being supposed ;onfined to the margins of the mass, and due to contacting on the older rocks. are all connected with the muscovadyte mentioned above, and are, as it rs, only conditions of that rock. In some cases the gabbro is said to become litic, and fine-grained, with development of considerable quartz, hypersthene otite; it is said to become non-feldspathic, making a pyroxene-olivine rock, or tyte, and to be charged, in other places, with titanic iron ore. It exhibits variations, not only in the relative proportions of the usual minerals, but in ccessional order in which they were generated. There is so much variety that aracters of the rock show almost endless change, and no special classification possible. The minerals concerned are olivine, quartz, magnetite, labradorite, sthene, biotite, augite, diallage. The details in some instances are given in apter of this report devoted to the special petrography of the crystalline rocks; ley have been presented in considerable minuteness by Prof. W. S. Bayley.* z and magnetite are present in greater quantities when the locality furnishing ecimen examined is from the immediate vicinity of some of the ore lenses alluded to as closely connected with the rock muscovadyte. They are some- wanting, and then the rock presents some of the varieties usually referred to ulitic gabbro," but there is no distinction that will hold, either structural or ;raphic, between the granulitic gabbros, with their variations, and the iron- g muscovadyte. They are parts of the same variable rock mass, and belong ally in age to the clastic greenstone member of the Archean. It cannot be ed that the muscovadyte, when free from quartz and magnetite, had a nt origin from the same rock containing those minerals, for these minerals all stages of increase, from zero to ninety-five per cent. When the rock consists ially of the former it is a vitreous quartzyte, and when essentially of the latter

ournal of Geology, vol. ii, p. 814; vol. iv, p. 1. "The peripheral phases of the great gabbro mass of northeastern a."

it is a magnetite iron ore, frequently, but not always titaniferous. In both there are still small amounts of the other minerals.

These minerals are all secondary in the sense that they have resulted from the metamorphism of some others. This can be inferred not only from the facts to be seen in the field but also from a study of the minerals themselves with the microscope. It appears, therefore, that there was a prior rock whose profound alteration has generated all these varieties. It appears also that such rock while being one that could furnish, for the most part, the phase known as granulitic gabbro, or muscovadyte, was sometimes capable of furnishing a large amount of quartz, or again of quartz and magnetite. No rock is known having such qualities and such variations except the clastic greenstones. They were mainly a basic effusive, as already shown in discussing the Archean, but they vary by being fragmental, acquire quartz, which was chemically precipitated, or was added mechanically, hold the jaspilyte lodes, and sometimes are coarsely conglomeratic. The minerals of the intermediate rock and its structures, which stand between greenstone and gabbro, can all be produced by reforming the greenstones under conditions not allowing complete liquidity. The agent was not heat alone, and the condition of the magma was not that of simple dry fusion, but that of aqueo-igneous transformation. In this process there is not believed to have been any important transpositions of the original elements from their original places. The change that passed over the original rock when the result came to be the muscovadyte was a chemical reëstablishment of the old minerals native to the original greenstones, but lost through decay and age, or of their congeners.

If the nature and origin of the Archean greenstones be recalled for a moment, it will appear how well suited to the production of such a rock they were, and especially how easily, on metamorphism, they could produce all the peculiar phenomena seen in the association of olivine and quartz with labradorite, hypersthene, etc., in the iron-bearing muscovadyte. The tuffaceous elements, falling into the ocean from volcanic ejection, the quartz and magnetite as limonite falling at the same time or interruptedly with the volcanic ash from chemical precipitation, gave origin to a stratified greenstone, or green schist, in which were included the iron bodies now known as jaspilyte. The basic layers associated with the vitreous Pewabic quartzyte were "tuffaceous eruptive fragmental elements" of cotemporary date with the quartzyte in its original condition.

These muscovadyte phases are to be considered as specialized conditions of the old greenstones, but complex and nondifferentiated stages of the gabbro due to exceptional conditions which arrested complete regeneration. We here reach the most interesting, and perhaps the most important, part of this topic, viz.:

The origin of the gabbro. In the foregoing only the greenstone alliance of the muscovadyte has been presented. The investigations of the officers of the survey have led them face to face continually with the gabbro alliance of the same. Prof. Bayley, in one of his earlier discussions, was so impressed with this alliance that he grouped not only the original greenstone and the muscovadyte as parts of the gabbro (much altered), but also insisted that the siliceous or quartzyte phase was only a silicified part of the base of the gabbro;* and in support of the latter he quoted the observations of several officers of the United States geological survey. Several years ago it was agreed by the members of the Minnesota survey, after a petrographic examination of specimens from various localities, that the muscovadyte proper is a phase of the gabbro, and that the name should be restricted to apply only to a rock directly connected with and presumably derived from the gabbro.†

The following is quoted from the report where this conclusion is published:

"It would appear from the foregoing that the term muscovado rock (or muscovadyte) has been applied in the field to rocks of different stratigraphic position and origin. This has already been asserted by Mr. H. V. Winchell in the seventeenth annual report, pages 130, 131. It is also apparent that one of these is produced by the action of the gabbro upon the sedimentaries. It appears also probable that the southern belt of muscovado [*i. e.* that at Muscovado lake] is a phase of the gabbro proper, and that, if to either the name should be continued, it should be applied to this southern belt.

"There remains, however, this possibility, if not probability, that this southern muscovado represents the profound action of the true gabbro upon a basic Archean greenstone which has been brought to the surface in the midst of the gabbro area by a later fault. We have learned from numerous observations that all the rocks in this region have in some places been extensively faulted. It will be well, therefore, still, before adopting this duplicate theory of the origin of the so-called muscovado, to examine further critical specimens collected at points where it can be shown that the true gabbro was superposed upon a basic greenstone of Archean age."

So far as possible since that date the term has been so used; but on making an exhaustive microscopical examination of the specimens collected, and of the notes and descriptions of all the members of the survey, both published and unpublished, the conviction returns that the muscovadyte is also allied with the Archean.

To account for the gabbro, therefore, is to find some way to explain the conversion of an Archean greenstone with its siliceous accompaniments into that rock. There is only one recourse—metamorphism, carried to fusion and intrusive action. This is the same principle appealed to and already adopted to account for the Archean granites.

Besides these petrographic and special considerations indicating such genetic relation, there are some broader inferences to be drawn from the general geology of the northern part of the state.

1. The great area, the manner of occurrence of the gabbro body and its wholly crystalline condition, indicate that in method of genesis it is comparable to that of the igneous granites, and hence that it should be found in the zone of a dynamic strain, or at least in line of a metamorphic belt.

2. The earlier metamorphic belts in the northeastern part of the state trend northeast and southwest, hence, if the comparison hold good, the direction of the greater axis of the gabbro belt should extend northeast and southwest.

* *Nineteenth Report*, pp. 193–210.

† *Twenty-first Annual Report*, pp. 143–152, 1892 [1893].

3. The lines of granitic protrusion and intrusion are found to be limited, in their main dimensions and directions, by the known earlier existence of areas of acid fragmentals, only encroaching in the form of apophyses, and rarely, as rocks of intermediate acidity, on the areas of earlier basic rock. Hence, again, if the comparison hold good, the gabbro should be found in a belt of Archean basic rock, or in the extension of that belt.

The first two of these statements are so evident from a moment's examination that they need no amplification. It may be well, however, to call attention to the probable further westward extension of the gabbro than is usually represented, and in a direction more westerly. Its surface exposure is cut off by a heavy drift covering. It is likely also that the spur of the gabbro belt which appears at Duluth in large part belongs to the Beaver Bay diabase which left the main mass by a grand movement toward the basin now occupied by lake Superior, and hence that the main trend of the gabbro body runs to the north of Duluth and toward the mouth of the Cloquet river in the St. Louis valley. Toward the northeast the gabbro fades out by running into a series of sills and dikes in the Animikie, and in this form it appears for many miles in Canada, there being no general gabbro area free from the Animikie.

In respect to the third of the foregoing general comparisons, it should be noted, in the first instance, that the uniform directions of the metamorphic belts of extreme metamorphism, which are approximately outlined by the ranges of granite, show a tendency to change as they approach the basin of Lake Superior. This is more apparent after the epoch of the gabbro than before it. Whatever may have been the cause or causes of this shifting in the direction of the later zones of metamorphism and eruption, it is apparent that it resulted in the more definite outlining of that basin in the later stages of its geologic history. It is apparently in keeping with this gradual change in the lines of metamorphic intensity, that the gabbro has its more southerly position and its somewhat crescentic shape, with its concavity toward lake Superior. The question now arises whether, where the gabbro now occurs a belt of Archean greenstone formerly existed. The line of direction of the northerly boundary of the gabbro between Gunflint lake and Kawishiwi river (T. 63-9 W.) is in contact with greenstone continually, and it is in this interval that are found its muscovadyte phases. Further southwest, and to Birch lake, it lies alongside the eastern part of the White Iron Lake granite. But it is known that this granite was intrusive at an earlier date in greenstones at White Iron lake and southwestwardly at Birch lake. It is hence to be inferred that the general greenstone belt extended originally at least to Birch lake. At the south of Birch lake the Animikie reappears. It lies on the Keewatin along the southern slope of the Giant's range; and this Keewatin, largely of greenstone character, is known to continue westward to the western confines of the Mesabi Iron range. Here the country is also much drifted, but it can be assumed that the same formation is practically continuous at the surface as far as the central and western part of Carlton county, and to the western part of Morrison county, where it is again well known. Whether in some parts of this drifted area it is covered by the Animikie, is immaterial.

Toward the northeast, at and near Gunflint lake, where the Animikie again appears distinct from the muscovadyte and the gabbro, the Animikie lies on granite, and this relation continues northeastwardly, according to Mr. E. D. Ingall, for many miles into Canada. Hence, if the greenstone belt above mentioned continues further east, it must run below the Animikie along the south side of this granitic belt. Toward the east, north and northwest, therefore, it is fair to assume that the gabbro is in intimate relations with a greenstone belt. Toward the west it is covered by drift and the nature of the rock is unknown, but is probably the same as far as to western Carlton county. Toward the south and east the older rocks are hid by the Keweenawan. This is sufficient to show that, in all probability, the crescentic line of folding and of metamorphism which outlines roughly the gabbro area in Minnesota, intrenched on a prior existing belt of greenstone which seems, toward the northeast, to have passed below the Animikie but caused the penetration of the Animikie by many great sills and dikes, and toward the southwest, as seen about Carlton and Cloquet, to have sent similar dikes into the contiguous formation.

If the greenstone member of the Archean, the oldest known rock, be the source of the gabbro, and the gabbro be the source of the sills and dikes of the Animikie, an important corollary can be drawn. The greenstones, underlying the gneisses of the Archean and being older than any of the granites intrusive into them, are capable of furnishing, on any similar occasions of refusion throughout geologic history, not only bosses of gabbro, but dikes of diabase, even to the present time.

The Manitou epoch of eruption. After the removal of the Beaver Bay diabase from the body of the gabbro there appears to have been a period of tumultuous oceanic transportation during which was formed the Puckwunge conglomerate. For a short time the igneous forces were comparatively still, allowing the accumulation, especially on the south side of lake Superior, of great thicknesses of coarse conglomerate. But even during the age of this conglomerate, and especially during the formation of the sandstones that followed it, there were occasional and local lava flows which must have extended for many miles. After each epoch of these later eruptions the lava sheet was covered by a sandstone, often conglomeratic, derived principally from the disintegration of the previous trap sheet. This succession of igneous and fragmental rocks characterizes the Lower Keweenawan of Irving. It is apparently much thicker on the south side of lake Superior than on the north. A single conglomerate on the south side has been found to have a thickness of about 2,000 feet, and the total thickness of coarse conglomerate on Keweenaw point has been estimated at 8,000 feet. The beds of this horizon on the north side of the lake do not probably exceed 200 feet in thickness. The igneous lava flows that followed the great conglomerate epoch are also much thicker on the southern side than on the northern. In the former they are estimated by Irving at 33,000 to 35,000 feet at Montreal river, whereas in Minnesota they probable do not exceed 1,000 feet; while, if the Puckwunge conglomerate and all the other fragmentals, together with the Beaver Bay diabase and red rock, be united under the term Keweenawan, the total thickness in Minnesota would probably not exceed 3,000 feet, and certainly would not reach 5,000 feet. It is to the eruptives of the epoch following the Puckwunge conglomerate that is applied the name Manitou.

These lava sheets extend along the lake shore from near Baptism river to near Grand Marais, except where they are replaced by the Beaver Bay diabase, or by some of the intersheeted fragmentals. It is uncertain how much of the immediate shore line east of Grand Marais is occupied by these traps. There is some reason for believing that the so-called "black traps" of Irving, seen eastward from the mouth of the Brulé, are a portion of the Beaver Bay diabase. Some part of the shore west from Grand Portage bay, as far as to near Red Rock bay, is made by trap sheets of later date than the Puckwunge conglomerate. The geographic distribution of the parts of the Keweenawan at Grand Portage, and for some miles westward, cannot be said to be sufficiently studied. The question is complicated by the occurrence of diabase dikes of great thickness cutting even the latest of the known trap sheets, as may be witnessed at Grand Portage island.

As to the source of the diabase forming these later sheets, and also the later dikes, it may have been from the same great gabbro mass, which must have extended laterally, beneath the later rocks, to great distances, and which must have cooled with great slowness. Such dikes and sheets may also have originated from the Beaver Bay diabase itself before it became solidified. Whether from one or the other they are of later and later dates toward the east and may be, at the last, as late as the dikes cutting the Trenton limestone at Montreal, as suggested by Lawson.

THE PETROGRAPHIC GEOLOGY OF THE CRYSTALLINE ROCKS OF MINNESOTA.

By N. H. WINCHELL and U. S. GRANT.

The following work is in keeping with the general plan which was adopted several years ago. The field numbers of the specimens are preserved. These numbers have been used to identify them in the various annual reports and in the several bulletins. The specimens, preserved in the university, will serve for many years to verify or correct the conclusions to which we have arrived. The intention has been to describe, with at least a classificatory designation, but usually with some exactness, and by means of microscopical examination of thin sections, every rock specimen that has been collected and reported with a field number in the annual reports, to which the student is referred for their field relations. In other places these lithological determinations are employed in the discussion of the systematic and areal geology, and in those chapters many new field observations will be found.

We have adopted the descriptions of other geologists whenever they have been sufficiently full and have served our purpose; but when our specimens did not answer to the descriptions published by others, or there was some doubt as to the identity of locality, we have made our own descriptions. It will be found that many of the field descriptions require correction, and that too, in some cases, when such descriptions were supplemented by some laboratory examination before publication. In some cases, also, some of the field numbers will be found missing from this enumeration. That is for the reason that the rocks represented were found to be of little importance or they were of doubtful relationship with the others, or because they are not found now in the collection.

Habitually we have given the megascopic and microscopic characters separately, and have made use of chemical analyses whenever possible, many of which are new.

The work is divided into two parts, viz.: *Part II*, which embraces all special petrographic facts, microscopic and descriptive, and *Part III*, which embraces such discussions and comparisons as to genesis and relationship as appeared to be the result of the foregoing, or to be germane to the *petrographic geology of the crystalline rocks of the state.* This, therefore, does not include the descriptive geology, which composes vol. iv, nor the systematic and structural geology which is given in Part I of this volume.

This work is based on the examination of about 3,000 microscopical thin sections. They were made by different assistants, and by M. C. Marchand, preparateur to the Museum d'Histoire Naturelle, Paris. The first thin section of rock ever made at the University of Minnesota was ground and mounted by the senior author of this in 1879, by the use of a lithologist's lathe procured of Prof. A. A. Julien, of New York.* Since that many other sections have been made on the same lathe by Messrs. Herrick, Terry, Oestlund, Wood, Meeds and Ogaard. It is run by the water-pressure derived from the city waterworks of Minneapolis; and from time to time some results of microscopical study have been published. We have had available as aids all the literature which has been published in this country bearing on the subjects investigated, and much of that of Europe. Our microscopes are, besides the original *Tolles microscope* purchased in 1879 and specially remodeled for petrography under the direction of Prof. Julien, an *Acme* lithologist's microscope made at Lancaster, Pennsylvania, and refitted by Bausch and Lomb, and a Nachet *Grand Modèle* with some recent attachments.

Finally, acknowledgments are due to Prof. A. Lacroix, of the Museum d'Histoire Naturelle, Paris, for assistance received during the year 1895, which was spent by the senior author at work in his laboratory on a series of Minnesota rocks. Many of the important and also of the special determinations have had the sanction of his approval. A second visit for the same purpose was made in 1898, and many suggestions were received again from Prof. Lacroix. We wish to record a lively appreciation of the enlightened generosity of the French republic in supporting at Paris such institutions as the Museum d'Histoire Naturelle, offered free to all naturalists for the research which they wish to carry on.

List of Publications to which Reference has Frequently Been Made, Bearing on the Petrography of Minnesota, Arranged Chronologically.

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1871. R. Pumpelly: The Paragenesis and Derivation of Copper and its Associates on Lake Superior, American Journal of Science (3), vol. ii, September, October and November.

1877. A. Streng and J. H. Kloos: Ueber die Krystallinischen Gesteine von Minnesota in Nord-Amerika. Neues Jahrbuch für Mineralogie, 1877 [translation in the Eleventh Minnesota Report].

1878. R. Pumpelly: Metasomatic Development of the Copper-Bearing Rocks of Lake Superior. Proceedings American Academy of Arts and Sciences, vol. xiii.

1879-1895. Annual Reports of the Minnesota Survey.

1880. R. Pumpelly: Lithology of the Keweenawan or Copper-Bearing Rocks. Geology of Wisconsin, vol. iii, pages 27-49.

1882. R. D. Irving: Microscopical Examination of the Archean Rocks of the Upper Flambeau Valley. Geology of Wisconsin, vol. iv (1873-1879).

1883. R. D. Irving: The Lithology of Wisconsin. Geology of Wisconsin, vol. i, pages 340-361.

1883. R. D. Irving: On the Paramorphic Origin of the Hornblende of the Crystalline Rocks of the Northwestern States. American Journal of Science (3), xxvi, page 27; xxvii, page 130; xxviii, page 464.

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* *Eighth Annual Report*, p. 10, 1879.

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1884. C. R. VAN HISE: Enlargements of Feldspar. American Journal of Science (3), vol. xxvii, pages 399-403.

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1887. C. R. VAN HISE: Hornblendes and Augites in Fragmental and Eruptive Rocks. American Journal of Science (3), vol. xxxiii., pages 385-388.

1887. M. E. WADSWORTH: Preliminary Description of the Peridotytes, Gabbros, Diabases and Andesytes of Minnesota. Bulletin ii, Minnesota Geological Survey.

1887. A. C. LAWSON: Notes on some Diabase Dikes of the Rainy Lake Region. Proceedings of Canadian Institute, Toronto, 1887. [Reprinted in the American Geologist, vol. i, pages 199–211.]

1888. W. S. BAYLEY: Spotted Rocks from Minnesota. American Journal of Science (3), vol. xxxv, pages 388–393.

1888. A. C. LAWSON: Report on the Geology of the Rainy Lake Region. Geological Survey of Canada vol. iii (New Series), Report F, 1888.

1888. HERRICK, CLARKE AND DEMING: Some American Norytes and Gabbros. American Geologist, vol. i, pages 339-346.

1888. IRVING, CHAMBERLIN AND VAN HISE: The Crystalline Schists of the Lake Superior District, International Congress of Geologists. Fourth Session, London, pages 156-170.

1889. W. S. BAYLEY: Quartz-Keratophyre from Pigeon Point and Irving's Augite-Syenites. American Journal of Science (3), xxxvii, pages 54–63, and vol. xxxix (1890), pages 273–280.

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1890. GEO. H. WILLIAMS: The Greenstone Schist Areas of the Menominee and Marquette Regions of Michigan. Bulletin lxii, U. S. Geol. Survey.

1891. N. H. AND H. V. WINCHELL: The Iron Ores of Minnesota. Bulletin vi, Geological Survey of Minnesota.

1891. GEO. H. WILLIAMS: Silicified Glass Breccia of Vermilion River, Sudbury District, Canada. Bulletin of the Geological Society of America, vol. ii, pages 138-140.

1892. R. D. IRVING AND C. R. VAN HISE. The Penokee Iron-Bearing Series of Northern Wisconsin and Michigan. Mon. xix, U. S. Geol. Survey.

1893. W. D. MATTHEW: On Phosphate Nodules from the Cambrian of Southern New Brunswick. Transactions New York Academy of Science, vol. xii, April 10.

1893. U. S. GRANT: The Geology of Kekequabic Lake in Northeastern Minnesota, with Special Reference to an Augite Soda Granite. (Thesis for the degree of Doctor of Philosophy.) Twenty-first Annual Report of the Minnesota Survey.

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1893. FRANK D. ADAMS: Ueber das Norian oder Ober-Laurentian von Canada (Inaugural Dissertation) Neues Jahrbuch für Mineralogie. Beil. Bd., viii.

1893. GEO. H. WILLIAMS: Notes on the Microscopical Characters of Rocks from the Sudbury Mining District, Canada. Geological Survey Canada, vol. v (New Series), Part I, pages 55–82F. See, also, Bulletin Geological Society of America, vol. iii, page 138.

1893. C. R. VAN HISE: The Huronian Volcanics South of Lake Superior. Bulletin Geological Society of America, vol. iv, page 435.

1894. J. EDWARD SPURR: The Iron-Bearing Rocks of the Mesabi Range. Bulletin x, Geological Survey of Minnesota.

1895. FRANK D. ADAMS: A Further Contribution to Our Knowledge of the Laurentian. American Journal of Science (3), vol. l, pages 58–69.

1895. SAMUEL WEIDMAN: On the Quartz Keratophyre and Associated Rocks of the North Range of the Baraboo Bluffs. Bulletin of the University of Wisconsin, Science Series, vol. i, No. 2, pages 35–56.

1895. J. MORGAN CLEMENTS: The Volcanics of the Michigamme District of Michigan. Journal of Geology, vol. iii, pages 801-822.

1895. N. H. WINCHELL: The Origin of the Archean Greenstones. Twenty-third Annual Report of the Minnesota Geological Survey, pages 1-32.

ABBREVIATIONS—

Ref.—References.
Meg.—Megascopic characters.
Mic.—Microscopic characters.

The method of labeling the specimens collected has been found very safe and permanent. It consists in mixing a solution of common shellac, such as can be got of a druggist, with some coloring material, and carefully placing the numbers on the specimens by hand. The alcohol rapidly evaporates from the shellac, which hardens, embracing the coloring material in the hardened mass. Such labels maintain their color and are insoluble in water. Specimens have been numbered as below.

The regular museum series, rocks, minerals and fossils, have their numbers in *red*, produced by mixing the shellac with "vermilion red."

The series of N. H. Winchell are marked with *blue* numbers, produced by mixing "indigo blue" with the dissolved shellac. Series from No. 1 to No. 2280. (These numbers are sometimes nearly or quite black.)

The series of A. Winchell are numbered in *black*. A mixture of shellac with India ink, and the figures also are followed by the letter W. Series from No. 1 to No. 990.

The samples collected and reported by H. V. Winchell are marked *pink*, formed by a mixture of vermilion red and white lead, and the numbers are followed by the letter H. Series, No. 1 to No. 542.

The samples collected by U. S. Grant are marked *green*, made by mixing Paris green with shellac, and the numbers are followed by G. Series, No. 1 to No. 1067.

The specimens of J. E. Spurr are numbered in *cream white*, and the numbers are followed by the letter S. Series, No. 1 to No. 231.

The specimens of A. D. Meeds are marked in *cream white*, and the numbers are followed by M. Series, No. 1 to No. 46.

The specimens of A. H. Elftman are marked in *white*, and the numbers are followed by the letter E, the series continuing from No. 1 to No. 767.

GENERAL INDEX TO THE GEOGRAPHICAL LOCATIONS OF THE ROCK NUMBERS OF N. H. WINCHELL.

[The exact locations are given in connection with the descriptions.].

Nos. 1 to 293. Along the shore of lake Superior from Duluth to Pigeon point.

Nos. 293 to 435. From Grand Portage north and west along the international boundary to Burntside lake, thence to Vermilion lake and the Squagemaw bridge (at Embarras lake).

Nos. 436 to 442. Eastward from the Embarras lake, on the Mesabi Iron range.

Nos. 443 to 510. From Fond du Lac to Knife falls.

Nos. 511 to 641. From Duluth to Pigeon point, Isle Royale, Silver Islet (Thunder Bay) and return to Duluth.

Nos. 642 to 796. From Grand Marais northwestward to Ogishke Muncie lake, and thence southwestward to the mouth of Poplar river.

Nos. 797 to 806. Taylor's Falls, East St. Cloud, Watab.
Nos. 807 to 819. Fond du Lac and Duluth to Beaver Bay.
Nos. 820 to 829. Taylor's Falls and southward along the St. Croix river.
Nos. 830 to 838. Sioux Falls, S. D., New Ulm, etc.
Nos. 839 to 862. Sauk Rapids, Motley, Pike Rapids, Courtland (Nicollet county), Duluth, Sauk Centre.
Nos. 863 to 1000. Vermilion lake eastward to Fall lake, Birch lake, Kawishiwi river, Long lake.
Nos. 1001 to 1109. From Long lake eastward to Kekequabic and Ogishke Muncie lakes.
Nos. 1110 to 1140. Collected by Dr. Wadsworth about White Iron and Birch lakes.
Nos. 1141 to 1147. From the Marquette and Gogebic Iron ranges.
Nos. 1148 to 1215. From the original Huronian region in Canada.
Nos. 1216 to 1255. From the Marquette region.
Nos. 1256 to 1263. From the Gogebic Iron range.
Nos. 1264 to 1452. From Grand Marais to Brulé mountain, Gunflint lake, Akeley (Chub), Gabimichigam a Ogishke Muncie, Kekequabic and Knife lakes to Tower.
Nos. 1453 to 1456. From Black River Falls, Wis.
Nos. 1457 to 1500. Collected by F. N. Stacy, northward from Gunflint lake.
Nos. 1501 to 1514. Tower and Ely.
Nos. 1515 to 1546. Redwood Falls, Pokegama falls, Duluth.
Nos. 1547 to 1572. Vicinity of Tower.
Nos. 1573 to 1606. Sudbury, North Bay and the Original Huronian region.
Nos. 1607 to 1614. Vicinity of Cloquet.
Nos. 1615 to 1626. Ely and vicinity.
Nos. 1627 to 1644. Mesabi Iron range, Republic mountain.
Nos. 1645 to 1669. Potsdam, N. Y., and the northern slopes of the Adirondacks.
Nos. 1670 to 1687. Little Falls and Philbrook, Morrison county.
Nos. 1688 to 1714. Mesabi Iron range.
Nos. 1715 to 1778. Kawishiwi river, Snowbank, Kekequabic, Knife, Zeta and Gabimichigama lakes.
Nos. 1779 to 1785. Eastward from Gabimichigama lake to Muscovado lake.
Nos. 1786 to 1806. Ely, Virginia, Duluth.
Nos. 1807 to 1859. Grand Marais eastward to Pigeon point and return to Grand Marais.
Nos. 1860 to 1906. From Grand Marais north on the Iron trail to Misquah hills, Brulé lake, Akeley (Chub) lake, Gunflint lake and Puckwunge valley.
Nos. 1907 to 1927. Iron mountain, Mich., Quinnesec falls, Republic mine.
Nos. 1928 to 1937. Keweenaw copper range, Calumet and Hecla.
Nos. 1938 to 1941. Gogebic range.
Nos. 1942 to 1953. Short Line Park, Cloquet.
Nos. 1954 to 1968. Ely, Soudan, Duluth.
Nos. 1969 to 1979. Carlton county.
Nos. 1980 to 2030. Ortonville, Vermilion lake.
Nos. 2031 to 2048. Knife and Saganaga lakes.
Nos. 2049 to 2065. Gunflint, Loon and Rove lakes.
Nos. 2066 to 2078. Puckwunge valley.
Nos. 2079 to 2091. Carlton county.
Nos. 2092 to 2113. Ely and Long lake.
Nos. 2114 to 2128. Long and Burntside lakes.
Nos. 2129 to 2134. Taylor's Falls.
Nos. 2135 to 2144. Mesabi Iron range.
Nos. 2145 to 2191. To Snowbank lake *via* Fall, Saturday, Urn, Bassimenan, Oak Point, Pine and Moose lakes.
Nos. 2192 to 2214. Snowbank and Disappointment lakes to Prairie portage.
Nos. 2215 to 2274. To Snowbank lake *via* Kawishiwi river, Triangle, Northwestern and Moose lakes.
Nos. 2275 to 2280. Vermilion lake and the "burnt forties."

Grand Divisions of the Coast Line.

Cabotian gabbro aud Beaver Bay diabase:

Short Line Park to Duluth.

Splitrock river to the base of the Great Palisades.

Brulé river to the west side of Deronda bay.

As sills and dikes in the Animikie to Pigeon river and Pigeon point.

Later Cabotian surface flows:

Duluth to Splitrock river.

Grand Marias to Brulé river (with red rock).

Manitou flows [and Puckwunge conglomerate]:

Baptism river to Grand Marias.

Deronda bay to Grand Portage.

PART II.

PETROGRAPHIC GEOLOGY AND DESCRIPTIONS.

No. 1. Gabbro. *(Rice Point Granite.)*

N. W. ¼ sec. 34, T. 50–14, Duluth.

Ref. Annual Report ix, pages 11, 18, 32; Annual Report x, pages 41, 72, 139, 201, 204; Bulletin ii, pages 73–75; American Association for the Advancement of Science, vol. xxx, page 162, 1882; Final Report, vol. i, pages 196–199; vol. iv, pages 571–580.

Compare J. H. Kloos, Zeit. d. deutsch. geol. Gesell, xxiii, pages 440, 441, 1871 (Translation, Annual Report x, pages 193, 194); A. Streng and J. H. Kloos, Neues Jahr. f. Min., etc., 1877, pages 113–117 (Translation, Annual Report xi, pages 51–54); N. H. Winchell, Annual Report viii, pages 22–26, 1880, and Final Report, vol. i, pages 147, 149, 1883; R. D. Irving, Mon. v, U. S. Geol. Survey, page 55, 1883; C. L. Herrick, E. S. Clarke and J. L. Deming, American Geologist, vol. i, pages 342–344, 1888; W. S. Bayley, Journal of Geology, vol. i, pages 696, 697, 1893; vol. ii, No. 8 and vol. iii, No. 1.

Megascopic characters. This rock varies considerably in color and grain, but as a rule is coarse grained, lavender gray or greenish gray and composed largely of feldspar whose twinning striations are very evident and which is usually crystallized in a uniform massive structure, but is sometimes distinctly porphyritic. Its tabular crystals are usually less than half an inch across, but one of our specimens exhibits a single crystal which has a roughly rounded outline and a diameter of an inch and a half on its cleavage face (compare, also, No. 128). Sometimes a lighter-colored feldspar with rectangular cleavages is sparsely scattered amongst the gray crystals, and this sometimes is whitish, and in other places pinkish, and in proximity to areas of red rock (No. 1B) these red feldspars are abundant. With such aspect this rock has received the name "orthoclase gabbro." Between the plagioclase grains, but making only a small part of the rock, are pyroxene and magnetite. The pyroxene has an irregular, though pronounced, cleavage-parting. It is usually in xenomorphic anhedrons, but occasionally it embraces the feldspar crystals ophitically. The magnetite is brightly metallic on fresh surfaces; on weathered surfaces it stands out rigidly after the other minerals have disintegrated. It is sometimes in tabular and other abnormal forms, owing apparently to the shapes of the cavities which it filled after the solidification of the other minerals.

In proximity to the lighter-colored feldspars are occasional nests of epidote and a rare crystal of pyrite. When the two feldspars are in contact the red coloration sometimes slightly penetrates the plagioclase crystal.

While this rock, as a whole, is coarse grained and uniform in texture, the large tabular plagioclases indicate two periods of crystallization. Still, the sizes vary much and the two periods are not sharply separated. In some places the smaller tabular plagioclases present lath-shaped outlines, and as the pyroxene approaches augite the rock becomes a coarse diabase, with more or less of an ophitic structure.

Microscopic characters. The *feldspar* is usually remarkably fresh, and displays brilliant color-bands, when not too thin, according to the widths of the intersected lamellæ. "Tested by the Levy-Pumpelly method it gives angles of 13° to 14°, and therefore would be classed as labradorite. It contains numerous tubular cavities arranged parallel to the twinning planes; also many glass and other inclusions. The feldspar is somewhat altered and cloudy, some of the sections having suffered greatly. Included in the feldspar is magnetite, chlorite (viridite), quartz and diallage closely approaching augite. The diallage is in places altered to uralite, etc." (Wadsworth.)

A thin section parallel to the brachypinacoid (010), cut from one of the porphyritic crystals, bringing out the cleavage parallel to the base (001) affords an extinction angle of 25° to 27°, which, according to the table of Fouqué,* indicates that the feldspar is labradorite-bytownite.

The twinning striations are more frequently seen on the edges of the tabular crystals (albite law), which exhibit also sometimes the less easy cleavage parallel to the brachypinacoid, than on the sides which are formed by the development of the brachypinacoid. These edges sometimes consist of a wide band without striations, adjoining another which is abundantly striated. Sometimes all the twins which stand in the same direction are narrow, like threads, consisting of the merest films, while their reversed fellows are broad. A basal section may therefore be governed largely, in its direction of easy cleavage, by the broad bands parallel to one of the sets of albite twins, and the narrow bands which are due to the thin albite twins may be inconspicuous or, in small slides, entirely wanting. This apparent absence of banding in basal sections is more likely to occur when the slides are so thin that they do not give colors higher than the grays of the first order in Newton's scale, in which case the lines separating the twins might be mistaken for cleavage. But even then the alternating extinctions are seldom obscured.

The section examined affords an interesting case of Carlsbad twinning in combination with albite twinning. One Carlsbad is cut parallel to the base, the other being oblique, and the two can be examined by the method of Michel-Lévy for the four positions of "éclairement commun."†

In a section cut at random from No. 1, the greatest equal extinction angle on opposite sides of a twinning macle was found to be 38° on one side and 37½° on the other. This, alone, is not diagnostic for labradorite, for anorthite has the same (see plates VI and VII, Determination des Feldspaths). But since in labradorite this

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

† *Determination des Feldspaths*, pp. 20–22.

measurement is near the locus of an optic axis, and in anorthite is far removed from it, search must be made for the proximity of the axial figure; the feldspar is thus again found to be labradorite.

Micro-chemical tests (Boricky) show the presence of lime and soda in this feldspar.

The specific gravity of small fragments of the feldspar from No. 1 was found to be 2.706. The trial was made in iodide of methyl on a Westphal balance.

The impurities of this feldspar, as exhibited in the section, tend to accumulate in lines or elongated masses parallel with the cleavage planes. They are more abundant in proximity to the other minerals, and especially adjacent to the pyroxenes, where an opaque whiteness often spreads irregularly for some distance on all sides, sometimes tinged with green. The same cloudiness accompanies all other cracks, which sometimes may be seen crossing the feldspars irregularly, and occasionally it pervades generally the mass of the feldspar, destroying the characteristic optical phenomena. In addition to this kaolinization are minute grains of magnetite (?) which are in groups or scattered. Occasionally they afford a cubic section, but generally their outlines are irregular. The pyroxene, which ophitically embraces the feldspars, is frequently, and perhaps usually in the specimens from Duluth, much decayed. The brilliant polarization which this mineral, when pure, presents between crossed nicols, in thick sections prepared for the microscope at low powers, is not usually seen, at least in sections cut from No. 1; but owing to incipient disintegration secondary products obscure it. These consist of magnetite, amphibole and chlorite, and sometimes a small amount of epidote.

Chemical analysis of the feldspar of No. 1. The following analysis was made by Prof. J. A. Dodge. He selected the feldspathic portion, by mechanical means, as clean as possible, but this portion was not wholly unmixed with other constituents of the rock:

SiO_2	49.78
Al_2O_3 } Fe_2O_3* }	32.36
CaO	11.55
MgO	1.43
K_2O	.41
Na_2O	3.39
H_2O	1.83
	100.76

The *pyroxene* was formed after the feldspars, filling the irregular, angular spaces between them, producing the ophitic structure. Usually the magnetite which has resulted from the breaking down of the pyroxene is in minute grains intimately associated with the resulting amphibole, but grouped together near the centre of the original pyroxene grain or in zonal arrangement at the periphery. But sometimes the amphibole occupies the entire original space of some of the pyroxenes, while magnetite occupies others. In each case the outlines of the pyroxene are preserved.

*The amount of oxide of iron is quite small.

The greenish alteration product from the pyroxene is, however, not always characterizable as amphibole. It is fibrous when the alteration is complete as amphibole, or granulo-fibrous when it is not far advanced. The change also proceeds to the production of a chlorite having the blue color and pleocroism of *pennine.*

There is also seen, rarely, another stage, a micaceous one, between amphibole and chlorite. It is hardly distinguishable, since, in all cases, so far as observed, the mica produced is so far permeated with chloritic characters, both in internal structure and in optical aspect, that it is intermediate in ensemble between chlorite and mica. When the micaceous characters remain they are expressed by higher double refraction and a more widespread uniform darkening at certain angles over the whole area of the grain or by evident cleavage. When the change is so far perfect as to constitute a chloritic element, the polarization is in shades of blue and yellow which supplement each other in rotation, each in the form of bright filaments, and the grain never assumes the darkness which is brought out in the micaceous stage. In ordinary transmitted light the micaceous grains are clear and structureless, or show a crooked cleavage, giving little indication of the fine, confused internal structure which the polarization colors express. The chlorite grains are continuously dark between crossed nicols when the section is parallel to their cleavages.

The pyroxene of No. 1 is further described under No. 1C. *Magnetite* appears both as apparently original and as secondary products. In the former state it constitutes an important ingredient in the composition of the rock, and as a secondary product it seems to have originated in an early stage of the rock's history, probably before it had become cool. Indeed, it is reasonable to suppose that many of the changes to which the various minerals have been subjected were completed prior to cooling. In the case of the magnetite, whether of the original minerals that segregated from the magma, or of those that arose from chemical rearrangement after consolidation, there seems to be no essential difference in its visible characters. The original grains are sometimes two or more millimeters in cross section, and occupy original positions amongst the larger grains, while the secondary grains are of microscopic size, and lie in the cleavage cracks of the labradorite and at the angles of the pyroxenes. Magnetite being normally one of the earliest of the original minerals to take its place in the consolidating magma, it is yet possible that the original and secondary grains, as here distinguished, did not differ widely as to the time of their formation. In any case the magnetite, even in its finest grains, can hardly be considered a product of ordinary weathering, nor of dynamic action, and the intimate relations subsisting between all the grains, especially the approximate pseudomorphism after pyroxene, indicate that some of the larger grains are likewise of secondary origin.

In the magnetite sections that are examined the outlines are not blurred by a leucoxene rim.

The secondary origin of all the magnetite found in this rock at Duluth, where it is so abundant as to have attracted attention as an iron ore (No. 1C), is therefore more than a possibility; that is, if the term secondary be understood with the above limitation. The fact that the large crystals of magnetite in this rock are seldom or never in their normal, entire, cubic forms, nor even as derivatives from the cubic form, but are of irregular shapes and dimensions, precludes their being considered, as now seen in the rock, as original in a molten magma. Yet, as magnetite, it must have originated early and before the final setting as to crystallization, which the rock now presents. If it be supposed that dynamic or other causes may have destroyed the original cubic shapes, it would still be likely, not only that the other minerals would have suffered similar deformations, but that in some places there would be still some remaining indication of an original quadratic crystallization. Neither of these conditions is found. On the other hand, it is a very common observation to note the encroachment of magnetite upon a grain of pyroxene, and the entire occupancy of the area of the latter by the substance of the former. There the magnetite takes the original shape of the pyroxene, which itself was later than the feldspars, and accommodates itself to its forms. Such microscopic quantities of of magnetite seem to be traceable, step by step, to the larger masses, and the secondary origin of all the magnetite seems to be a reasonable conclusion. It may have resulted from profound changes in the chemical or physical conditions just prior to final congealation, by reason of which some of the elements of the earliest crystallizations were rendered unstable, and a widespread resorption of some of the elements took place, leaving magnetite as a consequence.

In numerous places in No. 1C, the magnetite can be seen in contact with unchanged augite and feldspar, which shows that it began to form prior to the commencement of decay of the augite. Still, even in No. 1C, it is found in the central portions of what is now a chloritic mass, resulting from change of augite. Here also are some quadratic forms embraced in pure feldspar.

Chemical analysis of the Gabbro No. 1. The following results were reached by Prof. J. A. Dodge (No. I). Beside it is given (No. II) the composition of a "hornblende gabbro," reported by Streng from the St. Louis river near Duluth.

	I.	II.
SiO_2	50.43	49.15
Al_2O_3	23.83	21.90
Fe_2O_3	17.63	6.60 (FeO=4.54)
TiO_2	trace	....
CaO	4.79	8.22
MgO	2.46	3.03
K_2O	0.34	1.61
Na_2O	2.06	3.83
H_2O	....	1.92

There can be but little doubt that this is the rock which was examined by Streng under the name "hornblende-gabbro," and by Irving under the name "orthoclase-gabbro,"* obtained at Duluth. Streng's specimen was obtained "on the St. Louis river, near Duluth, and Irving's," near the center of sec. 33, T. 50–14. Irving refers to it as the "coarse gray rock of the St. Louis river bluffs, at and near Duluth." From the same mass or hill range, however, Irving reports (viz., on sec. 27, T. 50–14) an "orthoclase-free" gabbro. The sections of No. 1, here described, are from more decayed rock than is usually found in the gabbro range. Several other numbers more fairly represent it, particularly Nos. 1C, 512, 513, while No. 5 is an illustration of a still further impregnation of the same rock with elements from the contacting clastics.

The relations of this rock to a series of clastics of older date are very intimate. For a discussion of this association the reader may consult Part I.

In this rock Streng proved the titanic acid to exist in the form of titaniferous magnetite. The feldspar, after treatment twenty-four hours, was found insoluble, and its powder, after long treatment in the same acid, gave him no jelly. He concluded, therefore, that it is not anorthite, but comes near labradorite. On account of the percentage of 1.61 of potash in the rock, he concluded also that some orthoclase is present.

In the hornblende he found sometimes a "viriditic" substance, giving it a light-green color, with impaired dichroism, and a parallel or radiate fibrous structure. In other cases the brownish-green hornblende, without viridite, is parallel-fibrous and strongly dichroic. This hornblende he considered an original mineral ingredient, and not a product of change from diallage. The grains of diallage did not appear to him to encroach in the least upon those of hornblende, though the two were described as forming a mosaic, with sharp outlines. He mentions large, black metallic, angular crystals of magnetite and menaccanite, and smaller grains of the same embraced in the other minerals. These, with a little epidote, chalcopyrite, quartz and apatite, constitute the minerals of the rock. He concludes thus:

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

*_Eleventh Minnesota Report_, p. 51. _Mon. v, U. S. Geol. Survey_, pp. 50, 53.

menaccanite. The meager percentage of magnesia corresponds to the low content of hornblende and diallage in the rock. The apatite in the rock amounts to 0.81 per cent."

Seven sections examined.

Age. Cabotian of the Taconic (or Lower Cambrian). N. H. W.

No. 1A. Gabbro *(with orthoclase)*.

From the high land, Duluth. Same rock as No. 1, but further northeast; intersection of Fifth Avenue East and Seventh Street; near a contact with No. 1B.

Ref. Same as for No. 1. Also, Annual Report, x, pages 41, 141; Proceedings of the American Association for the Advancement of Science, vol. xxx, page 165.

Meg. As No. 1 approaches the "red rock" of the region (No. 1B) it begins to acquire other minerals, and a reddish, feldspathic spottedness, as expressed by this rock and by No. 5. At the contact the grain is sometimes considerably finer than at a distance from the contact. The section examined seems to have been derived from near the contact. It was described in the Proceedings of the American Association for the Advancement of Science, Cincinnati meeting (1881), when it was said to contain "labradorite, uralitic augite and titaniferous magnetite. Some of the augite is changed toward viridite; orthoclase in occasional grains;" and it was placed amongst the "mixed igneous and sedimentary rocks." It principally differs from No. 1 in having a visibly greater proportion of the orthoclase element. It is not an independent rock, but an altered phase of No. 1, as will appear more fully in the descriptions of some of the other samples.

One section examined.

Age. Cabotian. N. H. W.

No. 1B. Granite. *(Red.)*

Duluth; probably N. W. ¼ sec. 34, T. 50–14.

Ref. Annual Report, ix, pages 11, 12, 17, 18; Annual Report, x, pages 41, 140, 201, 204; Annual Report, xiii, pages 100, 103; Bulletin viii, pages xxx, xxxiii; American Association for the Advancement of Science, vol. xxx, page 163, 1882.

Compare R. D. Irving, Mon. v, U. S. Geol. Survey, page 119, 1883.

There are two hand samples of this number, both of which have been analyzed. As the two differ considerably, they will be described separately as Nos. 1B and 1B′.

Meg. A medium or rather fine-grained granitic rock of a brick red color. Composed principally of two minerals: a reddish feldspar and a black or greenish black substance, apparently hornblende; the former is in greater amount than the latter. Quartz, in smaller grains than the other two minerals, is not very evident, but is scattered throughout the specimen. A few small yellowish areas are also seen.

Mic. The section shows that the rock is highly altered, but as it is typical of certain phases of the "red rock" of the Cabotian, to which Irving has applied the term augite syenyte, it will be described rather fully. The structure is granitic, although the feldspar has a tendency to an idiomorphic development, and the following minerals are present, in the order of abundance: *feldspar*, *quartz*, *hornblende*, a greenish yellow, almost isotropic, mineral, *magnetite*, *epidote*, *muscovite* and *apatite.*

The *feldspar* is much altered and reddened, as is usual in rocks of this class, and has sometimes become opaque; thus some of the areas that were originally feldspar show almost no action on polarized light, and many of them have comparatively little of the feldspar material in its original state. However, in a few cases, the traces of polysynthetic twinning can be noticed, but not frequent nor distinct enough for determining the nature of the feldspar. Several simple twins, apparently of orthoclase according to the Carlsbad law, are seen, and also many untwinned grains, some of which are less altered than those which show twinning. From these facts, and from the analysis which is given below, it appears that the feldspars present are (1) Orthoclase, in some quantity; (2) Plagioclase of an undetermined variety, but probably near oligoclase; and (3) Anorthoclase is supposed to be present, as it is known to occur quite frequently in rocks of this class.

As secondary minerals in the feldspar are muscovite, quartz, epidote and a greenish yellow mineral. The last has almost no effect on polarized light, occurs in irregular areas or in branching vein-like forms, and is intimately associated with a fibrous mineral of about the same color; the latter appears to be hornblende. Epidote is seen in small areas and crystals; it is yellowish or colorless. Muscovite exists in small flakes. In altered feldspar crystals three zones can sometimes be distinguished; an inner one composed of rather fresh feldspar, outside of which is an opaque reddish zone more altered than the interior, and beyond this a zone of about the same nature, but less reddened. Very frequently the inner zone, instead of being the less altered, has almost no feldspar material left, but is composed largely of the isotropic mineral mentioned above, oftentimes associated with finely fibrous hornblende, epidote and a few muscovite flakes.

After the feldspars the most important ingredient of the rock is *quartz*, which occurs in two modifications. The first form occurs in the spaces between the feldspars. It has all the characters of ordinary granitic quartz. It is clearly younger than the feldspar by which its outlines are conditioned. The other form taken by quartz is an intimate micropegmatyte with the feldspar. This micropegmatyte pervades the whole rock and is a very characteristic microscopic feature of the granular acid rocks of the Cabotian. As the feldspar is so much altered and darkened, this structure is very easily seen in ordinary light. Large areas of feldspar are sometimes completely penetrated by this network of quartz; again, the quartz particles occur only around the peripheries of a feldspar grain. These apparently detached quartz grains are sometimes oriented with the larger quartz grains adjoining the micropegmatyte, and sometimes are entirely independent of them. This rock does not show the structure as well as some others which will be figured in this volume, but it is still very evident. For illustrations of this class of rocks and this structure, see plate XV of Irving's "Copper-Bearing Rocks of Lake Superior," and especially figure 1, which is of a rock from the same locality as the one here described.

Hornblende occurs in fibrous masses and in compact grains. The fibrous masses occupy areas which were probably originally filled with augite, but the slide now shows no trace of the original pyroxene. A few of these areas show partial outlines that resemble cross sections of augite. The compact hornblende is brownish-green and distinctly pleochroic, $\mathfrak{a}$ being straw-colored or greenish-yellow, $\mathfrak{b}$ dark-brownish, and $\mathfrak{c}$, nearly the same as $\mathfrak{b}$. The absorption is $\mathfrak{c} \geqq \mathfrak{b} \gg \mathfrak{a}$. The hornblende does not show well defined crystal outlines, but one cross section approaches closely to the form of a pyroxene cross section. The fibrous form is often intimately associated with the compact, the former probably being an alteration of the latter. That the compact hornblende is original, is uncertain, and it is quite probable that all the hornblende is secondary, the original ferro-magnesian constituent of the rock being augite, and the rock one of the augite syenytes described by Irving.*

Magnetite is abundant, occurring in well defined grains, after showing crystal outlines, and in irregular areas and minute grains associated with the hornblende. The rock powder yields many grains to the magnet.

Apatite is quite common in the form of long needles, which penetrate all the other minerals of the rock, even the magnetite.

Chemical analysis. The following analysis was made by Prof. J. A. Dodge and published in the thirteenth annual report, page 100 (Chemical series No. 148).

SiO_2	66.36
Al_2O_3	13.33
Fe_2O_3	7.89
FeO	2.96
CaO	2.14
MgO	1.20
K_2O	3.05
Na_2O	2.63
H_2O	1.21
	100.77

This shows a rock which is more basic than the average of "red rocks," and which has a lower percentage of soda than is common.

Remarks. As has already been stated, this rock belongs to the series of "red rocks" of the Cabotian. In Part III, of this volume, will be found a discussion bearing on these rocks; among the various points discussed will be: their origin, their relations to the gabbro, the secondary nature of the micropegmatyte and the hornblende.

One section examined.

Age. Cabotian of the Keweenawan. U. S. G.

* *Op. Cit.*, pp. 112-124.

No. 1B'. Granite. *(Red.)*

Duluth. Probably N. W. ¼ sec. 34, T. 50-14.

Meg. A rather fine-grained, reddish to flesh-colored granitic rock composed of quartz, a pinkish feldspar and a little epidote. A number of the feldspar grains are considerably larger than the other constituents and are surrounded by a finer groundmass of quartz and feldspar, but these larger grains are not sufficiently distinctly marked off from the rest of the rock to give it a porphyritic appearance.

Mic. The section shows a granitic groundmass of feldspar and quartz, the former in larger quantity than the latter. In this groundmass, and not very sharply separated from it, are larger areas of feldspar with which quartz is plentifully intergrown in most beautiful micropegmatyte; the feldspar of the groundmass does not show this feature. Frequently these areas of feldspar contain more than one crystal and occasionally a core which is not filled with quartz, but the feldspar does not show idiomorphic outlines. The feldspar is much altered and is cloudy, reddened and sometimes almost isotropic; the cleavage is poorly developed and good cleavage flakes on which to make determinations of the extinction angles are almost impossible to obtain. In some crystals traces of polysynthetic twinning can be observed, but most of the grains are too highly altered to show this. As the feldspar is the only mineral of any importance besides the quartz, the analysis of the whole rock, which is given below, will give a good index of the composition of the feldspar. The amount of soda is very high in comparison with the potash and lime, and a considerable part of the feldspar would thus seem to be albite, but anorthoclase, and perhaps some orthoclase, are also probably present.

Reddish iron oxide is quite common in minute flakes scattered throughout the section. A few small areas of chlorite and of epidote are also present. If the chlorite represents an original ferro-magnesian constituent, nothing can now be said as to what it was.

Chemical analysis. The following analysis of the whole rock was made by Prof. J. A. Dodge, and first published in the tenth annual report, page 204 (Chemical series 73).

SiO_2	75.78
Al_2O_3	11.09
Fe_2O_3	2.09
CaO	.86
MgO	.65
K_2O	1.06
Na_2O	6.43
H_2O	1.82
	99.78

Remarks. One of the "red rock" series. See under 1B.

Age. Cabotian of the Keweenawan. U. S. G.

No. 1C. Gabbro. (*"Rice Point Granite."*)

Duluth. From the rock which has been slightly explored for iron ore. Belongs to the same rock as No. 1 but from a point further east on the hill.

Ref. Same as for No. 1. Also Annual Report, x, page 41.

Meg. This is a fresh rock, of higher specific gravity than No. 1, grayish-black medium grained, having distinct ophitic structure, in some places largely made up of magnetite, in the mass of which sometimes may be seen rectangular surfaces.

Mic. The coloration of all the transparent grains in a thick section, between crossed nicols, is much more brilliant than that of No. 1, and the ophitic relations of the pyroxene and the plagioclase plates are very marked.

The *feldspar* exhibits Carlsbad and albite twinning, and occasionally also the pericline bands. A section approximately parallel to 010 gave extinction on the edge (001) (010) at $21\frac{1}{2}°$; another parallel to 001, gave an extinction of 22°, which indicate *labradorite*, approximating *bytownite*.

The *pyroxenic element* possesses special interest, as it is usually a lamellated *diallage*, with bright and contrasting polarization colors. The prismatic cleavage, in conjunction with that parallel to the face 100, is common. The fibrous disintegration which precedes the change to amphibole is always perpendicular to the last mentioned cleavage. There is a great range in the degree of change manifest in the diallage. In the section examined there is no apparent tendency to amphibole, but to chlorite; at least no amphibole colors nor cleavage is visible. Some of the diallages are nearly intact, and others are entirely changed. Those which are yet intact embrace magnetite in grains of considerable size, which sometimes show angular forms, as if original, while those which are changed have fine granular aggregations of magnetite of irregular shapes at their centres, the periphery of the diallages being made up of a rim of opaque veriditic matter, apparently of chlorite. The magnetites so embraced in decayed grains of diallage are frequently impacted in epidote, or epidote and chlorite. In the unaltered or slightly altered diallages the contact between the diallage and the included magnetites is clear and abrupt, indicating the original nature of the magnetite. See figure 3, showing cleavages of diallage.

The arrangement of the magnetite in some of the principal magnetic grains is in lines (as seen in section) or sheets. It suggests that the lamellation of the diallage parallel to 100 may have determined its position, and hence, on the view above that the magnetite in the main is not a magmatic secretion, but is a secondary generation after consolidation, before cooling, the lamellation of the diallage must have had a very early origin, prior to the genesis of this secondary magnetite, and hence was probably original, and not a result of change from augite. Still, it is possible, if not probable, that an earlier stage of the diallage was augitic, and that both the lamellation on 100 and the generation of magnetite date from the cooling period, perhaps contemporaneously.

Magnetite. From the above it appears that the genesis of the magnetite in this rock is not all referable to the same date, but that it was both original and "secondary." It is in quadratic forms embraced in the feldspars and in the diallages, in comparatively unchanged surroundings. It fills angular openings within the feldspars, where it seems to have taken the place of decayed pyroxenes (diallages), and in this form it constitutes the largest amounts. At the time of this substitution of magnetite for pyroxene, there was a general disintegration of the pyroxenes, so that their spaces are not entirely filled with magnetite, but epidote, and especially chlorite, appear as secondary minerals. *Pyrite* appears in a few small grains, mingled with the secondary magnetite.

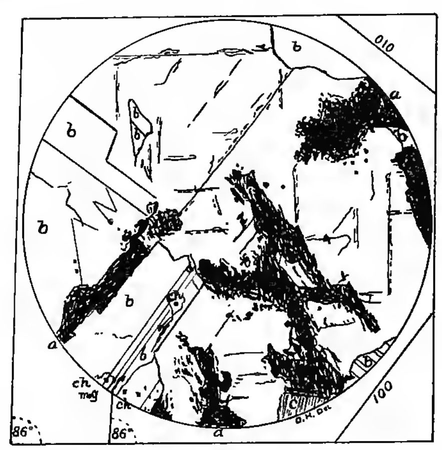

FIG. 3. A GRAIN OF DIALLAGE SEEN IN SECTION OF ROCK NO. 1C, SHOWING THE PRISMATIC CLEAVAGES AND THAT PARALLEL TO 100.

a—Magnetite (black). *b*—Feldspar. *c*—Fibrous diallage. *ch*—Chlorite.
The rest of the figure is occupied by a grain of diallage. In this section the fine fibrous structure is wanting.

The order of genesis of the minerals here seems to have been as follows:

Original—	*"Secondary," or without known order of genesis*—
1. Magnetite.	Chlorite.
2. Feldspar.	Magnetite.
3. Diallage.	Pyrite.
	Epidote.

In the magnetite sometimes there is a connection between a cubic or otherwise angular grain, which is so situated with respect to a feldspar or a pyroxene as to show its original date from the molten magma, and a mass of secondary magnetite, as if the change of the pyroxene had been provoked to begin at a magnetite nucleus, and to spread widely from it. In such a case the original cubic magnetite has a sharp line of separation from the surrounding minerals, whether of pyroxene or of feldspar, but the "secondary" increment has a laminated structure and an irregular outline, both due to the form of the original pyroxene.

These secondary minerals seem to have been derived entirely from the change in the diallage, for the feldspars are quite free from such change. There is sometimes a patch of chlorite surrounded by a feldspar grain, but in all such cases, so far as observed, there are a few fine grains of secondary magnetite embraced in the chlorite, showing that the place of the chlorite was originally occupied by a grain of diallage; or such chlorite grains can be referred to the effect of a neighboring disintegrated diallage.

From the foregoing, however, it is not established that the great masses of iron ore of the gabbro are of secondary date, though it appears probable. If such a generation be established by such evidence it is necessary to understand the term *secondary* to apply to a date just subsequent to consolidation prior to cooling, when chemical changes were liable to rapid production. The changes that have resulted since cooling, so far as seen in this rock now at the surface, are *nil;* but they may have been great prior to the removal of the weathered surface by the glacial period.

One section examined.

Age. The Cabotian eruptives of the Taconic. N. H. W.

NOS. 1D AND 1E. GABBRO. *(Globular masses, weathering from No. 1.)*

Duluth. At a point half way between Newson's quarry and the depot. Also seen on Michigan street, where it has been cut by grading and forms a bluff about fifteen feet high.

Compare Nos. 4A and 1799.

Ref. Annual Report, ix, page 11; Bulletin ii, pages 73, 74; Annual Report, x, page 41.

Meg. An extensive disintegration characterizes a belt in the gabbro seen at this place and again on Michigan street. It is finer toward the east. At the point where this specimen was obtained the masses were over a foot in diameter, with many smaller. Evidently these larger masses, being fresh and like the rock of No. 1, are of the nature of "boulders of disintegration," as defined by T. Sterry Hunt. But in other places the rock is in the nature of a *gravel of disintegration*, the small gabbro pieces being about the size of apples and walnuts, though surrounded by much decayed rock. The face of the cut on Michigan street presents much the appearance of a conglomerate (plate P, figure 1, vol. iv).

Mic. A thin section from No. 1E presents the same characters as No. 1, but the minerals are much decayed.

One section examined.

Age. Cabotian. N. H. W.

No. 2. Diabase.

Duluth. Dike running N. 30° W., separating No. 1A from No. 3.
Ref. Annual Report, ix, page 11; Annual Report, x, page 41.

Meg. A dark gray, compact rock of rather fine grain. Composed of plagioclase, a greenish mineral looking like an alteration product of augite and magnetite. The feldspar weathers whitish to pinkish.

Mic. A rather fine grained diabase, more or less altered. The ophitic structure is very distinct, and the *plagioclase* is usually little altered. In the angles between the plagioclase, and often penetrating it along the cleavage cracks and twinning planes, is a dirty-greenish alteration product of the augite. In some places fresh *augite* still remains; it has a purplish tinge similar to that of a large proportion of the diabasic augite of these rocks. *Magnetite* is quite abundant, but is confined largely to the areas of altered augite; it is in irregular grains, and especially in rod-like bodies, which often exist in small groups, in each of which the rods lie parallel. Sometimes one rod will have several smaller ones branching off from it at right angles, thus resembling the skeleton crystals of magnetite found in certain glassy rocks.* But in the rock under consideration, the rods are several times larger than these skeleton crystals.

One section examined.

Age. Probably a dike of Manitou.

Remarks. "A finer-grained rock of the same general character as No. 1A, and running in the form of a dike, N. 30° W., and separating No. 1A from No. 3."†

No. 3. Granite. *(Fine, red, hornblendic.)*

Duluth. Fifth avenue east and Seventh street, occurs as patches and veins in No. 1.
Ref. Annual Report ix, pages 11, 12, 17. Annual Report, x, pages 41, 140. American Association for the Advancement of Science, vol. xxx, page 163, 1882.

Meg. This is a fine grained, granitic rock of a reddish-brown color. The hand sample varies somewhat in shade, one side being brown and the other reddish, the change occurring gradually along the centre of the specimen. The mass of the rock is quite fine grained, but seems to be made of reddish feldspar and a darker hornblendic mineral in ill-defined grains, blotches, and some distinct crystals. A few large, but dark colored feldspar crystals two to three millimeters long are seen. These and the larger crystals of hornblende give the rock a sub-porphyritic appearance. The feldspars do not show striation. A weathered surface is lighter red and filled with small cavities due to the more rapid decay of the hornblende.

Mic. In thin section the rock is seen to be sparingly porphyritic with *feldspars.* While these are quite small, the largest one in the section being less than two milli-

* Compare H. Rosenbusch, Mikrosk. Physiog., Bd. I, Taf. II, figure 5, 1892.
† N. H. Winchell. *Ninth Annual Report*, p. 11.

meters long, still they are much larger than the other constituents, and are almost completely idiomorphic. Most of these crystals show no polysynthetic twinning, although in two of them traces of it are visible. An attempt to get cleavage flakes for the measurement of the extinction angle was unsuccessful, as the crystals are quite small and usually considerably altered to a pale-greenish chloritic substance. The porphyritic feldspars are rarely reddened as is the feldspar of the groundmass. No porphyritic hornblende is shown in the slide.

The groundmass is composed of feldspar, hornblende, quartz and magnetite. The feldspar is much altered and reddened, as is so common in the acid granular rocks of the Cabotian, and shows no twinning striations, and the cleavage is ill developed; it is very probably orthoclase. *Quartz* occurs in sharply defined grains and also in micropegmatitic intergrowths with the feldspar. This micropegmatyte pervades almost all the feldspars, and at times becomes almost granophyric. As to how much of this structure is secondary it is impossible to say. The groundmass is, however, holocrystalline and is finely granitic in structure. Hornblende, of the usual green variety, is quite common; it occurs in allotriomorphic grains and in minute flakes, which have a slightly bluish tinge and are scattered throughout the rock. Some of the areas of hornblende appear partially granular and much resemble hornblendes that are secondary after pyroxene, but in no case was any pyroxenic material seen nor suggested by the outlines of the hornblende areas. *Magnetite* is quite abundant; it occurs in a few irregular masses two to three millimeters across and in numerous minute idiomorphic grains.

One slide examined.

Age. Cabotian.

Remarks. The rock is a brownish red, very fine grained, sub-porphyritic, hornblende granite. "This [No. 3] spreads wider and is to be seen at other points back of Duluth, yet appears rather to be in patches, or in veins in other rock. At Newson's quarry a similar red rock penetrates the gray rock in seams, and occupies a larger area in the lower part of the quarry."* U. S. G.

No. 4. Diabase. *(Coarse, decayed.)*

Duluth. Near the Union station.
Ref. Annual Report, ix, page 11; Annual Report, x, page 41.

Meg. This is a much decayed, light gray to flesh-colored rock of medium grain. Feldspar makes up more than half the rock; it is whitish to pinkish in color and appears like decayed orthoclase. Several larger crystals occur in the hand specimen; these have a greenish shade and are one-half to three-fourths of an inch across, but they are not sharply marked off from the rest of the rock and so do not give it a

*N. H. Winchell. *Ninth Annual Report*, p. 11.

porphyritic aspect. Areas of a soft, dark-green mineral, which seems to be chlorite, are common, as are also small particles of epidote. Magnetite is also present.

Mic. This rock is much decayed. The chief minerals present are feldspar, chlorite, epidote and magnetite. The feldspar is largely altered to a mass of minute, grayish, sericite-like fibres, but in many places enough of the original mineral remains to show that it possessed frequent twinning lamellæ. The fibrous alteration product is sometimes arranged in groups of fibres radiating from a point or from a line. The feldspar crystals are partially idiomorphic, and in the spaces between them are some angular areas now filled with chlorite and fine grains of magnetite. The rock thus appears to have been a diabase with the augite now represented only by the chlorite areas. These are, however, in comparatively small amount, as the feldspar makes up the great part of the rock. Epidote has developed to some extent in the feldspar; it occurs in granular aggregates and irregular areas and is colorless to straw colored, the more colored parts being somewhat pleochroic. Magnetite is quite common, and the rock powder yields many grains to the magnet. In some places, however, what appears to be magnetite is probably ilmenite, as it is found partially surrounded by a whitish substance resembling the usual alteration product of ilmenite.

Three sections examined.

Age. Probably an eruptive of the Cabotian.

Remarks. This rock appears to have been originally a rather coarse-grained diabase. Possibly some orthoclase feldspar may have been present, thus giving the red feldspar of the hand sample, as orthoclase is found to some extent close by in basic rocks (diabase or gabbro), where it is intimately associated with the acid "red rocks" (compare No. 1B). In this case, however, it seems possible that the red color of the feldspar is due to staining during the process of decay, and that it was not originally orthoclase. "A cementing material for rounded masses of No. 1."* U. S. G.

No. 4A. Gabbro. *(Breccia, reddened.)*

Duluth. Near the same point as No. 1D and No. 1E, east of Newson's quarry.
Ref. Ninth Report, page 11; Tenth Report, pages 41, 99. See also descriptions of Nos. 1D, 1E, and 1799.

Meg. The specimen is much reddened, but there is no certainty of any other feldspar than a plagioclase, whose albite twinnings are sometimes visible. It is specked or spotted with red and gray, also with epidotic green, and in general is quite coarse. The specimen marked No. 4A is not a fair representative of the description made in the field, but is rather a coarse sample from the matrix which embraces the undecayed and rounded masses. The origin of this breccia (?) is problematical.

No section.

Age. Cabotian? N. H. W.

* N. H. Winchell. *Ninth Annual Report*, p. 11.

No. 5. Gabbro *(with orthoclase)*.

Duluth. Near the old passenger station of the St. Paul and Duluth R. R. [The outcrop from which th sample was obtained was entirely worked out and the spot covered on the construction of the new union depo but this rock is not an uncommon one at Duluth, as it is a phase of the contact phenomena and fusion of tl sedimentary rocks with the gabbro No. 1. It is seldom seen so coarsely crystalline, however.]

Ref. Annual Report, ix, pages 11, 12, 19, 57. Annual Report, x, pages 41, 141. Bulletin ii, page 8 American Association for the Advancement of Science, vol. xxx, page 165, 1883.

Compare R. D. Irving, Mon. v, U. S. Geol. Survey, page 55, 1883.

Meg. A heavy, dark-reddish rock of rather coarse grain, composed of pinkis feldspar, gray feldspar, pyroxene and magnetite. The rock has the appearance of coarse diabase, except that half or more of the feldspar has a pinkish color, and th rest is gray plagioclase. Where the latter is more abundant, the pyroxene an magnetite are in larger quantity; there thus appear irregular areas, not sharpl separated from each other, one of a pinkish, and the other of a darker color; yet, i the areas occupied mostly by one feldspar, crystals of the other frequently occu: There are also some grains which are intermediate in color, and a complete gradatio in color, from the pinkish to the gray, can be seen; moreover, in some cases, a singl crystal will be pinkish in one part and gray elsewhere; in such cases the centre i usually of the latter color, while the margin is pinkish. The gray feldspar sometime shows twinning striæ, but none were seen on the pinkish variety. Magnetite, i grains of considerable size, is quite abundant; some of it yields readily to the ordinar magnet, while some does not, thus indicating that at least part of what appears t be magnetite is really ilmenite. In some of the areas of pinkish feldspar a fe small grains of quartz are to be seen.

Mic. A basal section was made from each of the *feldspars*. The gray feldspa in this section shows a cleavage trace, and the whole slide extinguishes at 4° or 5' indicating either albite or labradorite (Fouqué, page 148).* A single basal sectio is not sufficient to decide, since it is impossible to know from which direction it i examined, whether on the right or left of the obtuse angle 001:010; in other word whether it is before the observer in the "conventional position" of a triclinic crysta with the obtuse angle 001:010 at the right. In order to determine between these, careful test was made with hydrofluosilicic acid, by the method of Boricky, the resu being numerous large monoclinic micro-crystals of fluo-silicate of lime, as well a irregular spreading and branching growths of the same, many fine hexagonal micr crystals of soda, and a few cubes of the same salt of potassium. This result preclude albite and indicates labradorite, in which a small portion of the soda is replaced b potash. Several measurements were made on sections nearly 010, for the extinctio angle, which is uniformly high, ranging from 26° to 33°, this result indicatin labradorite or bytownite. In one of the sections examined, is a small rectangula section of this feldspar, showing nearly rectangular cleavages and striations, o

*Compare, also: *Bulletin de la Société Française de Minéralogie.* Tome xvii, p. 428, 1894.

which extinction is 24°. In the feldspars the plane of the optic axes is practically in the plane 010, and gives an interference figure indicating the optic normal within the field of the microscope. Comparing this with the "épures" of Michel Lévy (Minéraux des Roches, plate VI, the optic normal (n_m) is found situated between $30\frac{1}{2}°$ and 20°; practically at 24°. This again indicates labradorite with the proportions Ab_3An_4. All methods of examination which have been made of this feldspar, *i. e.*, the original gray feldspar of No. 1,) lead to labradorite.

The red feldspar in No. 5 was subjected to the same test. Large cubes of fluosilicate of potash, some of them so rapidly formed as to be partially opaque, monoclinic crystals of lime and an occasional hexagonal rod of soda, pointed unmistakably to orthoclase in which a part of the normal potash is replaced by soda. This shows a mutual interchange between these feldspars, one giving up a little soda and receiving potash and the other receiving soda in exchange for potash. This indicates a tendency on the part of the orthoclase toward the composition of anorthoclase. In general, the red feldspar is nearly or quite opaque, from some alteration, while in immediate contact are the lath-shaped labradorites, with evident cleavage and twinning bands. In the interior of the red feldspars are frequent grains of quartz. The labradorites were formed earlier than both the quartz and the orthoclase. Not infrequently a fringe or red border of orthoclase surrounds the labradorites, a kind of reaction rim between the previously formed labradorite and the acidic elements which subsequently enveloped it. Indeed, there is good reason to assume that, in many cases, the red color simply marks such changed labradorites. This reddened feldspar often constitutes a border round the clearer crystals of plagioclase, and in such cases the border, or colored zone, seems to be a continuous part of the clearer central crystal. This can be explained on the supposition that the crystal is a zonal one, the outer zone being less basic than the inner, and that it has consequently undergone the reddish alteration to which the more acid feldspars of these rocks are so subject. Or, on the other hand, this reddened zone may be simply a peripheral altered portion of a practically homogeneous crystal. However this may be, the reddened feldspar between the clearer crystals appears exactly similar to the similarly colored feldspar of the acid granular rocks, which is known to be orthoclase and anorthoclase. In these areas of reddened feldspar is considerable quartz in small grains, and frequently these two minerals have grown together in the form of micropegmatyte. Such parts of the section resemble sections of the acid red rocks—granites and augite-syenytes (see Nos. 1B, 3).

The *pyroxenic* mineral appears much as in No. 1C, but is not so evidently diallagic. It is much changed to chlorite and replaced by magnetite. Occasional grains are cut nearly perpendicular to an optic axis, as shown by the interference figure.

It embraces the labradorites ophitically but never the orthoclases. On the contrary the orthoclase surrounds it, in a manner somewhat similar to that in which it surrounds the labradorites. There is, however, an important difference. When the pyroxenic element is surrounded by the orthoclastic the former is uniformly and deeply changed, and converted into chlorite, magnetite, quartz, while the labradorites have usually maintained their forms and chemical integrity. The formation of the orthoclase and the quartz seems to have been consequent, or at least coincident, with the demolition of some of the pyroxene grains. In these sections there is no evidence of the mechanical intermixture of any of the foreign (acidic) elements from the clastic strata, but only of such chemical transformations as the near proximity of such minerals under pressure, heat and moisture may have promoted. This transformation took place, of course, during the cooling period. It may not be inferred that the change in the pyroxenes was due to the action of these acidic transfusions, because similar changes, except the introduction of quartz, took place in the same mineral where it was not subjected to such influence. It is only allowable to infer that the cooling period was the date of activity of both agents of change, and that they combined in No. 5, and added quartz and orthoclase to the usual products.

Magnetite is of two dates, as in No. 1C. By far the larger portion, however, is of secondary (cooling stage) date, and has taken the shape of the original pyroxene or of a glassy residue. See figure 4.

FIG. 4. SECONDARY MAGNETITE FROM NO. 5.
The included grains are of clear feldspar.

Figure 4 is a reproduction of a drawing of a part of a mass of magnetite in No. 5, made by the use of the camera lucida. It shows the form which the magnetite sometimes presents. A fracture line in the section separates this from another portion of the same grain of magnetite, the latter showing similar outlines and inclusions, though not so large as this. The included parts are bright feldspar, which also surrounds the whole mass, there being no augite in contact with it unless it be represented by chlorite scales, which are seen about the larger end. The smooth rounded outline of the border, and the general absence of pyroxene and its residue suggest that this may have taken the place of some of the uncrystallized magma, yet its ophitic relation to the feldspar is more like that of pyroxene.

Apatite appears in the midst of the red feldspar, probably not of original crystallization, but a result of change consequent on mineralization after the protrusion of the molten mass, during the cooling stage.

Quartz is not abundant, but is in sizable grains. They are uniformly in the midst of the altered portions of the other minerals, or associated with the red feldspar.

Four sections examined.

Meg. Cabotian eruptives of the Taconic.

Remarks. This rock is thought to represent the intermingling of the basic (gabbro or diabase) magma with the material of the red granites (Nos. 1B and 3). The question of the intermingling of these two magmas will be discussed in Part III.

This rock has been called "orthoclase gabbro." The location of the bare knob from which the samples were derived was favorable for the collection of samples by all visitors arriving by railroad from St. Paul. It consequently has been described by several petrographers, and has been considered the type of the Duluth gabbro. Unfortunately Irving fell into this error. At the same time the "hornblende gabbro" of Streng and Kloos seems to be a phase of the same rock, the pyroxene element being replaced largely or wholly by secondary hornblende. Both phases are due to the transformations attendant on the long cooling time, when in contact with the clastics of the Animikie or older rocks. No. 5 is the same rock as No. 1797, and the same as No. 13 of the Minnesota rocks collected by Prof. A. Lacroix in 1888, preserved at the College de France, Paris. No. 5 is also very similar to No. 53B. N. H. W.

No. 6. Diabase.

Duluth. From near the bay in front of the site of the old "Clark house," east of the Spalding hotel, now covered by buildings and by grading. No. 43 is probably the equivalent of this. By the lake the rock had the appearance of being a wide dike, but No. 43 spreads widely, more in the manner of a general massive.

Ref. Annual Report, ix, pages 12, 18, 19; Annual Report, x, pages 41, 141; Bulletin ii, page 110; American Association for the Advancement of Science, vol. xxx, page 165.

Compare Nos. 8, 43 and 53.

Meg. Medium grained, gray, homogeneous, resembling No. 1C or a fine-grained condition of No. 1.

Mic. The thin section is much like that of No. 1C, but with less magnetite and with a little quartz. Labradorite, pyroxene (augite), magnetite are also easily distinguished. Apatite spicules are in the quartz. The presence of quartz and a little coloration (reddish) of some of the feldspar grains indicate the effect of the same agencies during the process of cooling, as alreadv mentioned in describing No. 5, although, in general, in the hand specimens collected, such coloration is not distinguishable. The segregation of the quartz seems to have been shortly preceded by the formation of the apatite spicules, both as secondary products.

One section examined.

Age. Probably Cabotian of the Taconic. N. H. W.

No. 6A. Diabase *(with olivine)*.

Duluth. An extensive outcrop formerly existed beside the railroad. This is probably an equivalent c No. 43, and a phase of No. 6.
Ref. Annual Report, ix, pages 12, 17.

Meg. A dense, rather fine-grained rock, dark gray in color, having the aspec of an ordinary diabase.

Mic. The *feldspar* of the first generation is evident but in fragmentary crystals Apparently the same feldspar has taken part in the second consolidation. At leas the distinction between the first and second crystallizations is so obscure that appar ently the same species grades from one to the other. They are decayed and mucl twinned.

The *olivine* is changed to an almost isotropic substance, with a light green tinge along the cleavages of the original olivine much magnetite is gathered.

Augite, much altered, is greenish, but shows its ophitic relations.

Quartz is sparse, likewise *pyrite*. *Magnetite* is not abundant.

Two sections examined.

Age. Probably Cabotian of the Taconic. N. H. W.

No. 6B. Diabase.

Duluth. In immediate contact with No. 6A. Undistinguishable from No. 6A, of which it is probably portion, but more plainly porphyritic, in thin section, with feldspar.
Ref. Annual Report, ix, page 12.

One section examined.

Age. Probably of the surface Cabotian eruptives. N. H. W.

No. 6C. Diabase. *(Spotted with red, and porphyritic.)*

Duluth. Foot of Lake street. Essentially the same rock as Nos. 6A and 6B. It is, however, spotted wit irregular small areas which apparently consist largely of orthoclase and pyrite. The red color faintly pervade the entire specimen. Microchemical test for potassium made on the red substance gave large cubes of fluosil cate of potassium; also, many crystals indicating lime and soda. The whole rock is finely porphyritic with plagioclase. The red spottedness should not be mistaken for an amygdaloidal structure. The red areas are c another rock and are foreign inclusions in the basic eruptive.
Ref. Annual Report, ix, pages 12, 18.

Age. Probably Cabotian. N. H. W.

No. 7. Diabase (?)

Duluth. Between Second and Third avenues, close to the water. Underlies immediately No. 7A. Di E. 18°.
Compare No. 42.
Ref. Annual Report, ix, pages 12, 18; Annual Report, xiii, pages 100, 102; Annual Report, x, pages 63, 10 140; Bulletin viii, pages xxx, xxxiii; American Association for the Advancement of Science, vol. xxx, page 163.

Meg. A dull, brownish, compact rock of fine grain. Composed of small crystal of reddish feldspar in a darker, very fine-grained groundmass. A very few porphy ritic red feldspars are present; these are not more than five millimeters in lengtl One of them is a simple twin. There are two cavities in the specimen which ar now filled by quartz, with sometimes a little epidote along the edges; possibly these represent amygdaloidal cavities.

Mic. The section shows small, crowded, lath-shaped feldspars in a rather sparse groundmass of alteration products. The feldspar is much altered and reddened; many of the crystals show traces of twinning striæ. Their exact nature cannot be determined, but from the analysis of the whole rock given below, it is probable that this mineral would fall in the labradorite series. These feldspars are from .25 to .75 millimeters in length. The section contains none of the rare porphyritic crystals. The groundmass is clearly secondary and is a confused aggregate of quartz, magnetite, chlorite, calcite and muscovite. What the original nature of this groundmass was is uncertain. It may have been principally augite (and the rock is a fine-grained diabase), or possibly the finely crystalline groundmass of a porphyryte, or even glassy material. Apatite needles are rather common. There is no indication of what the original ferro-magnesian mineral of the rock was, and there are no areas now filled with alteration products, which might represent porphyritic crystals of pyroxene or hornblende.

*Chemical analysis.** The following analysis of this rock was made by Prof. C. F. Sidener and was published in the Thirteenth Annual Report, page 100 (chemical series 149), and in Bulletin viii, page xxxiii:

SiO_2	53.71
Al_2O_3	14.96
Fe_2O_3	14.45
FeO	3.65
CaO	3.35
MgO	4.59
K_2O	0.56
Na_2O	1.40
H_2O	1.60
	98.27

From the data now available this rock can be regarded as most probably an altered fine-grained diabase.

Age. Probably Cabotian. U. S. G.

Remarks. This rock has to be removed from the category of the "red rocks" with which it has been classed in an earlier description.† Its color and the presence of quartz were the characters that led to that classification, but its crystalline feldspars, which seem to prove original complete fusion, and its rather low percentage of silica, seem to preclude its origination from the acid source which gave rise to the most of those rocks. If, however, the red rocks as a group are referable to the fusion of clastic rocks it is necessary to admit that various degrees of acidity and different stages of crystallization must have been the result. The rock is massive, dense and clean, and has the appearance outwardly of having preserved its characters as well as most of the massive rocks of the region. Hence it is allowable, still, to suggest

**Ninth Annual Report*, p. 12, 1881.

†*American Association for the Advancement of Science*, vol. xxx, p. 163, 1882.

that this may be one of the varied results of the action of the basic eruptives on the varied nature of the clastics with which they came into contact; although it is more likely to have originated from a quickly cooled basic magma which at first took the character largely of zirkelyte, a name applied by Wadsworth to a microlite-charged basic glass in such conditions, afterwards partially or wholly devitrified. (Bulletin ii, Minnesota Survey, page 30.) N. H. W.

No. 7A. Amygdaloid.

Duluth. Apparently overlies No. 7.
Ref. Annual Report, ix, pages 12, 17.

Meg. Nearly black, amygdaloidal, at least with cavities nearly or wholly filled with segregated minerals. The most conspicuous of these secondary minerals is yellowish green, resembling epidote; another is dark green, and appears in the form of radiated coatings, and resembles delessite. Pyrite also is sparse. The structure is very fine, but somewhat irregular and globular.

Mic. This rock is like the last in its essential characters. In some places the section appears reddish, by reason of the abundance of the red feldspars. In others it is porphyritic with fine feldspathic *microlites*. But the whole rock is much decayed, and is seamed by irregular transparent veins and threads, which consist largely of *quartz*.

One section examined.

Age. Probably of the Cabotian eruptives of the Taconic. N. H. W.

No. 7B. Tuff (?)

Duluth. This rock is wrought, or was in 1878, in the alley between First and Superior streets, and Fourth and Fifth avenues east.
Ref. Annual Report, ix, page 12.

Meg. This rock is brownish, but spotted with greenish amygdules and with inclusions of some foreign rock. This foreign rock is of a dun color, rather compact but appears itself like a fragmental rock. On weathered surfaces it is pitted from the oxidation of pyrite. These foreign pieces vary from the size of a pea, or perhaps a pinhead, to about two inches in diameter, which is about the size of a mass attached to the museum sample preserved. They are scattered heterogeneously in the amygdaloidal portion of the rock.

Mic. A section of the matrix which embraces the foreign pieces shows a much decayed condition. There are reddish *feldspars* which come from the first epoch of consolidation, some of them plainly twinned polysynthetically. They are charged with alteration products, such as *epidote, pennine, pyrite, hematite (?) magnetite,* and apparently *zircon*, although these minerals are not always arranged so as to prove they are included in areas formerly occupied by feldspars. They, indeed, fill up the space not plainly embraced within the feldspars. There is no remaining evidence of the nature of the other original minerals.

A better section, made by Marchand, shows distinctly a tuffaceous nature. There is a portion of the microlitic magma, composed of spicules of *plagioclase* surrounded by devitrified *glass*, now greenish, and a portion made up of a minutely fragmental rock, which, between crossed nicols, is nearly dark, but plainly contains numerous angular *quartzes*. In the former are large translucent areas which are contrasted with the dark surrounding rock, and in these areas is seen much of a finely granular gray mineral, having high refraction and also high double refraction, which probably is *epidote*. This mineral is associated with much quartz in these areas, and also is disseminated throughout the rest of the rock in more minute particles.

Two sections.

Age. Cabotian.

Remark. This marks the first discovery of tuffaceous rock in the series that has been called Cupriferous, in the lake Superior region. It appears by the following descriptions that volcanic tuff is not an uncommon substance in the region of Duluth, and at points further east. N. H. W.

The following criteria for the recognition of ancient volcanic rocks have been given by Dr. George H. Williams (Journal of Geology, ii, page 10):

Criteria for the recognition of ancient volcanic rocks.

It is a self-evident proposition that the identification of certain rocks as volcanic products is in no way dependent upon their present association with a recognizable crater or volcanic mountain. By volcanic rocks we understand igneous or pyroclastic material which has solidified or been deposited at or very near the earth's surface. It is of little moment whether or not it was ever piled into conical mountains. That the rocks themselves bear witness to their origin and conditions of formation is sufficient. The successive effects of erosion on the easily removed volcanic mountains has often been so graphically described* that no further reference to the subject is here necessary. If the Eocene or Triassic volcanoes have so disappeared as to leave only traces of their original forms, what may we expect of those of Paleozoic or Archean times?

On the other hand, the association in dissected volcanic regions of the effusive rocks with correspondingly abyssal types naturally suggests that volcanoes may have once surmounted many areas of coarsely granular ancient igneous rocks. As this, however, cannot be proved, only such regions are here considered as yield rocks of unmistakably surface origin.

Again, ancient volcanic rocks may have been subjected to metamorphosing processes severe enough to have destroyed most of their original characters. In such cases, patient study and a careful weighing of all evidence is necessary to decide their origin, and even that may not avail. Igneous rocks may be so altered as to be indistinguishable from metamorphosed sediments, but in many cases where this at first appears to be the fact, some decisive clue may be discovered.

In establishing the volcanic nature of rocks occurring in ancient and more or less crystalline terranes, attention must be given to several different sets of characters. The field relations must be carefully studied and the material collected on the spot and afterward studied in the laboratory. The criteria for deciding on their igneous and volcanic origin may be arranged as follows:

I. If the rocks are igneous, whether abyssal or surface, they will:

1. Conform in chemical composition to certain well established types.

2. Show an association of petrographical types which, both chemically and mineralogically, follow the laws of consanguinity.

II. If they are volcanic:

1. They may be found in the field to occur in distinct sheets, flows or necks.

2. They will have produced little or no contact action in the adjoining rocks.

*See De La Beche: *Geological Observer*, pp. 526-537, 1851. M. Neumayer: *Erdgeschichte*, vol. i, pp. 202-204, 1887. W. M. Davis: "The Lost Volcanoes of Connecticut." *Popular Science Monthly*, December, 1891.

3. They may include irregular fragments of other rocks.

III. If they are volcanic:

1. They may appear to be striped, banded, or pseudo-"stratified" conformably to adjoining sedimentary deposits.

2. They will probably be accompanied by fragmental (pyroclastic) material, which may or may not itself be really stratified. Such material will vary greatly in coarseness, containing bombs, agglomerates, breccias, tuffs, sands and ashes. The characteristics of these are: (1) Indiscriminate mixture of all sizes and shapes of fragments; (2) Material of same kind as the igneous rocks; (3) Cement, either finer fragmental material (tuff-breccia) or lava (flow-breccia); (4) Very angular shape of smallest fragments (microscopic glass shreds); (5) If ancient volcanoes were on the shore line, such material may have been immediately worked over by water and interbedded with more or less normal aqueous sediments.

IV. Most important of all, however, is the identification of those characteristic structures known to originate only in glassy, half-glassy, or very fine grained porphyritic rocks, solidifying at the surface, or in very narrow dikes where solidification has been rapid. These will be found to be very persistent and can usually be identified under the microscope in spite of devitrification, alteration or even a considerable degree of dynamo-metamorphism. The most common of these structures are:

1. A vesicular, scoriaceous, pumiceous or amygdaloidal structure.
2. A sharply defined, small porphyritic structure with a glassy, half-glassy or felsitic (cryptocrystalline) base.
3. A spherulitic structure, due to either large or small lithophysae, hollow spherulites, or compact-spherulites, arranged either irregularly, or in more or less discontinuous bands or layers.
4. A flow structure, produced either by the elongation of vesicles or the parallel arrangement of constituents or crystallites. It may also be produced by the interlacing of different colored magmas (eutaxitic structure).
5. Corroded phenocrysts, quartz, with embayments, or skeleton crystals due to rapid or imperfect growth.
6. Microscopic spherulites, globulites, trichites, crystallites, real or devitrified glass inclusions, quartz with orientated siliceous aureoles, axiolites, etc.
7. Perlitic structure, wholly or partly devitrified.

Although some of these structures may occasionally occur in dikes or other igneous rocks which have rapidly solidified beneath the surface they are nevertheless so essentially characteristic of effusive lavas, that, in lack of any evidence to the contrary, they may be regarded as fairly safe guides in establishng the effusive nature of rocks. This evidence is beyond doubt, if such rocks are accompanied, as they generally are, by ash material.

While a single one of these characteristics may not be sufficient to identify a volcanic occurrence, many, if not all of them, will be found to occur together, and only in rare instances will it be found that some of them, at least, have not survived the vicissitudes of metamorphism.

No. 7C. Diabase *(with olivine)*.

Duluth. From a dike in contact with No. 7A, equivalent to No. 47, roughly in line of bearing with No. 6. Compare No. 47.

Ref. Annual Report, ix, pages 12, 18, 19.

Meg. A dark gray diabasic rock of medium grain, ophitic, considerably decayed, and with the feldspars about the only mineral that is fresh.

Mic. The structure is distinctly ophitic, and the constituents are plagioclase, augite, magnetite and alteration products. The plagioclase is rather fresh. A series of ten sections of the *feldspar* measured for greatest equal angle of extinction on opposite sides of the twinning line, gave 29½° and 30°. According to the "épures" of Michel Lévy, this might indicate either a *labradorite* (Ab_3An_4) near *bytownite*, or anorthite. Since, however, an optic axis is also found to pierce the section just outside the area of the microscopic field, the feldspar is certainly near labrador-bytownite. In another section of the same feldspar the bisectrix (n_p) appears in the centre of the field, with distinct black cross and shifting hyperbolas. This grain, however, being encroached on all sides by surrounding grains, no crystallographic character was afforded for measuring the angle of the axial plane, except on an imperfect cleavage trace. This gave an extinction angle of 59½° to 60°, which also indicates, so far as it is of value, a labradorite, or labrador-bytownite.

It is evident by the partial darkening of the lamellæ that this rock has been subjected to strain and slight distortion. The feldspar in this dike was earlier to solidify than the pyroxene.

The *pyroxene* is, in general, much decayed by the formation of the usual greenish chloritic substance, but some of it is entirely free from it. When thus altered the pyroxene is accompanied by the usual appearance of *magnetite*, which presents a hackly metallic surface in reflected light, and is easily identifiable on turning away the mirror below the stage. There are many areas in the section that were once very probably occupied by *olivine*, though none of this mineral is now present. These areas are filled largely by sepentine (?), and the peculiar net-like structure, so common in altered olivines, is well shown. Frequently the dark threads of the net-work have on either side a narrow strip of a rather brightly polarizing mineral. This shows a cleavage running at right angles to the thread, and is distinctly pleochroic, the ray vibrating parallel to the cleavage being greenish, and that at right angles to it straw yellow. The extinction is nearly parallel. A similar mineral is found in small areas elsewhere in the altered olivines; it is probably hornblende.

One section examined.

Age. Perhaps Manitou. It is also possible that this is a dike of Cabotian age, which supplied the magma of the supposed sill Nos. 44′, 41 and 43.

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

No. 7BC. Porphyryte.

Duluth. Contact rock between Nos. 7B and 7C.
Ref. Annual Report, ix, page 12.

Meg. A dark gray to purplish, porphyritic rock. The groundmass is very fine-grained, and its components cannot be determined macroscopically. The porphyritic crystals are feldspars of all sizes up to ten millimeters in length; these are scattered regularly and plentifully throughout the rock. They are light gray to reddish in color, being the latter color more especially where exposed the most to weathering. A little pyrite is visible.

Mic. The most noticeable feature of the section is the presence of numerous sharply defined, large *plagioclase* phenocrysts. These are frequently abundantly twinned. Small areas of *chlorite* and of *epidote* are not uncommon in these feldspars. The porphyritic crystals are imbedded in a groundmass of very fine grain, conspicuous in which are numerous lath-shaped feldspars two- to three-tenths millimeter in length. Besides these the groundmass is composed of a rather confused aggregate of *magnetite*, green *hornblende*, chlorite, epidote, minute *apatite* needles and a weakly polarizing interstitial substance that may be feldspar or quartz. The chlorite and epidote are secondary, as are also probably the hornblende and part of the magnetite. It is possible, however, that the hornblende is original, and that, with the exception of the epidote and chlorite, the groundmass is now not much altered from the condition in which it solidified; in such case the rock might be called a dioryte porphyryte, and it is similar to some of the rocks described by Iddings, from the Yellowstone National park.* It, however, seems more probable that the groundmass is considerably altered from its original condition, which might have been an aggregate of lath-shaped plagioclase (still remaining) and augite, making the rock a diabase porphyryte, to which species it is here provisionally referred. U. S. G.

Age. Perhaps Cabotian.

Remark. This rock seems to be from a series of very old eruptives, which at Duluth and elsewhere are cut by a series of later dikes, and are associated with the red rock series. N. H. W.

No. 7D. Diabase.

Duluth. From a dike near the lake running toward Minnesota point, and apparently extending under the point.

Ref. Annual Report, ix, page 12.

Meg. A fine-grained, dark greenish ophitic diabase.

Mic. The *feldspar* preceded the pyroxenic element in date of crystallization. It is uniformly lath-shaped, with more or less tapering extremities, and is less affected by later alteration than the pyroxenes. It composes about three-fourths of the entire rock.

The *pyroxene* is almost entirely altered to a greenish chloritic mineral, with simultaneous generation of much *magnetite,* there being only a few remnants which yet polarize distinctly. The alteration product, aside from the magnetite, consists of a confused mesh of chloritic shreds that overlap each other and give a characteristic felted polarization between crossed nicols. So far as can be seen, the magnetite is entirely of secondary date, taking position in the interstices of the original pyroxenes, and occasionally developing also their forms. The relation of the pyroxene to the earlier feldspar, areally, is that of a mosaic, rather than of ophitic structure. The forms of these minerals are not perfected, the feldspar because of the interference of many cotemporary growths, resulting in a crowded crystalline mass, the latter because of the later generation which allowed them only the interstices between the feldspars for a field in which to develop.

The magnetite and chlorite very probably originated during the cooling stage of the rock (see Part III).

Age. Perhaps Manitou. N. H. W.

* *Twelfth Annual Report U. S. Geol. Survey,* pp. 569-664, 1891.

No. 8. Porphyryte. *(Amygdaloidal.)*

Duluth. Separated near the wall of contact of No. 6.

Ref. Annual Report, ix, pages 12, 13. Annual Report, x, page 140. American Association for the Advancement of Science, vol. xxx, page 164.

Meg. Dense, dark colored, with indistinct small porphyritic feldspars, and in some places amygdaloidal cavities filled apparently with chlorite, or chlorite and quartz.

Mic. The prevailing mineral is a lath-shaped *feldspar* of a brownish red color, apparently one of the first of the minerals to solidify.

Pyroxenic element is not discoverable, as such, but its former presence is indicated by chlorite, and by magnetite. The latter is in numerous cubic and irregular forms, which are seen within the fine quartzes distributed in the body of the section.

The amygdaloidal spaces are occupied sometimes by chloritic substance, and sometimes by quartz, and often by both in more or less zonal arrangement.

Pyrite is occasionally seen in the borders of the amygdules.

Age. Probably Cabotian.

One section examined. N. H. W.

Remarks. Another form, also numbered 8, is much less amygdaloidal, and more porphyritic. It is very fine grained, compact and varies in color from dull black to dark brown. None of the constituents of the mass of the rock can be distinguished. Where the color is black the rock is homogeneous, but as the color becomes brownish numerous rather indistinct small dark blotches are seen. A few irregular areas of reddish feldspar occur; one of these is three-eighths of an inch across. There are also a few larger areas where the rock is colored reddish; in the centre of these areas is often a yellowish substance, probably epidote. One of these areas, or large blotches, is seen to have a centre of yellow material, outside of which is a distinct narrow black band; and beyond this is a red band, which passes into the general color of the rock. The black portion of the hand specimen closely resembles, macroscopically, some of the black flinty slates of the Animikie.

Still other forms of this rock are sparsely porphyritic with a feldspar which has a tendency to become red. Compare Part III. U. S. G.

No. 8A. Tuff. *(Inclusion in No. 8.)*

Ref. Annual Report, ix, page 12. Annual Report, x, page 140. American Association for the Advancement of Science, vol. xxx, page 163. American Geologist, vol. xviii, pages 211-213.

This is similar in all respects to the fine rock seen in No. 7B, as foreign inclusions. It is nearly totally dark between nicols, but shows numerous fine angular quartz grains. With one nicol and the condenser lowered, a varied structure comes out to view. It is difficult to describe it. The glassy grains, charged with inclusions, are sometimes brown and sometimes light green. Some *epidote* is distinguishable by its high refractive power; and large areas are separable from the rest by reason of a greater darkness, or by a curly, minute, somewhat crescentic structure which embraces the translucent and greenish grains, the crescentic areas themselves being most translucent.

One section examined.

Age. Cabotian. N. H. W.

No. 8B. Tuff (?)

Duluth. At the lake shore near the base of Minnesota point (the spot is now hid by the growth of the city). *Ref.* Annual Report, ix, pages 12, 13. Annual Report, x, page 140. American Association for the Advancement of Science, vol. xxx, page 164.

Meg. This is a light colored rock with disseminated red feldspar crystals, having the aspect of a porphyry. A light greenish yellow mineral, probably epidote, more or less pervades the rock, this being the principal cause of the light colored aspect. The rock effervesces freely with dilute hydrochloric acid. The feldspar crystals are polysynthetically twinned, and the rock has in places a roughly amygdaloidal structure. This structure, however, is not sufficiently prevalent and characteristic to indicate that the rock en masse was ever in the form of a surface flow. The matrix of the feldspar crystals is confused and made up of various minerals that result frequently from the alteration of the minerals of original basic rocks.

Mic. The rock is much altered. The *feldspar* is charged with ferruginous impurities. A series of ten statistical measurements of the extinction angle on opposite sides of the twinning line gave the following figures: 9°, 9°; 19°, 4°; 9°, 11½°; 10°, 8°; 11½°, 6°; 18°, 5°; 5°, 15°; 10°, 1°; 10, 18°; 8½°, 20°.

If the first measurement (9°, 9°) be taken as the maximum equal extinction, according to the spherical projections of Michel Lévy (Det. des Feldspaths, plate 1) the feldspar is *albite*, but owing to its greatly decayed condition this result is not beyond doubt, while the effervescence, indicating calcite, seems to require the presence of a ready source for considerable lime.

No *pyroxene* element can be detected, nor indication of its earlier existence. The angular spaces which are sometimes surrounded by the feldspars may have been occupied originally by a pyroxene which has now been changed, but at the same time there may have been a variety of minerals so included between the feldspars, or even tufa pulp, or a glass, the time elapsed having been sufficient to change either of these into the matrix that now exists.

Quartz is common, but not as a pegmatitic intergrowth in the feldspar. It is sometimes in angular grains, isolated and irregular, and it sometimes embraces portions of the surrounding chlorite and other minerals. It is also in nests resulting from secretion from the rock, and then presents a multiple or aggregate polarization.

Chlorite is abundant, and sometimes its color between the nicols is blue, indicating *pennine*. It constitutes independent angular masses, as if it had resulted from alteration of some allotriomorphic mineral. In small flakes it is distributed generally throughout the rock.

Magnetite occurs in the same manner as the chlorite and is equally abundant.

There may be other minerals in this rock, besides *calcite*, but the section made is not favorable for their determination.

One section examined.

Age. Cabotian.

Remark. When collected this rock was supposed to have resulted from metamorphism of clastic material, through the action of eruptive rock in the vicinity. But the feldspar proves to be twinned, like a plagioclase, and the structure suggests that the feldspars may have once been embraced by crystals of augite or by zirkelyte. While resulting in part apparently from cooling from fusion, and subsequent alteration, this rock, as a whole, may still have been composed of fragmental volcanic ris, or it may have *resulted* from fusion of the clastics at the point of contact of rocks of the gabbro series, since the ophitic structure is not unquestionable.

N. H. W.

No. 8C. Diabase. *(Fine.)*

Duluth. From a dike in No. 8.
Ref. Annual Report, ix, page 13. Annual Report, x, page 140. American Association for the Advancement of Science, vol. xxx, page 164.

Age. A very fine grained, compact, black to brownish, diabasic rock.

Meg. The rock is composed of minute lath-shaped feldspars in a more or less confused groundmass, which is largely stained to a brownish color. Aside from the feldspars the rock is made up quite largely of magnetite, which occurs in very minute grains, in irregular and often ill defined areas, and in needle-like forms. The rest of the groundmass is quite fine grained and seems to contain chlorite, calcite and probably some little quartz and muscovite. The groundmass appears to be all secondary, except possibly some of the magnetite, but what its original nature was is uncertain. The rock is here called provisionally a diabase, but it may have been a basalt, *i. e.*, its groundmass may have been of the nature of zirkelite.

One section examined.

Age. Probably a Manitou eruptive. U. S. G.

No. 9. Porphyryte. *(Amygdaloidal.)*

Duluth. Not far from the base of Minnesota point.
Ref. Annual Report, ix, page 13.

Meg. The rock is dark brown in color, presenting a dark aphanitic groundmass in which are reddish brown porphyritic crystals of striated feldspar and amygdules. These amygdules are filled with a yellow mineral *epidote* and a dark mineral *chlorite*. Some of the amygdules contain only one of these minerals, while others contain both. In the latter case the epidote forms a narrow rim around the outside of the cavity, and within this is usually chlorite, or sometimes chlorite and epidote. At times inside of the rim of epidote is another thin layer of chlorite, and inside of this a mass of epidote.

Mic. Under the microscope the rock is seen to be decidedly altered. The porphyritic *feldspars*, on account of their changed condition and the general reddened appearance of the whole section, are sometimes not sharply separated from the groundmass of the rock, when viewed in ordinary light; but in polarized light, they are distinct. They are plagioclase, but their exact place in the series was not determined. The phenocrysts are replaced more or less completely by epidote, and this epidotization of the feldspars is a marked feature of the section.

The *amygdules*, as stated above, are filled with epidote and chlorite. The former is in a finely granular condition, while the epidote of the feldspar phenocrysts is in crystalline grains of some size. The chlorite of the amygdules is more characteristic than the chlorite of many of the rocks here described in its marked pleochroism and in the fact that it furnishes a beautiful example of the dark blue interference colors of this mineral.

The *groundmass* of the rock is composed chiefly of minute lath-shaped plagioclases. These are closely matted together and fill up nearly the whole section. The little space in the groundmass not occupied by these feldspars is filled with a confused, fine grained mass of chlorite, epidote, magnetite and apparently a little quartz. In fact, these minerals are scattered throughout the section, and are clearly secondary. The original nature of the groundmass aside from the feldspar is uncertain. The rock is provisionally called a diabase porphyryte, although it is not improbable that it was more in the nature of a trachyte.

Two sections. Only one, however, was examined, as the other is an inferior section, and there is some doubt about its being correctly labeled.

Age. Probably a Cabotian eruptive. U. S. G.

No. 10. Porphyryte. *(Amygdaloidal.)*

Duluth. Overlies No. 11.
Ref. Annual Report, ix, page 13.

Meg. This rock closely resembles No. 9, except that its color is reddish. It has the same porphyritic feldspars and amygdules filled with *epidote* and *chlorite*. The epidote, however, is much more abundant than the chlorite.

No section.

Age. Cabotian eruptive. U. S. G.

No. 11. Porphyryte. *(Diabase.)*

Duluth. East of the elevator; extends along the shore about 800 feet.
Ref. Annual Report, ix, page 13.

Meg. The groundmass of the rock is dark brown to black in color, is aphanitic, and is thickly strewn with reddish porphyritic feldspars. Blotches of epidote are scattered through the rock, and there are spots of epidote and chlorite which perhaps represent amygdules, although it seems most probable that there are no true amygdules and that the rock is one of the pseud-amygdaloids described by Pumpelly and Irving.

Mic. The most prominent feature of the section is the sharply defined *plagioclase* phenocrysts. They have been more or less altered to a micaceous mineral, and sometimes to *epidote.* The groundmass is composed of small interlacing plagioclase laths, much *magnetite,* with *hornblende, chlorite, epidote* and perhaps a little *quartz.* With the exception of the feldspar, and possibly some of the magnetite, all these minerals are secondary. The hornblende is in small grains, usually fibrous, and occurs in the interstices between the feldspars. It evidently is an alteration product from augite, and in places part of the original augite is questionably present. Small *apatite* needles are rather common.

One section examined. U. S. G.

Age. Cabotian.

Remarks. This rock is very similar to Nos. 7BC and 9. While none of these certainly show augite in the groundmass, there still seems good reason to assume that it was there originally, and so the rocks are called diabase porphyrytes.

"No. 11 is mainly a massive, homogeneous rock, but in some places finely jointed, so that under the weather it parts into numerous angular blocks. In it are veins (near its eastern extension) that seem to cause a greater abundance of the red feldspar crystals in the mass of rock adjoining on either side; * * *"† U. S. G.

No. 11A. Calcite and Epidote.

Duluth. From a vein in No. 11.
Ref. Annual Report, ix, page 13.

Meg. The calcite and epidote are arranged in rough bands, from one-eighth to one-half inch wide. Some reddish material is mixed with the epidote.

No section.

Age. In the Cabotian porphyryte. U. S. G.

No. 11B. Geode.

Duluth. From No. 11, which extends about 800 feet along the shore. Some geodes are several feet in diameter, and are rather layers than geodes.
Ref. Annual Report, ix, page 13.

† *Ninth Annual Report,* p. 13.

Meg. The minerals in the specimen are promiscuously arranged, and seem have been deposited secondarily in a porous rock, much of which has been chang into these minerals. The rock is spotted coarsely with white (calcite and quartz green and yellow (chlorite, epidote) and red (which is perhaps orthoclastic). The are also considerable areas of a gray or dun-colored aphanitic rock, not so durable the red mineral.

Mic. The foregoing named minerals all appear in the slide. The red miner appears in the prepared slide as an irregularly disseminated reddish powder, scatter sometimes abundantly, but without crystalline form. Some of its crystalline grair taken from other parts of the specimen, subjected to hydrofluosilicic acid, gi crystallites of potassium fluosilicate, large and abundant, with some of lime, b none evident of soda, thus proving the *orthoclastic* character of the feldspar.

In another part of the slide a portion of the original rock is seen. It is fine sprinkled with slender microlites of a *feldspar* that is lath-shaped, but tapering the extremities. In immediate connection with this are also a number of lar *apatites*, showing their characteristic transverse fissuring. The great thickness the section is shown by the fact that these apatites gave colors of double refractio viz.: yellow and red. The slide must therefore have a thickness of about . millimeters, according to the scale of Newton's colors, given by Lévy and Lacroix

One section examined. N. H. W.

No. 12. Porphyryte. *(Amygdaloidal.)*

Duluth. Extending forty-nine paces along the lake shore, east of No. 11.
Ref. Annual Report, ix, page 13.

Meg. A brown amygdaloid, containing numerous porphyritic plagioclases. Tl amygdules are filled with epidote, chlorite and quartz.

Mic. Essentially the same as Nos. 7BC, 9 and 11, except in two particula First, the feldspars are in part replaced by chlorite, and second, the lath-shape plagioclases of the groundmass are fewer in number.

One section examined.

Age. Cabotian. U. S. G.

No. 12A. Quartz. *(Nodule.)*

Duluth. A large nodule from No. 12.
Ref. Annual Report, ix, page 13.

Meg. The quartz is white and grayish, having a fibrous structure that radiat from a centre, but a coarse banding somewhat agate-like, but without coloration. I radiated and banded structure shows the continued growth of crystals from a comm point, with some variations in the environment. The central nucleus of the mas

* *Minéraux des Roches* (plate).

or of the masses, since there are several nuclei, is sometimes seen to be a knot of finely granular or cherty quartz. The elongated fibres are quartzine, being positive.

N. H. W.

No. 13. Aporhyolyte.

Duluth. Near midway between Minnesota point and Chester creek, at the lake shore.* Extends fifty-four paces.
Ref. Annual Report, ix, pages 13, 14.

Meg. A fine grained brownish rock, in which the only identifiable mineral is a minute lath-shaped plagioclase whose cleavage affords a reflecting surface visible under the loop. The rock breaks with a conchoidal fracture, and outwardly, in the field, it weathers into a laminated or slaty structure which dips east 15°. In other places it is a lumpy amygdaloid with epidotic spots and veinings. A little pyrite also is visible in the mass of the rock.

Mic. The lath-shaped *feldspars* are usually gray, but some of them are reddened by iron. In reflected light fine metallic particles are visible, both of *magnetite* and of *pyrite.* If the rock ever contained pyroxene, it is wholly changed, for the matrix of the feldspars consists of a fine mass of *chlorite*, *magnetite*, *quartz* and apparently of a little *calcite.*

One section examined.

Age. Cabotian.

Remarks. This seems to be one of a series of rocks, of which several have already been described, viz.: the porphyrytes and diabase porphyrytes, Nos. 7BC, 8, 9, 10. No. 13A is also similar. They may all be considered Cabotian lavas that followed soon after the Beaver Bay diabase. N. H. W.

No. 13A. Diabase Porphyryte (?)

Duluth. Overlies No. 13, being apparently a layer of No. 13.
Ref. Annual Report, ix, pages 13, 14.

Meg. Slightly amygdaloidal and porphyritic, having a brown color and close texture. Except in its disseminated red feldspars, which appear more on one side of the specimen than on the other, this rock is like No. 13.

Mic. The *feldspars* are fine and tubular, striated, much decayed. The intervening groundmass consists of *quartz*, *calcite*, *pennine*, *magnetite*, and an isotropic substance whose nature is unknown. *Epidote* is not abundant, but occurs sparingly.

One section examined.

Age. Cabotian.

* The lake shore east from Minnesota point was formerly rock bound. It was examined carefully, and these specimens were collected when the alternations could easily be noted. Since then buildings have been erected, which, with street grading, have effectually hid all these outcrops. It can only be said that from No. 7D up to No. 36 from the mouth of Kinichigaquag (now Chester) creek, the descriptions apply to rocks occurring between Minnesota point and that creek, all situated within the limits of Duluth. There will probably never be an opportunity to verify the succession. In general these numbers represent the "porphyry-like melaphyr" mentioned by Mr. Kloos.

Remarks. In the hand specimen are visible both varieties of this series of rocks, viz.: the porphyritic, represented by No. 8, and the non-porphyritic, represented by No. 13. They apparently grade into each other, the latter becoming very fine grained, as if from contact on cooler rocks, along one side, and also assuming a darker color. This rock might have the name zirkelyte, on the supposition that the matrix of the feldspars was originally glassy. N. H. W.

No. 13B. Zirkelyte. *(Glassy basalt.)*

Duluth. A layer of No. 13.
Ref. Annual Report, ix, page 13.

Meg. Earthy, amygdaloidal, thin sheeted, green, fine grained.

Mic. The amygdules are largely occupied by *quartz*. The rock, in general, is made up of a confused mixture of very fine crystallites which cannot be separated sufficiently for determination. They seem to have prevailingly a stout and even globular form, often stained by a green viriditic substance which in some places renders the slide dark, even like an isotropic substance between crossed nicols. Quartz is disseminated in these darkened portions of the slide, as well as in the amygdaloidal spaces.

The rock seems to have resulted from devitrification of a glassy amygdaloid, of the basic sort.

Age. Cabotian. N. H. W.

No. 14. Zirkelyte.

Duluth. A dike, breaking through No. 13, running W. 10° N.
Ref. Annual Report, ix, page 13.

Meg. A compact, very fine grained, brownish rock showing minute feldspars.

Mic. The section is composed of small lath-shaped plagioclases in a groundmass of altered material which consists of *magnetite, chlorite, calcite,* and some feldspathic material.

Age. Manitou (?)

Remarks. This rock is very similar to Nos. 13 and 13A, but its occurrence as a dike indicates it is younger than they are. It has no porphyritic feldspars. The matter between the feldspar microlites is semi-isotropic, appearing like a devitrified glass rather more than like a changed augitic mineral. N. H. W. AND U. S. G.

No. 15. Diabase *(with olivine).*

Duluth. A dike fifteen feet wide, running N. 25° W.
Ref. Annual Report, ix, page 14.

Meg. A medium grained, dense, apparently fresh, dark-colored rock glittering with cleavage surfaces of the pyroxene element, and with the striated feldspar, the latter, however, being less conspicuous and acicular in outline.

Mic. The *feldspar* has an average extinction, on 010, on a cleavage, of 25° to 28°. On the face 010, in convergent light a curved dark bar is the only portion of the interference figure that is visible. Most of the grains are in the form of lath-shaped twinnings, elongated parallel to the edge 001: 010; and extinction is not coincident on all portions of the separate lamellæ. This indicates some deformation since consolidation. By the statistical method the highest equal extinction angle on opposite sides of a line separating two twins is found to be 19°. This result agrees with the foregoing measurement on the cleavage in indicating labradorite, although the measurement on the cleavages seen in 010 seems to show a tendency toward bytownite.

After some search, some sections of this feldspar can be found showing, in convergent light, optic axes and bisectrixes. In the latter case, in two instances, it proves to be n_g ($\mathfrak{c}$) in one case not in connection with distinct cleavage, but in another on a face showing evident cleavages parallel with the striations, indicating that the section is nearly on 010. It is therefore the positive bisectrix appearing somewhat obliquely in the brachypinacoid, which is characteristic of the labradorites and bytown-labradorites. Many of the microlites are crossed nearly at right angles by a pericline twinning.

The *pyroxene* was later in crystallization than the feldspar, and embraces the feldspar. It extinguishes over considerable areas, often involving several detached parts. It is quite fresh, in some grains. The optic plane makes an angle of 4° to 5° with a distinct cleavage, and with a coarse parting an angle of about 40°. These measurements are made on the straightened dark bar crossing the interference figure of a single optic axis. On this figure, in blue light, the curved dark hyperbola is further dispersed than the same in red light, hence the red color lines the concave side, indicating, for this axis $\rho < v$, but as the dispersion in the monoclinic pyroxenes is inclined, these colors may be reversed in the interference figure, in the manner of their position on the hyperbolas.

After some search a small crystal of the augite is found perpendicular to a bisectrix. Its form is roughly that of a prismatic section, with a cleavage that nearly agrees with the position of extinction. This cleavage must therefore be that parallel to the brachypinacoid. Other cracks cannot be identified with certainty with any cleavage. In other sections nearly rectangular cleavages are frequent. The optic axes are carried beyond the field of the microscope, and are not brought within it by the use of methyl iodide as immersion liquid. This bisectrix is n_g ($\mathfrak{c}$), as shown by the use of the *teinte sensible.*

The *olivine* is almost entirely changed. The change consists in the formation of both serpentinous fibres and a great many minute crystallites of quartz, and calcite and of a ferruginous dark substance that may be magnetite. The olivines thus changed show their nature sometimes by the remnants left of the original grains, and nearly always by their relation to the feldspars, which they preceded in origination. Although the changed olivine resembles somewhat the product of change from augite, these two are frequently alongside of each other without interpenetration. The figure below (figure 5), illustrates the different aspects of the augite and the olivine. It was drawn from No. 15 by camera lucida and shows the parts all magnified about seventy-five diameters. The changed mineral (olivine) is frequently closely associated with the unchanged (augite) in so much that in some instances, either by superposition or by some corresponding alteration in the augite, there is difficulty in separating them at a definite boundary. They both enclose irregular grains of magnetite. The olivines, however, crowd upon and indent the feldspars, though their forms are never perfect, while the augites, being later than both, are interrupted by their contours.

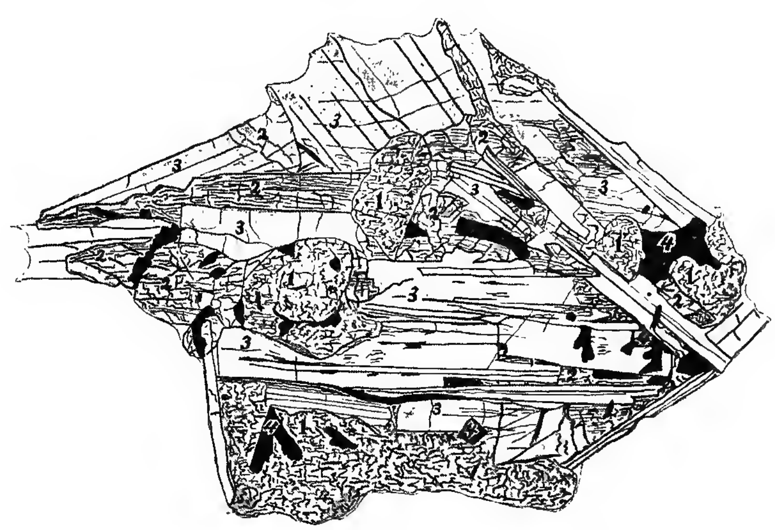

FIG. 5.

No. 1—Olivine. No. 2—Augite. No. 3—Labradorite. No. 4—Magnetite.

Magnetite is in all forms, especially in angular to subangular sections, sometimes almost square, and in rods. These rods are sometimes between two minerals, or between cleavages, but they are also often sections of tabular sheets of magnetite. The largest amount of magnetite is within the decayed olivines.

One section examined.

Age. Manitou (?)

Remarks. This rock is noticeably contrasted with the eruptives which it cuts, in two respects: (1) It is not porphyritic nor amygdaloidal, but has a uniform granular structure. (2) It is comparatively fresh, with a preserved ophitic structure.

N. H. W.

No. 15A. Diabase *(with olivine)*.

Duluth. From the west side of the same dike as No. 15.

An ophitic diabase like No. 15, but here the augite is wholly lost by decay, and in its place is *chlorite* (or *penninite*) charged with magnetite. This change is not due to a simple weathering, but to the activity of super-heated water during the process of cooling. This *magnetite* is all plainly of that origin.

One section. N. H. W.

No. 16. Diabase (?) *(Amygdaloidal.)*

Duluth. A modification of Nos. 13 and 13A, extending (next east of the brewery) 125 feet.
Ref. Annual Report, ix, page 14.

Meg. A black, apparently much decayed, aphanitic rock with epidote amygdules.

Mic. The rock is composed of small lath-shaped *plagioclases*, between which is largely an opaque black substance (in part *magnetite*) *chlorite* and some small grains of *epidote*. This groundmass does not entirely exhibit the characters of an alteration from augite, and it is not improbable that the rock was originally glassy.

The amygdules, some at least of which appear to be pseud-amygdules, are filled with epidote and *quartz* in small grains.

One section.

Age. Cabotian. U. S. G.

No. 17. Tuff.

Duluth. From the series east of Minnesota point, near the old breakwater, east of the Brewery creek; extends twenty feet, having a dip 43° E.

Ref. Annual Report, ix, page 14; Annual Report, x, page 140; American Association for the Advancement of Science, vol. xxx, page 164; American Geologist, vol. xviii, pages 211–213.

Meg. A firm, granular, brown, fragmental rock.

Mic. At a glance at the thin section the fragmental character of this rock is apparent. The constituent grains are of two sorts, viz., lapilli and glass. The former are vesicular, their more minute cavities now being filled with a translucent mineral, and their framework charged with ferruginous matter, rendering it nearly opaque. The latter are similar to the former, but are sometimes translucent, or partly opaque and partly translucent. They differ from the lapilli in being simple instead of composed of a number of vesicular masses embracing several translucent areas. It appears that the rock was originally essentially a glassy tuff, composed of glassy vesicular lapilli and of angular or sub-rounded *glass* fragments.

Between crossed nicols the whole slide is nearly dark, which is due to the opaque, ferruginous products, the isotropic chloritic areas, and the possible remnants of the original glass. The only light particles, as seen between crossed nicols, seem to be of secondary *quartz* and *epidote*. They are very fine, and multiple, the former not affording sufficient area for the action of convergent light to

There are no feldspathic or augitic fragments that can be detected, and judgin from the persistent endurance of the minute feldspar microlites, at least in form, i the lavas and all the diabases of the series, it is necessary to conclude that they neve existed in this rock. An abundant cement of *calcite* is distinguished by its iridescen polarization.

Ordinary erosion and sedimentation could hardly produce such a rock, an although it has a slaty or bedded structure which suggests sedimentary action, it i probable that the ocean had but little to do with its origination. Its dip is coinci dent with that of the lavas and amygdaloids of the immediate vicinity. Its strati form arrangement may have been the product of oceanic forces in spreading out th debris of volcanic ejection.

Three sections examined.

Age. Cabotian.

Remarks. Although some of the former numbers of this series (Nos. 8A, 8E 7B) have already been described as probably of tuffaceous origin, this rock is th first which has been met with presenting positive characters of that kind. Indeec it is the first positively identified tuff in the so-called Keweenawan. N. H. W.

No. 18. Diabase *(with olivine)*.

Duluth. East of the Brewery creek, and east of Minnesota point, at the lake shore. Over this com down a little creek; this rock extends perhaps 300 feet, nearly into the bite of the next little bay, and at th eastern limit of the exposure it has a dip easterly of 26°.

Ref. Annual Report, ix, pages 14, 16; Annual Report, x, page 36.

Meg. A much decayed, rusty-green, finely-granular, massive but remotely jointed rock. On the weathered surfaces it is finely pitted by the loss of some mir eral, apparently olivine. In other places it is amygdaloidal, and in others it crumble like a rotted shale. It appears, in the field relations, like a surface flow of diabas Its weight indicates a considerable percentage of magnetite.

Mic. Microlitic *feldspars* are frequently reddish, from ferruginous oxidatior no coarser feldspars present.

Augite shows, though much altered and in general without its original form occasionally its ophitic relation to the feldspars.

Olivine, though conspicuous in the section, is changed to an almost isotropi chloritic substance, yet which sometimes is finely fibrous, a fact which is seen o lowering the lower nicol. These grains are the most conspicuous in the slide. The show, by the dark lines of ferruginous matter, the original cleavages of the olivin

Quartz is a product of alteration, sometimes arranged radially, surroundin chloritic masses.

Magnetite is usually plainly of secondary origin, and is disseminated widely.

One section examined.

Age. Cabotian.

Remarks. This rock seems to fall into the class named melaphyr by Pumpelly. t is similar to No. 6A, in its petrographic characters. N. H. W.

NO. 18A. VEIN MATTER IN NO. 18.

Duluth. From laminations in No. 18.
Ref. Annual Report, ix, page 14.

Meg. Light greenish yellow and white, granular, but mingled apparently with ıore or less rock matter. Apparently largely composed of a honey-like garnet and alcite.

Mic. Besides *garnet* and *calcite* the microscope reveals *quartz*, *magnetite* and itaniferous magnetite, and *apatite*, and, further, a little *gold (?)* The *magnetite* is ı very fine particles, visible only microscopically, an alteration product. The *titan-ferous magnetite* is in larger grains which are frequently surrounded by a rim of gray ub-opaque substance, which is taken for *leucoxene.* In some cases such dark grains re mostly changed to such sub-opaque substance. This mineral does not appear in he midst of the calcite and garnet, but in those portions which are probably rock ragments. They are microscopic rods and angular masses. They are associated vith *quartz, epidote* and secondary minute magnetite grains. A fine, white fibrous ıineral is probably *tremolite.* The small amount of gold present is associated with he garnet. The only particles seen were subjected to nitric acid and remained right. The particles having been lost in the examination, the existence of gold in his vein matter requires further evidence.

Two sections. N. H. W.

NO. 19. ZIRKELYTE. *(Amygdaloidal.)*

Duluth. At the lake a short distance west of Chester creek, suddenly replaces No. 18 on the east and xtends about 200 feet.
Ref. Annual Report, ix, page 14. Annual Report, x, page 36. Annual Report, xiii, pages 100, 102. ulletin viii, page xxxiii.

Meg. A compact, almost aphanitic rock, of a dull reddish or brown color, with few scattered, brick-red feldspars a quarter of an inch long, but not enough to varrant the unqualified term porphyryte for the rock. There are also some scattered mygdules now filled with what appears to be epidote. These amygdules are from ery minute size to one-half inch across.

Mic. Rock is composed of minute interlocking laths of *feldspar*, in a confused ıass of magnetite grains, yellowish granules (apparently of *epidote*) and some *hlorite.* One of the larger feldspar crystals is seen in the section; it contains small akes of a *muscovite*-like mineral. In general these larger feldspars are striated. 'he brownish red color is evidently due to the fine dissemination of *hematite* which fine linear crystallites are common. *Magnetite* in fine grains is scattered everywhere. A dirty greenish or grayish mineral can be seen abundant in the vicinity of the magnetite, resembling that seen in No. 18A, probably the result of alteration of the magnetite, and indicating its titaniferous nature.

The rock contains also some *quartz,* in minute granules embraced in the general trachytic areas, also a mono-axial mineral darkening with the nicols which appears to be *apatite.*

One section examined.

Age. Cabotian.

Remarks. This rock has been grouped by the Minnesota Survey in the series of "red rocks." The microscopic characters seem to indicate that this is not correct. The following chemical analysis* shows the rock is rather lower in silica than the most of those rocks.

SiO_2		57.50
TiO_2		.....
Al_2O_3		13.29
Fe_2O_3		11.62
FeO		4.54
MnO		.....
CaO		6.12
MgO		1.63
K_2O		0.80
Na_2O		1.85
H_2O		1.48
	Total,	98.83

N. H. W.

No. 19A. Calcite and Epidote.

Duluth. From a large concretion in No. 19.
Ref. Annual Report, ix, page 14.

Meg. A mass of epidote, calcite, a light-gray, soft rock and a dark greenish rock.

Mic. The section is largely a mass of calcite grains in which is considerable epidote in small crystals and grains and some quartz. A little chlorite is present, as is also magnetite. Scattered through the calcite is a gray opaque substance, which at times is arranged so as to give the calcite a zonal structure.

One section.

Age. Concretion in Cabotian rocks. U. S. G.

No. 20. Zirkelyte. *(Amygdaloidal.)*

Duluth. A tougher condition of No. 19. Embraces angular masses of No. 21, and extends about forty feet.
Ref. Annual Report, ix, page 14.

Meg. A dark aphanitic rock containing a few red porphyritic feldspars. The rock is thickly strewn with small vesicles which are in part empty and in part contain epidote, and sometimes quartz or calcite..

**Thirteenth Annual Report,* p. 100.

Mic. Only two small fragments of the porphyritic *feldspars* are seen in the ction. These are untwinned and are considerably altered; one contains a grain of *idote.* The amygdules are filled largely with *quartz,* with some *epidote* and a little *lorite.* One amygdule contains some *calcite.* The rest of the rock is composed of inute feldspar laths and a very fine grained confused mass of magnetite, chlorite, idote and opaque matter. It seems probable that the mass of the rock outside of e feldspars was originally a *glass.*

One section.

Age. Cabotian. U. S. G.

NO. 20A. TUFF.

Duluth. Embraced in No. 20.
Ref. Annual Report, ix, page 14.

Meg. An aphanitic, brownish gray rock, looking some like a hardened shale. seems to be the same as No. 8A, which see.

No section.

Age. Cabotian. U. S. G.

NO. 21. TUFF.

Duluth. Overlies No. 20, extending fifteen feet.
Ref. Annual Report, ix, page 14.

Meg. Laminated like a shale, also fine grained, of a light green color, but ined in spots with iron oxide. Apparently a fragmental rock.

Mic. This rock varies in relative prevalence of the fragmental parts, making appear varigated with light and dark. Scattered throughout are sharply angular s of quartz lying in a confused, fine matrix of granular devitrified glass. This *ssy* element is sometimes much finer than throughout the most of the section, ving been originally in the form of an ash or dust. Again, on the other hand, ne areas in the section are remarkably coarse, but these all consist of the same ments. The glassy particles are sub-rounded, clouded by hematite or by other aque impurities, or are changed to a green chloritic substance. In all cases it is actically dark continually between crossed nicols. Rarely a feldspar microlite pears in one of these grains, and still more rarely they seem to be of the nature lapilli. Such is a grain in which is much *magnetite,* with only a few translucent ecks. In one translucent, quartz-looking grain an interference figure indicating bisectrix (n) was discovered in making examination in convergent light.

One section.

Age. Cabotian.

Remarks. This is not a typical volcanic tuff, but a subaqueous deposit of faceous material. The contrast in contour between the sharply angular quartzes d plagioclases) and the rounded glassy matter is the most striking and inexplicable

No. 22. Zirkelyte. *(Amygdaloidal.)*

Duluth. Overlies No. 21. Extends about 300 feet along the lake shore.
Ref. Annual Report, ix, page 14.

Meg. A dark gray, aphanitic rock confusedly mottled with black and yellowis areas, the latter apparently containing considerable chlorite. The rock thus seem to be an amygdaloid.

Mic. The main part of the section contains many minute *feldspars*, mostl lath-shaped, in and between which is a confused fine-grained aggregate of *magnetit chlorite, epidote, leucoxene,* and apparently a little *quartz* and *calcite.* The rock is muc altered, and it is thought to have originally contained some glassy material, althoug this is not certain. Scattered through the section are amygdules, or rather pseu amygdules, which contain quartz, chlorite, epidote and calcite. Much of the quar shows distinct undulatory extinction, thus indicating that the rock has been subjecte to pressure or strain since the quartz was deposited in the cavities.

One section.

Age. Cabotian. U. S. G.

No. 23. Diabase *(with olivine)*.

Duluth. From a dike which cuts No. 22, fifteen feet wide, running north and south. Compare No. 8C.
Ref. Annual Report, ix, page 14.

Meg. A fine grained, brownish black rock.

Mic. *Feldspar,* not much stained, appears in lath-shaped microlites, and in th angular interspaces is seen the remaining stage of the *augites* which are considerabl though not entirely, altered to chloritic and ferruginous products.

Olivine, in the same manner, appears in the form of greenish spots, which a accompanied by magnetite, but these differ from those resulting from augite, i the fact that they crowd on the shapes of the feldspars, having preceded the feldspa in date of formation.

One section.

Age. Probably Manitou. N. H. W.

No. 24. Tuff.

Duluth. Next east of the dike represented by No. 23, with laminations of green. It is coarser than N 17, dips 35° to 40° easterly, and extends fifty feet along the beach.
Ref. Annual Report, ix, pages 14, 15; American Geologist, vol. xviii, pages 211–213.

Meg. Apparently a fragmental rock of a brown, granular appearance, but witho evident silica grains.

Mic. The slide is made up of irregularly shaped areas of lighter and dark rock, the latter being apparently embraced in the former. The dark areas are fr quently rounded but not wholly. Some are elongated and more rough, and some them are themselves vesicular. The minerals in these dark areas are *magnetit* *epidote*, *calcite* and an isotropic substance which is greenish and similar to that which frequently follows an alteration of olivine or augite. These areas are darker, apparently, because of the greater proportion of the magnetite. The matrix which embraces these darker areas consists of about the same secondary minerals, with also much devitrified *glass*, but having less of the greenish isotropic substance and less of the magnetite. Also, the opaque substance has more frequently the color of hematite than of magnetite. Quartz is not wanting, but is very scarce.

Two sections examined.

Age. Cabotian.

Remarks. This rock, when collected, like several others obtained in the immediate vicinity, was considered a shale belonging to the sedimentary series. It is not probably wholly, nor perhaps chiefly, due to erosion of other rocks, but its general stratiform structure points to the action of oceanic forces in giving distribution to a fine ash, in which were mingled also larger masses of a vesicular rock of the same nature as the ash, but probably of the origin of volcanic lapilli. N. H. W.

No. 25. Zirkelyte. *(Amygdaloidal.)*

Duluth. Occurs twenty feet east of No. 24 and extends 100 feet.
Ref. Annual Report, ix, page 15.

Meg. A brownish aphanitic rock in which are many amygdules, some of which are half an inch across. The amygdules contain much epidote; especially are the outer layers of the amygdules of epidote. Calcite, sometimes in crystals of considerable size, also occurs, as does a soft, greenish, clay-like material.

Mic. The section is too thick for careful study. It is composed almost entirely of quartz and an opaque greenish yellow substance. The section was evidently cut from one of the amygdules.

One section.

Age. Cabotian. U. S. G.

No. 26. Diabase *(with olivine, altered)*.

Duluth. A rocky point near the old Fishery.
Ref. Annual Report, ix, page 15.

Meg. The rock is aphanitic and almost black. Its most noticeable feature is the presence of numerous red areas which at first appear like porphyritic feldspar crystals. But on closer inspection these areas are seen generally not to possess crystal outlines; they are in fact very irregular in outline and are not rounded like amygdules. The red material exhibits no cleavage surfaces; it is easily scratched with a knife, and effervesces with cold nitric acid. There are also other less sharply defined yellow areas (epidote), and the lens shows that these yellow areas, often of the hand specimen. Sometimes these red and yellowish elements are united in the same spot, the former surrounding the latter, and occasionally the red spots show distinctly a twinning on the albite plan.

Mic. The rare porphyritic *feldspars* are much decayed, showing quartz and hematite, and apparently calcite, as resultant minerals, the iron probably derived from the surrounding matrix, yet they are distinctly striated in some places and undoubtedly they resulted from the cooling of a molten basic magma. Throughout the rock are also microlitic plagioclases.

The *augitic* element is so changed that it cannot be identified as such, but the products of change from augite are the only evidence of its former existence (see No. 27).

That *olivine* was originally in the rock, is shown by the roundish green chloritic isotropic areas, crossed by the ferruginous bands that indicate the original cleavage of that mineral. These areas crowd on and displace the crystalline boundaries of the feldspars, showing their earlier date.

A micro-chemical test was made on the red element, not showing definite crystalline characters, and the only result was the appearance of fluosilicate of lime with very rare hexagonal rods of the same salt of soda. The conclusion to be drawn from these facts seems to be that the feldspar was a lime-soda plagioclase. In decay it has given up its soda, its lime has given rise to calcite, and, with the formation of a little quartz, the forms of the plagioclases have been lost, a red stain involving not only the remnant of the plagioclase itself but spreading irregularly through the surrounding rock, thus converting a porphyritic feldspar into irregularly shaped areas of a red color.

One section examined.

Age. Cabotian.

Remarks. This rock seems to be one of the series of eruptives extending along the shore eastward of Minnesota point, mingled with amygdaloidal and tuffaceous material. The red stain, which usually is evidence of the proximity of some of the clastics of the Animikie and of the fusion, or at least the wide dissemination of some of their elements in the basic eruptive, cannot certainly be attributed to that cause in this rock. Yet it is also equally impossible to exclude that agency in the change of these feldspars—a change that took place, probably, mainly while the rock was yet hot, a period during which both gas and water must have permeated the eruptive, carrying out such chemical alterations as were fittest to the nature of the attacking agent.

N. H. W.

NO. 27. DIABASE *(with olivine)*.

Duluth. A dike cutting No. 26. This dike changes its direction twice. It leaves the lake in a direction ; and west, but on ascending the rocky bluff it immediately changes to W. 15° S. It runs so about eight feet shifts again to nearly west.
Ref. Annual Report, ix, page 15.

Meg. Very fine grained and dark; not porphyritic.

Mic. Fine feldspathic microlites lie in the midst of the usual ferro-magnesian d magnetic minerals. This rock differs in one particular from many of the asso- ted and similar rocks already described. A considerable amount of *augite* still nains. This is colorless and shows alteration to greenish to colorless grains, which en have borders of *magnetite*. These grains are fibrous in structure, have a low tinction angle, and polarize in rather bright colors. They are referred to *hornblende*. No. 26 there is no augite, but the hornblende grains are very abundant and are nilar to those in No. 27.

One section.

Age. Probably Manitou. N. H. W. AND U. S. G.

NO. 28. DIABASE *(with olivine)*.

Duluth. Next east of No. 27.
Ref. Annual Report, ix, page 15.

Meg. Fine grained but scantily porphyritic with the earlier plagioclases. This ;k is quite similar to No. 27, but when collected it was considered the continua- n of the rock on the easterly side of the dike represented by No. 26. It has an ident bedded dip, extends 300 feet and passes, on the east, under No. 29.

Mic. This rock differs from No. 26 in wanting the irregular red areas, but it ows some scattered *red feldspars*. At the same time it very closely resembles No. 27.

Age. Cabotian.

Remarks. Nos. 26, 27 and 28 are lithologically closely allied, but structurally ey are widely separated. No. 27 is a dike which cuts the rock Nos. 26 and 28, these o being from opposite sides of the dike. It is only on the ground of these struc- al relations that the dike is classed as probably Manitou and the other as probably botian. N. H. W.

NO. 29. BASALT. *(Amygdaloidal.)*

Duluth. Apparently the amygdaloidal upper portion of No. 28; about five feet thick.
Ref. Annual Report, ix, page 15.

This rock is much altered to *epidote*, and it crumbles in the weather. Micro- pically it differs none from several that have been described.

Age. Cabotian. N. H. W.

No. 30. Sandstone. *(Pyroclastic.)*

Duluth. Rock next west of Mallmann's dike, east of the old Fishery. Extends 400 feet.

This rock shows non-conformable stratification or cross-bedding, perhaps separated by igneous eruptions and lava flows in other places. One part dips but little, and the other part dips east 30° south, and in amount about 15° or 20°. It varies from a brownish, siliceous sand rock to one that is greenish and aluminous.

Ref. Annual Report, ix, pages 15, 20; Annual Report, x, page 36.

Meg. A thinly bedded, grayish or greenish rock, of homogeneous grain and aspect.

Mic. The section shows a fragmental structure, and a composition mainly of particles referable to eruptive agencies. These grains consist of *quartz*, titaniferous *magnetite* (changed to *leucoxene*), *plagioclase*, *epidote*, *sphene*, and devitrified *glass*. These are cemented together by *chlorite*, *calcite* and probably some *hematite*. There are a few grains that have the appearance of having been derived as particles from a glassy rock.

Two sections.

Age. Cabotian.

Remarks. This rock is probably of sedimentary origin, even by erosion. There cannot be distinguished any lapilli, as a product of explosive action, but the particles consist almost entirely of mineral fragments frequently rounded as by beach friction.* N. H. W.

No. 31. Diabase *(with olivine)*.

Duluth; from Mallmann's dike.

Ref. Annual Report, ix, page 15.

Meg. Fine-grained, nearly black. Similar to Nos. 7D and 15.

Mic. Ophitic relation of the *feldspars* to the augite (or the devitrified glass) is conspicuous at a glance. They are twinned, lath-shaped, and although more stained with hematite than the feldspars in No. 15, their large extinction angle (about 28°) indicates that they are probably labradorite. Sections cut parallel with the tablets (*i. e.*, about parallel to 010) exhibit sometimes a zonal or shelly structure.

The *augite* (?) is entirely changed to a greenish substance, with accumulation of much magnetite. It is impossible to affirm what portion of this ophitic substance was originally augite—perhaps none of it. It appears that in some cases, after the crystallization of the feldspars, the rest of the magma never gave birth to augite, but, being consolidated in a more or less glassy condition, has afforded products that are undistinguishable from altered augite, and this may be the case in many others of these rocks.

Olivine, though giving a product very similar to that of augite, yet shows the following differences: (1) The earlier original independent crystalline form is apt to be preserved. (2) The magnetite accumulates along the original cleavages, or

* Compare "Volcanic ash from the north shore of lake Superior," by N. H. Winchell and U. S. Grant. *American Geologist*, vol. xviii, pp. 211-213. October, 1896.

fissures, and hence appears more frequently in lines. The border is also always heavily charged with magnetite as well as these fissures, leaving one or more central areas free from magnetite; while in the decay of augite the secondary magnetite appears more uniformly throughout the grain often as a fine powder or in particles of some size. (3) The greenish substance that takes the place of these minerals is apparently, in chemical composition, the same in one as in the other, but in the case of olivine the alteration product is apt to show a finely fibrous structure. (4) In this slide a further noticeable difference consists in the presence of considerable hematite with the magnetite, in the changed augite, and the almost entire absence of this mineral in those changed grains that are unmistakably derived from olivine. These differences are not always pronounced, and do not always coexist, but by one or more of them usually the original olivinitic nature of the rock, pro or con, can be determined.

Hematite, as already noted, is quite abundant, not only in the form of fine powder staining the feldspars, but in company with the magnetite in the grains that have resulted from the change of the pyroxenic mineral, where it appears as brownish red microscopic crystalline scales and groupings. Such hematite groupings appear dull red in ordinary light, both transmitted and reflected, but when the stage is rotated in strong reflected light they show minute reflecting surfaces which reappear at the proper angles.

Calcite is seen in isolated patches.

Two sections examined.

Age. Probably Manitou. N. H. W.

No. 32. ZIRKLEYTE.

Duluth. At the lake shore, east of Minnesota point, on the east side of a fault.
Ref. Annual Report, ix, page 15.

Meg. A very fine-grained rock, dark brown in color, spotted with clusters of green epidote or epidote and chlorite.

Mic. This is a very fine basalt in which the minute *plagioclases* are lath shaped and rarely twinned beyond two lamellæ, and embraced ophitically in the now changed matrix, which was probably glassy.

Magnetite is abundant.

With the *epidote* and *chlorite* filling the amygdaloidal (?) spots, is a little *quartz*.

One section examined.

Age. Cabotian. N. H. W.

No. 32A. ZIRKELYTE. *(Weathered modification.)*

Duluth. Taken from No. 32 near the top of the bluff, where it becomes reddish-brown and breaks into angular blocks of a few inches.
Ref. Annual Report, ix, page 15.

Meg. A fine-grained, brown-weathered condition of No. 32. Perhaps was at first largely of *glass*. It is now permeated with *epidote* and *calcite*. N. H. W.

NO. 32B. VEIN MATTER *(from No. 32).*

Ref. Annual Report, ix, page 15; Annual Report, x, page 141.

Greenish, fine grained, consists of *epidote, calcite, quartz, leucoxene*, some of the last showing the *sagenite structure, plagioclase* (albite ?). These minerals all appear as fragments, somewhat rounded, and without any evidence of vein structure.

One section. N. H. W.

NO. 33. AMYGDALOID.

Duluth. About sixty feet east of No. 32, on the east side of a fault, near the lake level. The cavities and the fissures have been generally filled with epidote and calcite, with a layer of greenish segregated material, probably delessite, lining each cavity nearest the rock.
Ref. Annual Report, ix, page 15.

No section. N. H. W.

NO. 33A. APORHYOLYTE (?)

Duluth. From patches in No. 33.
Ref. Annual Report, ix, page 16.

Meg. A reddish compact aphanitic rock with a few apparent amygdules. On one side two of these extend out from the rock, and appear somewhat like pebbles.

Mic. Very minute *feldspar* microliths are scattered through a groundmass which is composed of irregular ill-defined areas of *quartz*. This quartz contains the microliths and the minerals of the groundmass poikilitically (see No. 42). The rest of the groundmass, aside from the quartz, is composed of *epidote, chlorite, magnetite* and minute red particles (hematite).

One section.

Remarks. It is not certain just what this rock is, but it is thought to be a devitrified lava, perhaps as acid as a trachyte.

Age. Cabotian. U. S. G.

NO. 33B. PORPHYRYTE. *(Amygdaloidal.)*

Duluth. Taken from the stratigraphical equivalent of No. 33.
Ref. Annual Report, ix, page 16. Proceedings American Association for the Advancement of Science, vol. xxx, page 164.

Meg. A brown, very fine grained rock, containing many red, porphyritic feldspars; also considerable epidote.

Mic. The section is poor. It shows very few of the porphyritic feldspars, and these are highly altered. The groundmass contains small lath-shaped feldspars and the usual alteration products. There is also present a considerable amount of very fine grained material between these feldspars. This probably is largely quartz.

One section.

Age. Cabotian. U. S. G.

No. 34. Amygdaloid.

Duluth. Near the mouth of Chester creek.
Ref. Annual Report, ix, pages 16, 20.

Overlies No. 33B, and is about fifteen feet thick, the two passing gradually into each other across the bedding. This is a beautifully specked and spotted amygdaloid, some of the concretions being white (one-half to one inch across), some red (one-fourth to one-half inch), some green (one-fourth inch), and some with a red centre enclosed in a green coating. The rock itself is so altered that it is impossible, in the thin section at hand, to identify the original minerals. It can only be said that a reddened twinned plagioclase whose general forms are still sometimes quite distinct, is distributed idiomorphically amongst the other minerals. The matrix consists of chlorite, magnetite, altered glass, hematite, quartz.

Two poor, very small sections examined.

Age. Cabotian. N. H. W.

No. 34A. Concretions, etc. *(from No. 34).*

Ref. Annual Report, ix, page 16.

The red amygdules are colored by *hematite*, which seems to be distributed with slight reference to any crystalline structure or form. It is occasionally in parallel or radiating coarse fibres. The rest of the section is largely made up of a light-greenish chloritic substance which is so fine that it appears dark, like an amorphous substance, or when coarser affords an aggregate polarization. This chloritic substance pervades the whole mass, except where a few grains of quartz or of calcite have been generated. The hematite seems to be distributed through this chloritic substance. With the exception of a few irregular grains of *magnetite* and of *epidote* which are independent of the hematite, this constitutes the nature of these red amygdules. The white concretions are of *quartz* or partly of *calcite*.

In some parts of the slide the forms of the hematite indicate that it has taken the place of some fibrous or radiated mineral. Some of these amygdules, when stained red, have a *calcite* matrix, which, when they are broken, shows its cleavage distinctly. Both the calcite and the quartz sometimes embrace the red material in a micro-poikilitic manner.

Two sections examined.

Age. Concretions in Cabotian surface lava. N. H. W.

No. 35. Diabase *(with olivine).*

Duluth. Near the mouth of Chester creek, on the west side.
Ref. Annual Report, ix, pages 16, 17.

Meg. A hard, reddish imperfect amygdaloid, with numerous natural seams layer twelve feet thick; much decayed; fine grained; evidently a phase of the same rock as No. 34.

Mic. The feldspar is reddened, lath-shaped, and idiomorphically distributed amongst the other grains, which, however, are none of them in their original condition. They consist of *magnetite, hematite, chlorite, glass (?), epidote, leucoxene.* In strong polarized light (the same is less evident in natural light) and high powers the whole section glitters with bright specks, either sericitic or chloritic, or with fibres which appear to be serpentinic. This effect is hightened by lowering the polarizer. Even the opaque grains of magnetite are thus seen to be impure. They are more or less involved in this iridescence, and enclose minute parts of the minerals for which they are substituted. This is another evidence of their secondary nature. Most, if not all, of the magnetite in the section is of this character. The only evidence of original titaniferous magnetite, or of ilmenite, consists in occasional gray sub-translucent grains which are apparently *leucoxene.*

One section.

Age. Cabotian. N. H. W.

NO. 36. DIABASE (?)

Duluth. West side of Chester creek.
Ref. Annual Report, ix, page 16.

Meg. Hard, gray, or brownish-gray, fine-grained, and fresher condition of the eruptives at the mouth of Chester creek, a basic trap with alternating and irregular belts of amygdaloid.

Mic. The *feldspars* are very fine and lath-shaped, lying ophitically amongst the more or less altered pyroxenes and the remnants of the magma.

The *pyroxene* occasionally shows its bright polarization colors. The sections show much of the light-green, amorphous substance supposed to result from residuum from the magma.

Two sections.

Age. Cabotian. N. H. W.

NO. 36A. DIABASE (?) *(Amygdaloidal.)*

Duluth. Amygdaloidal porous condition of No. 36, from the upper portion of the bluff immediately west of the mouth of Chester creek. This porous condition occurs in layers or belts in No. 36.
Ref. Annual Report, ix, page 16.

Meg. An aphanitic brown to reddish rock in which are numerous cavities of all sizes up to those a quarter of an inch in diameter. These cavities sometimes contain epidote, and this mineral also permeates almost the whole rock.

Mic. The slide is made up of numerous *feldspar* microliths in a groundmass which is composed of *magnetite,* in large amount, and an almost colorless isotropic substance. Under a high power this isotropic substance is seen to be greenish, fibrous *chlorite*. The cavities of the rock are in part filled with *epidote* and a little chlorite, and the former mineral is found in abundance in the groundmass. The groundmass shows no evidence of having contained augite, and it may have been originally *glass*. No. 36, however, of which 36A is a part, contains augite.

One section.

Age. Cabotian. U. S. G.

No. 37. Diabase (?)

Duluth. At the shore immediately east of Chester creek, standing up like a dike.
Ref. Annual Report, ix, page 16.

Meg. Compact, fine, basaltiform, with some large geodic concretions; pyritiferous; extends four rods. This rock is not essentially different from No. 36, but has spots of calcite and epidote. It is more decayed and contains more numerous gray grains that are semi-opaque and seem to be *leucoxene*.

One section.

Age. Cabotian. N. H. W.

No. 37A. Calcite.

Duluth. From a concretion in No. 37.
Ref. Annual Report, ix, page 16.

Meg. The hand specimen is a large mass of well crystallized *calcite*. On one side of the specimen is some *epidote* and *hematite*.

No section.

Age. Concretion in Cabotian eruptives. U. S. G.

No. 38. Diabase.

From a dike east of the mouth of Chester creek. This dike runs north and south, and hangs toward the east 10°. It is eighteen feet wide. On the west side the adjoining rock has been hardened and rendered similar to the dike in external aspect. This dike cuts the foregoing eruptive sheets.
Ref. Annual Report, ix, page 16.

Mac. The rock is fresh and gray, medium grained, evidently a basic rock of the gabbro family.

Mic. The *feldspars* are embraced ophitically by the pyroxenes. A section perpendicular to the bisectrix (n_g) gives extinction on cleavage at 25° to 28°, and on macles at 0° to 2°. The optic plane, determined by the greatest curvature of the hyperbola in a section nearly perpendicular to an optic axis, makes an angle, with cleavage, of about 12°. If this section be near 001 the measure indicates *labrador-bytownite.* If it be near 100 the indication lies between *andesine* and *labradorite.* A tabular section showing distinct cleavage is taken for 010, and extinction on it is 25° and on another 30°, also pointing to labrador-bytownite. (This cleavage, in the first case, is not parallel with the macle. Many of the microlitic feldspars are crossed by such cracks sometimes at right angles to their elongation and sometimes obliquely.)

The *pyroxene* in the body of the rock is ophitic and tolerably fresh. A vein or fissure of later date crosses the section, and this is filled with *chlorite* scales standing vertically on the sides of the fissure. This chlorite, in some instances, spreads more widely, affecting chiefly the pyroxene. In many cases this chlorite is in leaves, favorably cut, and shows a strong pleochroism.

Magnetite is in angular masses, as if it had taken the position of some mineral, or of a residuum of the magma, since the consolidation of the feldspars. It is also in fine particles in the altered pyroxenes.

The good preservation of this rock, in contrast with the sheets of eruptive rock about Chester creek, the latter cut by the former, seems to prove a shorter period of exposure for the dike or better protection from the atmosphere.

One section examined.

Age. Manitou. N. H. W.

No. 39. Graywacke. *(Breccia.)*

Duluth. On the east side of the dike, No. 38. Extends thirty-five feet, and dips east.
Ref. Annual Report, ix, page 16.

Meg. The most of the hand specimen is composed of a fine-grained siliceous rock, which might be called graywacke. It has pyrite crystals disseminated through it. It has on one side, and was apparently surrounded when *in situ* by a very different kind of rock. The appearance is as if a gray siliceous breccia had a cement of a basic eruptive.

Mic. The rock is made up of fine angular and sub-rounded fragments of *quartz* and *plagioclase*, and of devitrified *glass*, with a few scattering grains of *pyrite*, and a few larger areas of secondary quartz. Except in its much greater content of quartz this included rock is similar to some already mentioned, viz.: Nos. 7B, 8B, 21 and 30. Its fragmental manner of occurrence in the lava is also similar.

Two sections examined.

Age. Inclusion in Cabotian eruptives. N. H. W.

No. 40. Diabase *(with olivine)*.

Duluth. East of Chester creek, at the lake shore, about forty feet east of the dike, No. 38. Hard, firm beds, in thin contorted layers, varying in durability and in color, some greenish and some brown, some nearly black. The whole is fine-grained, compact, of a dark grayish or brownish color.
Ref. Annual Report, ix, pages 16, 17.

Meg. Compact, rather fine grained, occasionally with a porphyritic feldspar crystal, and other colored spots. Undistinguishable from numerous others that outcrop between this point and Rice's point.

Mic. The texture does not present the strong idiomorphic characters seen in the feldspars of No. 38, yet it is an ophitic rock. The *pyroxene* is changed to the usual decomposition products. *Chlorite, magnetite* and *hematite* abound.

One section examined.

Age. Cabotian. N. H. W.

NO. 41. DIABASE *(with olivine, in basaltic columns).*

Duluth. Across a little bay, east from the last. Basaltic rock, the columns dipping about 10° from the perpendicular toward the northeast. Varies from a texture like that of No. 7C, to a finer grain, much like No. 43. Adjoins No. 50 on the east.

Ref. Annual Report, ix, pages 17, 18.

Meg. A tolerably fresh, medium grained, dark, basic rock, showing a polysynthetic feldspar, magnetite and a pyroxene.

Mic. The feldspar is *labradorite,* its extinction angles on opposite sides of a twinning line being as high as 25° and 27½°, and 31° and 33°.

Pyroxene is generally well preserved and exhibits a characteristic relation to the feldspars. It is in the form of *augite.* Some of it was at first taken for olivine, owing to its generation earlier than the feldspars, as evidenced by its independent outlines. In some instances the earlier and the later augite grains are associated in groups, in which their different relations to the surrounding feldspars are contrasted. In order to determine these earlier grains more certainly, the slide was uncovered, washed with turpentine to remove the Canada balsam, then with alcohol, and lastly with water. It was then immersed in hydrochloric acid during about eighteen hours, in order to convert it, if olivine, to gelatinous silica. The slide, after washing again in water was then covered with iodine green and left for twenty minutes. When examined for gelatinous silica, none was found; at least those augites which most clearly maintained their independent outlines were found unattacked, and as clearly polarized light as before the test. Other grains absorbed the color, some of them being probably *olivine* and others remnants of the magma uncrystallized. The latter were originally greenish, and chloritized. This is the first rock in which we have distinguished augite amongst the early generations from the magma. It is still more interesting that it was also later than some of the feldspars. In one instance, indeed, a single augite grain can be noticed, which is ophitic toward one feldspar crystal and idiomorphic toward another.

Olivine. There appears to be some later olivines which can hardly be distinguished from pyroxene, except by a careful noting of the cleavage and extinctions. They are both colorless or faintly straw yellow, and their double refraction, in a section of ordinary but unknown thickness (though less than 0.03 millimeters), is so nearly the same that the interference colors are not characteristic. Two sections were found, however, perpendicular to an optic axis and showing two cleavages perpendicular to each other, in which extinction takes place parallel to the cleavage cracks. One cleavage was distinct, even marked, and the other was imperfect. These grains, therefore, unless they be of augite cut in the zone of symmetry, must be of olivine, cut in the zone 100:010, and the cleavages those parallel to the prism and to the base 001. The oldest olivines, which were numerous, are wholly changed to magnetite and the usual green products.

Magnetite is not only in the fresh and undecayed pyroxenes, but also in the feldspars, though less commonly. It is most abundant in connection with the greenish grains which are now chloritic, and in this situation it is very often the result of a change from other substances, probably, in the main, from the older olivines whose forms are outlined by the chloritic areas. Although a part of the magnetite seems to date from the magmatic state of the rock, no distinct cubic outlines are perceptible.

Apatite needles pierce the feldspars in great numbers and are in the other minerals.

Chlorite masses are common and seem to have the form of the olivinitic grains of the earliest generation.

Quartz is present in scattered grains, so sharply separable from the surrounding minerals that it has the appearance of being an original secretion from the magma. Were the rock much decayed this quartz might be taken for a secondary product; but the rock is quite fresh.

One section examined.

Age. Cabotian.

Remarks. Another section of this rock, made later, brings out some characters not before distinguishable, viz.: some of the green "chloritic" masses are green hornblende instead of chlorite. These hornblendes are derived from or accompanied by a chloritization apparently of the early olivines. Through them run the magnetite accumulations, marking the irregular cleavages of olivine, and these are also seen in the chlorite areas, though here they do not follow so exactly the old cleavages. The hornblende cannot be said, correctly, to have epigenized on the chlorite, although these two are sometimes found in the same grain so related as to suggest that origin; but probably they are nearly cotemporary growths after olivine. In a single case a brown hornblende forms a part of a border of an augite.

Brown remnants of the glassy magma are also discernible. This rock is so strikingly like the great dikes at Grand Portage bay (Nos. 248, 253) that it seems necessary to classify it with them. Its structure and composition even conspire to warrant the designation *hornblende gabbro.* It is hence of Cabotian age, and an eruptive that preceded the Manitou. This is evidently a heavy surface flow allied to the Beaver Bay diabase but of later date, or a sill in the Animikie now denuded.

N. H. W.

No. 42. Aporhyolyte (?)

Duluth. Four blocks north of the depot.
Ref. Annual Report, ix, pages 12, 17. Annual Report, x, pages 62, 109. Annual Report, xiii, page 40.

Meg. An aphanitic rock of a reddish brown color. Scattered through it are very small reddish porphyritic feldspars and irregular areas of epidote and of a darker mineral, probably chlorite.

Mic. The most striking feature of the rock is that under polarized light it breaks up into irregular interlocking, often not sharply outlined, areas of quartz. (This is similar to, but more pronounced than in No. 33A.) The whole rock is composed of these quartz areas holding the other materials poikilitically. This structure has already been described many times in altered igneous rocks; it has been described by Irving* from the lake Superior rocks, and recently Miss Bascom† has discussed this structure from the rocks of South mountain. In the latter article are many references to other descriptions.

The porphyritic *feldspars* are very much altered. They in no case show polysynthetic twinning; however, some of them are so highly altered that no trace of this twinning could be expected to remain.

A few *quartz* grains, not showing crystal outlines, but possibly representing corroded quartz phenocrysts, occur. Frequently the quartz of the groundmass in the immediate vicinity of one of these grains has the same orientation as the grain.

Throughout the section are small particles of magnetite, chlorite and epidote, and red stains and specks (hematite).

Two sections.

Age. Cabotian.

Remarks. Because of the nature of the groundmass, which is similar to that found in altered acid lavas, the presence of quartz which was possibly porphyritic, and the apparent orthoclastic nature of the porphyritic feldspars, this rock is thought to represent an altered acid lava, most probably a rhyolyte. The name aporhyolyte is applied in accordance with the usage proposed by Miss Bascom.‡ No. 42 is similar to No. 45; also No. 850.

U. S. G.

No. 42A. Concretion *(in No. 42)*.

Duluth.
Ref. Annual Report, ix, page 17.

Meg. This concretion seems to grade into the mass of the rock through a siliceous periphery. The concretion, which is two and a half inches in diameter, is composed almost entirely of finely crystallized epidote.

No section.

Age. Concretion in Cabotian rocks.

U. S. G.

* *U. S. Geol. Survey, Mon. v*, pp. 99, 100, plate 13, figures 13, 14, 1885.
† *Journal of Geology*, vol. i, pp. 814-817, 1893.
‡ *Loc. cit.*, p. 825.

No. 43. Diabase.

Duluth. On the hill slope, back from the base of Minnesota point, in front of the engine house. Width and form of this rock could not be made out. Surface rounded over by glaciation. Apparently has a dip east 30° north. Approximately the equivalent of No. 6A, and of No. 44 ′, and perhaps of No. 41.
Ref. Annual Report, ix, pages 12, 17. Annual Report, x, pages 107, 109.

Meg. Generally of very uniform character, but in some places finely porphyritic with a red feldspar.

Mic. The *feldspar*, without further specification, may be said to be a plagioclase, and probably labradorite. It is much changed, showing secondary microlites of various sorts.

The *pyroxene* is also much changed, some of it being entirely lost, but some still plainly preserving sufficient of its molecular structure to give the high polarization colors characteristic of thick sections.

Olivine grains are quite common, but largely serpentinized so as to give an aggregate polarization. They are the favorite gathering-places for magnetite which forms strings and reticulations marking the original irregular cleavages of the olivine. It is apparent that in some cases olivine grains have been entirely replaced by magnetite. These olivine grains preceded the feldspars in generation, although they do not now manifest perfect crystalline outlines.

A considerable portion of the section is occupied by a mineral substance now changed so as to give a similar aggregate polarization, but coarser. This is apparently the same that was described in section No. 41 as uncrystallized magma. Toward this the feldspars are idiomorphic but it also spreads widely throughout the slide.

Magnetite is common, and apparently is entirely a secondary product, occupying the place of either olivine or of pyroxene.

Chlorite scales are sparse in the changed feldspar, but more common as a product of decay of the pyroxene and in the masses of undifferentiated magma.

Pyrite in fine grains is seen occasionally.

Age. Cabotian, allied to the Beaver Bay diabase. N. H. W.

No. 43A. Diabase *(with olivine)*.

Duluth. Same locality as No. 43.
Ref. Annual Report, ix, page 17.

Meg. A fine-grained diabase with small, red, porphyritic feldspars. The red color also penetrates somewhat into the mass of the rock.

Mic. The rock is essentially like No. 43, of which it is a part. However, most all of the feldspar is reddish. The porphyritic feldspars are very highly altered, but some of them still show traces of polysynthetic twinning.

One section.

Age. Cabotian. U. S. G.

No. 44. Mica Schist. (*"Black Rock."*)

Duluth. From the top of the hill at the head of First Avenue East. Very fine grained, black, like a basalt. Apparently this is what has been known later as "the black rock."

Compare Nos. 1966 and 1967.

Ref. Annual Report, ix, page 17.

Meg. Even with a loop nothing can be seen that would distinguish this rock, in the specimens at hand, from a very fine diabase.

Mic. But under the objective, and especially between crossed nicols, it is seen at once to be very different from any of the fine-grained rocks so far described. It has no ophitic structure, but is finely granular, with many translucent areas resembling *quartz*. These are of irregular shapes, but sometimes several contiguous darken simultaneously, as if they had the same crystalline orientation. In other areas the darkening comes on in spots and disappears in the same way, showing several independent grains. In general, finally, this same mineral (quartz) seems to extend as a cementing framework throughout the section, being invisible in other places on account of the presence of brightly polarizing or of opaque grains of other minerals. The interference figure, so far as seen, consists of a broad straight bar which crosses the field, indicating a uniaxial mineral.

Besides the foregoing are two other principal minerals which make up much of the rock. One is entirely opaque and black, and on reflecting surfaces has the metallic lustre of *magnetite*. It is scattered promiscuously as a powder, with no definite crystalline form, or is aggregated into granular masses of some size, the cement even then being the same quartz. The other is in very fine grains or scales which, in ordinary transmitted light, give a brown-gray coloration when they are frequent and superposed, somewhat resembling in this respect the color of *biotite*. Between the crossed nicols they extinguish four times in a revolution. Sometimes they show an elongation, but usually they are of irregular shapes and of sub-oval or orbicular angular outlines. When they are lengthened the extinctions take place parallel to the elongation. Sometimes they are aggregated in sufficient thickness to give a polarization color of reddish-yellow or of light blue, but their principal effect is to darken the matrix of quartz in which they are intimately embedded.

While these are the principal minerals there are also *calcite* and *epidote* in small amounts.

One section examined.

Age. Taconic (Animikie).

Remarks. This rock is the same as rock No. 1, of the series collected at Duluth by Prof. A. Lacroix, in 1888, deposited at the College de France. The biotite has the forms and relations to the quartz characteristic of "contact" mica as distinguished from granitic mica and the mica of gneissic rocks, *i. e.,* it embraces the quartzes, instead of being embraced by them. Its forms are secondary to the quartz. This is true of the original quartz grains, yet there is a secondary quartz also, which surrounds some of the biotite grains. This latter is that which spreads widely and constitutes apparently the matrix. It contains bubbles.

It is difficult to find a suitable name for this rock. Its relations to the gabbro and to "red rock" are interesting and important, and will be found discussed in Part III. N. H. W.

No. 44′. Diabase.

Duluth. Top of Kinichigaguag falls. Apparently the eastward extension of No. 43, and a part of No 41.
Ref. Annual Report, ix, page 17.

Meg. This rock consists of plagioclase in lath-shaped forms, very fine, and of a changed pyroxene, with magnetite and chlorite.

One section.

Age. Cabotian. N. H. W.

No. 45. Aporhyolyte.

Duluth. From a ravine between No. 44 and No. 1B which is further north on the hill.
Ref. Annual Report, ix, page 17.

Meg. An aphanitic, reddish brown, compact rock, holding small, red, porphyritic feldspars. There are also scattered through the rock, small areas, sometimes showing crystalline outlines, of a black mineral.

Mic. In all essential characters this section is like No. 42. However, epidote does not seem to be present in No. 45, and the porphyritic *feldspars* are in part not so highly altered. None of these feldspars show polysynthetic twinning, although many of them are so highly altered that no trace of this twinning would remain even if it was originally present. The least altered of these porphyritic feldspars show untwinned and simply twinned crystals. The alteration of these crystals is usually toward chlorite, and some of them are entirely replaced by this secondary mineral. Where this replacement has been entire the crystal appears black in the hand specimen.

One section.

Age. Cabotian.

Remark. This rock is similar to Nos. 42 and 850. U. S. G.

No. 45′. Slate (?) *(Altered.)*

Duluth. Foot of Chester Creek falls.
Ref. Annual Report, ix, page 17.

Meg. An aphanitic, dark, almost black rock, streaked with gray and reddish.

Mic. The section is a confused mass of *quartz, magnetite, chlorite, epidote* and *calcite.* The quartz, which is in minute interlocking grains, forms the background of section. Magnetite occurs in irregular grains and in minute dust-like particles.

None of the minerals, except some grains of epidote, show any crystal outlines. The magnetite and chlorite are in some places more abundant than in others, thus giving an indistinct mottled appearance to the slide. The calcite sometimes spreads widely with the same orientation, embracing numerous grains of the quartz and of the magnetite.

One section.

Age. Animikie.

Remark. It is impossible to state definitely what was the origin of this rock. It is thought to be a slate, or very fine graywacke. The groundmass of crushed and stretched quartz porphyries frequently resembles this section, but in this case there is no evidence of the remains of old phenocrysts, nor of dynamic action in the rock, nor in the associated strata. The overlying rock No. 44′, occupies the position of a sill similar to those in the Animikie along the boundary. U. S. G. AND N. H. W.

NO. 46. BASALT. *(Zirkelyte.)*

Duluth. Brewery creek.
Ref. Annual Report, ix, page 180. Annual Report, xiii, pages 100 (No. 151), 102. Annual Report, xi, page 39.

Meg. A black aphanitic rock thickly strewn with porphyritic crystals of dark red feldspar. Epidote has pervaded the rock to some extent, sometimes partly replacing the phenocrysts and sometimes occurring in small areas in the groundmass. On one corner of the hand specimen is an area of finely crystallized quartz about one half an inch in diameter. This is surrounded by a narrow green rim which contains some epidote, and outside of this is a wider rim of epidote which is not very sharply separated from the mass of the rock.

Mic. The porphyritic *feldspars*, which are such a characteristic feature of the hand specimen, and which constitute nearly one-half the rock mass, are imbedded in a groundmass which is composed of minute plagioclase laths and a black opaque substance appearing like *glass.* The feldspar of the groundmass and also of the porphyritic crystals is highly altered and reddened, and its exact composition cannot be determined; but, judging from the analysis of the whole rock given below, both of these feldspars are quite basic plagioclases. In some cases they still show the remains of polysynthetic twinning, although usually altered too highly to show this.

The black glass-like material on examination with a high power is seen to be composed almost entirely of black specks (magnetite) and chlorite. It seems most probable that this substance was originally glass.

Epidote and *chlorite* have both pervaded the rock in irregular patches.

One section shows part of an area similar to the quartz area described on the hand specimen. This is made up of epidote, quartz, chlorite, *calcite* and magnetite. In one part of the area the quartz, calcite and magnetite are arranged concentrically.

Chemical analysis. This analysis was made by Prof. James A. Dodge, and was first published in Thirteenth Annual Report, page 100 (No. 151).

SiO_2	48.81
Al_2O_3	23.27
Fe_2O_3	11.80
FeO	3.66
CaO	5.15
MgO	1.72
K_2O	.75
Na_2O	2.38
H_2O	2.53
Total	100.07

Age. Cabotian. U. S. G.

NO. 46'. RED GRANITE AND GABBRO *(contact of)*.

Duluth. Weller road, south side of hill. Showing contact of No. 1B and No. 1.
Ref. Annual Report, ix, page 18. Annual Report, x, page 142. Proceedings American Association for t Advancement of Science, vol. xxx, page 165.

Meg. The specimens show two rocks in contact. One is a fine grained grani composed of red feldspar, quartz, epidote and hornblende. The other is dark color and made up almost entirely of plagioclase; in places it contains long thin crysta of this mineral. A few reddish feldspars are also seen in the gabbro. The tv rocks are closely welded together and the granite extends in vein-like forms in the gabbro, thus showing it to be at least a little younger than the gabbro.

Mic. The section shows both rocks. The *granite* is made up of *quartz* and *r feldspar*, with some *epidote*, *hornblende*, *magnetite* and *chlorite*. The feldspar, lil the usual orthoclase or anorthoclase of these red acid rocks of the Cabotian, is mu altered and completely filled with minute dust-like red particles (hematite). Tl gabbro is essentially composed of plagioclase, somewhat altered, and not ve distinctly separated into grains and twinning lamellæ under polarized ligl Throughout this plagioclase and embraced poikilitically by it, are scattered grai and rough rods of magnetite; also chlorite and grains of brownish hornblend

The junction of the two rocks is quite a distinct line, and there is no minglii of the elements of one with the other, except that the red stain of the feldspar the granite has, just at the contact, penetrated to a small extent the feldspar of tl gabbro.

One section.

Age. Cabotian. U. S. G.

NO. 47. DIABASE *(with olivine)*.

Duluth. From a dike, same as No. 7C, from on outcrop on Superior street.
Ref. Bulletin ii, page 110. Annual Report, ix, pages 12, 18.

Meg. Medium grained, showing a plagioclase, a pyroxene, magnetite, pyrit and occasionally a spot reddened by hematite; a massive homogeneous rock of tl gabbro series.

Mic. The description of No. 7C applies well to this rock, except that it is less decayed. It might be added that the generally fresh condition of the rock, and the contrast between the undecayed augite (sometimes *diallage*) and that which is presumed to be a changed condition of the pyroxenic element renders it doubtful whether the pyroxenic element has really suffered this change. It provokes the query why such change should attack some of the grains and continue to total obliteration, and leave the rest wholly fresh. The *augite* in this section shows numerous grains cut so as to show optic axes and bisectrices in the field of the microscope, and occasionally an optic normal. The decayed, now chloritic, substance may be a condition of the residuum of the magma.

Olivine is quite common in the slide and is distinguishable from the augite by the fact that its boundaries encroach on all the other minerals, by its slightly darker tint of yellow in common light and by the irregularity of its cleavages. It is further distinguished, when a bisectrix can be found perpendicular to the plane of the slide, by the axial angle being about 90°. In the case of augite the smaller axial angle is much less than 90°, and the larger one much more. One such bisectrix (n_p) occurs in the slide examined. The olivines are quite fresh in this rock, but in No. 7C they are much altered.

The *magnetite* is angular and fresh, as if an original secretion from the magma.

One section.

Age. Manitou? (but possibly a feeder to the Cabotian sill No. 44'.)

Remark. The freshness of some of the augite in the thin section, contrasted with the completeness of the alteration in some of the other ophitic, greenish substance, suggests the possibility that the alteration product does not arise from augite. Its evident late date in the generation of the various minerals shows that it can have arisen, if not from augite, only from a non-differentiated portion of the original magma. Again, the freshness of the olivine rather precludes the supposition that the augite may have suffered so much. N. H. W.

No. 48. Basalt.

Duluth. Second street, corner Fourth avenue east. This runs from in front of C. Markell's house, under the Hayes block. It is a large member, at least 150 feet thick, and apparently falls between Nos. 7 and 6C.

Ref. Annual Report, ix, page 18. Annual Report, x, page 38.

Meg. Close grained and firm, hard, bluish gray to black, heavy, not visibly amygdaloidal, but finely and sparsely porphyritic.

Mic. The groundmass is made up of microlitic feldspars and magnetite. Evidently several other minerals are also present, but they are too fine, and the section (too thick at best) is too much decayed in general to warrant any attempt to differentiate them. The section shows a portion of a tabular crystal of a porphyritic feldspar, likewise charged with impurities. The rock has the appearance of a basalt, but it is not impossible that it is a condition of the "black rock" mentioned under No. 44. It contains, however, no observable quartz, or very little, and the feldspars are distinctly idiomorphic in the midst of the other grains.

Age. Cabotian.

Remark. This rock falls into the category of which Nos. 6C and 7 are other examples. If, as the field notes record, this falls into the unobserved interval between Nos. 6C and 7, it shows a thickness of at least 200 feet of such rock. The note already made, under "remarks," in connection with No. 7, is even more applicable to this rock. It is necessary further to call attention to the great thickness of this dense black rock. In that respect it resembles the outcrops on Piedmont avenue (Nos. 1966 and 1967), and, as an eruptive amongst clastics or as a surface lava, it ought to manifest considerable more variation in texture. While, therefore, No. 48 is classed with Nos. 6C and 7, with the basalts, it should be noted that there are certain structural reasons, and some anomalies unexplained, as yet, which render that reference questionable, and which seem to point to an alliance with rock like No. 44, or Nos. 1966 and 1967, *i. e.*, to the action of the basic eruptives on the black slates of the Animikie, and hence to a greater age than the Cabotian.

Remark. Another section, made thin, shows that this rock is a micro-crystalline basalt, in which there is still a considerable amount of isotropic glass. Among the minerals may be distinguished feldspar, augite, olivine, much magnetite, while an isotropic substance, probably resulting from glass, renders the whole slide very nearly dark between crossed nicols. N. H. W.

No. 49. DIABASE *(with olivine)*.

Duluth. Behind the M. E. church, between Second and Third streets, and Third and Fourth avenues west.

Ref. Annual Report, ix, p. 18; Annual Report, x, p. 139; Proceedings American Association for the Advancement of Science, vol. xxx, page 162; Bulletin ii, p. 108.

Meg. A rather coarse diabasic rock, of black color; some of the feldspars are grayish and a very few inclined toward a pink color.

Mic. The description of Dr. Wadsworth (Bulletin ii, page 108) is as follows: "The section is granitic in texture and composed of lath-shaped, somewhat kaolinized feldspar, magnetite, brownish augite, greenish pseudomorphs of serpentine after olivine bearing much magnetite, apatite, viridite, pyrite and quartz. Of these the only original minerals are the feldspar, augite, olivine and part of the magnetite."

One section.

Age. Cabotian; allied to the Beaver Bay diabase. U. S. G.

NO. 50. LAVA. *(Vesicular.)*

Duluth. Next east of No. 41.
Ref. Annual Report, ix, pages 17, 18.

Meg. A reddish-brown, aphanitic rock with many vesicles which are in part empty and in part filled with calcite. The specimen also contains fragments of other rocks. A few small, red, porphyritic feldspars are also seen; dip, E. 10° S. 18°; extent about 150 feet.

Mic. The section is very thick, but on its edges it can be seen to be made up of a transparent background in which are crowded specks and grains of a red material, probably *hematite.* Where the section is thicker this red material renders it completely opaque. Under a high power and in polarized light the background breaks up into a very finely crystallized aggregate of *quartz.* It is possible that some of this background is feldspathic, but no feldspar could be determined. In small areas the red material becomes much decreased, or entirely lacking, and here the quartz is in larger interlocking grains. The few porphyritic feldspars seen in the slide are much altered, but seem to be *orthoclase.* While the original nature of this rock is not clear, it still seems likely that it was a highly vesicular, probably rather acid lava.

One section.

Age. Cabotian. U. S. G.

NO. 51. DIABASE. *(Porphyritic.)*

Duluth. From a point, the next one beyond No. 50. Extends 200 feet. Sometimes rises twelve feet perpendicular from the water.
Ref. Annual Report, ix, page 18.

Meg. A fine-grained, brown rock made up of small, reddish feldspars, a dark, almost black, substance, and epidote. There are a few porphyritic red feldspars, and some larger areas with narrow, red periphery and dark interior. These latter, perhaps, represent large tabular feldspars which have been largely replaced by chlorite. One of these is three-fourths of an inch in diameter.

Mic. The section is composed of small lath-shaped *plagioclases*, which are much altered and reddened. Between these crystals are *quartz, magnetite, calcite, chlorite* and some *epidote. Apatite* needles also occur in the rock. The most characteristic feature of the section is the large amount of quartz in distinct grains. This fills in the spaces between the feldspars, and occasionally a considerable area is seen to be covered by quartz of like orientation; thus the quartz sometimes embraces the feldspars poikilitically. One section has on its edge a part of one of the porphyritic feldspars. This is reddened, much altered and contains some chlorite, and on the edge of the section it passes into an area of almost pure chlorite. It thus seems very probable that the large black areas already mentioned in the hand specimen represent feldspars replaced by chlorite, although we have no complete section of one of these dark areas.

Two sections.

Age. Cabotian.

Remark. The structure of this rock allies it with the diabases. The quartz is regarded as secondary. In almost every particular this rock resembles No. 7. An analysis of No. 7 is given and there are also some remarks concerning the origin and nature of the rock. In the field this rock disintegrates into small angular pieces according to innumerable weather joints. U. S. G.

No. 52. Basalt *(or zirkelyte).*

Duluth. Underlying No. 51, to which there is, in the field, a gradual transition, and overlying No. 53. This rock makes three heavy layers, or beds, each bed being finely and closely basaltiform, the columns being set so as to constitute layers running west 10° north, and east 10° south, from an inch to two inches in thickness, in position perpendicular to the heavy bedding. They were doubtless produced by the baking effect of No. 53, which comes on suddenly.

Ref. Annual Report, ix, pages 18, 19; Annual Report, x, pages 109, 110.

Meg. Apparently a dense, black diabase, contacting with cooler rocks. There is great uniformity of aspect in this rock. It shows in some parts a finely disseminated microlitic feldspar, and in others such feldspar is wanting entirely. It has much pyrite in isolated fine specks, and occasionally in form of a thin seam.

Mic. Sections made from this rock differ somewhat in fineness of grain, and in the amount of *quartz* present, but they are essentially the same. In some of the sections the feldspars are quite well formed, though small, the *augite* can with some uncertainty be identified, and the *magnetite* and spongy *pyrite* are abundant, particularly the former. There is a brown amorphous and isotropic glassy remnant of the magma which in the angles between the feldspars acts ophitically about them. *epidote* is gathered sometimes, in these coarser portions of the rock, in the pseudamygdaloidal areas, and in other small areas quartz appears. *Apatite* crystals pierce the section in all directions.

Other thin sections evidently come from more glassy portions. The *feldspar* crystallites are identifiable only occasionally as straight openings amongst the aggregated globulites of magnetite and augite(?) or olivine(?). When the section is highly magnified the magnetite globules appear crowdedly immersed in the glassy matrix, and occasionally are ranged so as to form fine thread-like crystallites.

Between crossed nicols the sections are nearly dark constantly, owing to the prevalence of the glassy magma.

Three sections.

Age. Cabotian.

Remark. Nos. 50, 51 and 52 are allied in the field and in petrographic characters. The first and the last are coarser grained, and have much more quartz. No.

51 lies between them. They were probably all cooled at or near the surface, and they show the volume of the basic and glassy floods which occurred at or near the surface in Cabotian time in the vicinity of Duluth. N. H. W.

No. 53. Diabase *(with olivine)*.

East Duluth. At the lake shore, N. W. ¼ sec. 24, T. 50–14. Has a basaltic structure.
Ref. Annual Report, ix, p. 19; Annual Report, x, p. 139; Bulletin ii, pp. 106, 107; American Association for the Advancement of Science, vol. xxx, p. 162.

Following is Wadsworth's description:

"This is microscopically a dark-gray, compact crystalline rock, showing lath-shaped feldspars. Microscopically the section is seen to be composed of a brownish *augite*, *feldspar*, *olivine*, *magnetite*, *apatite*, and various secondary products. The augite shows the ophitic structure first described by M. Michel Lévy,* and later by professor Pumpelly under the name 'lustre-mottlings.'† Attention has further been called to this structure by professors A. Geikie,‡ R. D. Irving§ and J. W. Judd.‖ This structure consists of a large irregular area or various areas all belonging to the same augite or diallage individual and cut by lath-shaped divergent feldspars. In one form or another this structure is very common in the diabases, and usually is the form of crystallization standing next to the granitic, in its coarseness of texture, or one step nearer the fine-grained basalts. Many of the preceding described rocks show the ophitic structure more or less perfectly, but not so well as this section. The olivine is altered for the most part to greenish, yellowish brown, brownish yellow and black serpentine, containing secondary magnetite sometimes marking the former olivine fissures. Considerable dirty green viridite and secondary apatite occur in the section, while some secondary biotite was observed in the vicinity of the magnetite. The augite in places has the secondary cleavage of diallage."

Age. Probably one of the Cabotian eruptives of the Taconic. See *remarks* under No. 52, etc. N. H. W.

No. 53A. Diabase *(with olivine)*.

Duluth. Same locality as No. 53.
Ref. Annual Report, ix, page 19.

Meg. A decayed, earthy condition of No. 53.

No section.

Age. Cabotian. U. S. G.

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* *Bulletin Société Geologique de France*, 1877 (3), vol. vi, p. 156.
† *Proceedings American Academy of Arts and Sciences*, 1878, vol. xiii, p. 260.
‡ *Transactions Royal Society*, Edinburgh, 1880, vol. xxix, p. 495.
§ *The Copper-Bearing Rocks*, 1883, p. 42.
‖ *Quarterly Journal, Geology Society*, 1885, pp. 360, 361; 1886, p. 68.

No. 53B. Diabase. *(Modified.)*

Duluth. N. W. ¼ sec. 24, T. 50-14. From the longest rocky point; a part of No. 53, but here containing some flesh-red crystals, making it resemble No. 5.

Ref. Annual Report, ix, page 19; Bulletin ii, page 107.

Mic. The section shows a rather coarsely crystalline rock quite similar to No. 5, except that it seems to embrace more *quartz*. The grains of this quartz are sometimes of considerable size. They are both irregular in form and also sharply angular. In the latter case the quartz embraces in an ophitic manner portions of the reddened feldspars and some of the greenish products of decay from other minerals. It also encloses *apatite* and *magnetite*. This shows it to be of later origin than these minerals, but these minerals themselves, excepting, perhaps, the apatite, are not original, as shown by numerous observations already noted. While taking part, therefore, in the general transformation during the cooling process, quartz was the latest of the secondary minerals to take its place. The presence of quartz here, and not in most other cases of such change, is to be assigned, as in No. 5, to the proximity of some of the clastic rocks which afforded it in connection with the general metamorphism resultant from the cooling period when hot, and hence silicified waters would have been abundant.

The *apatite* has every appearance of being one of the earliest crystallizations. It is not only in the greenish and serpentinous grains resulting from change in pyroxene, and perhaps from olivine, but it is in the unchanged or comparatively pure pyroxene and in the feldspars, whether the latter be reddened or entirely fresh. Its spicules are large and persistent, and sometimes very long. Its sections, perpendicular to the principal axis, are numerous and hexagonal. The fact, mentioned by Wadsworth in description of No. 6, that apatite when "entirely enclosed" in secondary quartz is probably of secondary origin, seems not sufficient to prove it so, but, on the contrary, simply shows it was of earlier date than the quartz. In the section, as stated, while it is perhaps more common in the vicinity of, and embraced in, the secondary minerals, it is not confined to them. Some conspicuous spicules penetrate the freshest of the feldspars. Its prevalence in the decayed minerals is probably due to its previous greater abundance in the pyroxenic grains.

Biotite in small scales is rare in connection with the alteration products.

Two sections examined.

[Evidently Wadsworth's description assigned to No. 53B is of some other rock.]

Age. Cabotian.

Remarks. This rock resembles No. 5. It thus connects No. 53 with the age of the great gabbro, or eruptive epoch, that closed the Animikie, and in that respect again points to the eruptive origin of the doubtful rock No. 52 and its equivalents, as the surface expression of the great Cabotian eruptive revolution. Compare the description of rocks Nos. 854G and 854aG, and the accompanying remark. N. H. W.

No. 54. Diabase.

East Duluth. From a dike three and one-half feet wide, associated with others, cutting No. 53 in a direc-
on N. 50° E., forty rods east of No. 53B.
Ref. Annual Report, ix, page 19.

Meg. A black, fine-grained diabase.

Mic. Lath-shaped *feldspars* occur imbedded in *augite*, alteration products of
ne same, and black opaque material, much of which is *magnetite.*

One very poor section.

Age. Probably Manitou. U. S. G.

No. 55. Aporhyolyte.

East Duluth. In the bite of a little bay, continuing half a mile, by the coast, becoming broken and
ightly amygdaloidal. It is reddish, angularly and finely jointed, sometimes a jaspery-looking rock; overlies
o. 54; sometimes dips at 60° N. E.
Ref. Annual Report, ix, pages 19, 20; Bulletin ii, page 118.

Mic. This rock is like the red elements in No. 53B, but is finer grained. This emark applies to the gray, or slightly reddish-gray, portions, of which one section is xamined.

Another section, numbered 55, and evidently from that part of No. 55 which in he field description was considered jaspery, is almost wholly red, but had originally mygdaloidal spots which are now filled with *quartz* having various orientation.

Quartz is also otherwise widely disseminated. This is a finer-grained rock than he last, but evidently a portion of the same mass more altered.

Two sections.

Age. Cabotian. N. H. W.

No. 55A. Quartz *(from No. 55 in concretions.)*

Duluth. Same locality as No. 55.
Ref. Annual Report, ix, page 19.

Meg. A red-brown, very fine-grained, earthy rock, irregularly blotched with arker areas. Scattered through the rock are areas of quartz mixed with and sur-ounded by brick red material, which is a little redder in color than the main mass f the rock. A few small porphyritic red feldspars are also seen.

Mic. The section is very thick, but seems to show a rock essentially like No. 0. The section shows one area of coarsely crystalline *quartz* into which extend nall prisms of a brown to black opaque substance, which in reflected light is red like ne mass of the rock. These prisms in outline and general relation to the rock and) the quartz remind one of the epidote crystals which are so common in such situa-ons, and it is not impossible that they are altered epidotes. There is, however, no race of the original epidote substance in any of the prisms.

One section.

No. 56. Aporhyolyte (?)

Duluth. A condition of No. 55.
Ref. Annual Report, ix, page 19.

Meg. Almost exactly like No. 55A, except that the porphyritic red feldspars are more abundant.

Mic. This rock is similar in general aspect to Nos. 50 and 55A, but the background of the rock, instead of being composed of quartz in minute grains, is made up of larger areas of quartz holding the other materials poikilitically. The slide contains one small black mass which is composed of black granular material (magnetite), in which are a few feldspar microliths and one highly altered feldspar phenocryst.

One section.

Age. Cabotian. U. S. G.

No. 57. Diabase.

East Duluth. From a dike cutting No. 56, which is said to be a condition of No. 55, running N. 5° E., four feet wide.
Ref. Annual Report, ix, page 19; Final Report, i, pages 196–199.

Megascopically this is a brownish, dark, compact and fine-grained rock.

Microscopically it is an ordinary diabase, consisting of lath-shaped *plagioclases* and pyroxenic element much obscured by change. *Magnetite* is abundant and *hematite* rare.

One section.

Chemical analysis. The following analysis was made by Prof. J. A. Dodge and first published in the Final Report, vol. i, pages 198, 199:

SiO_2	48.51
Al_2O_3	13.79
FeO / Fe_2O_3	19.34
CaO	8.34
MgO	4.81
K_2O	0.19
Na_2O	1.67
Total	96.65

The specific gravity was found to be 2.95 by one determination, and 3.005 by another.

Age. Manitou. N. H. W.

No. 57A. Vein Material.

Duluth. Just east of No. 57, from another dike.
Ref. Annual Report, ix, p. 19.

Meg. A roughly laminated mass of quartz, calcite and a dark green chloritic material. Evidently from a vein.

Mic. The sections show aggregates of *calcite, chlorite, hornblende (?)* and finely crystallized *quartz.* A considerable amount of *ilmenite,* largely altered to *leucoxene,* is also present.

Three sections.

Age. Vein material in a Manitou dike. U. S. G.

NO. 58. PORPHYRYTE. *(Diabase.)*

Duluth. On the lake shore, a little west of the line between ranges 13 and 14. Extends 15 rods. Sometimes rises in a bluff twenty-five-feet high.
Ref. Annual Report, ix, page 20.

Meg. A dark-brown, fine-grained rock consisting of small feldspars in a darker background. Porphyritic plagioclases, of a light-brown to pinkish color, are abundant. Minute bright red spots or stains are seen throughout the rock.

Mic. This rock is quite similar to some already described (Nos. 7BC, 46). The large *plagioclase* phenocrysts are embedded in a groundmass which consists of minute lath-shaped feldspars in a mass of alteration products—*magnetite*, *chlorite*, *calcite*, *quartz* and red material (*hematite*). It is not improbable, although not at all certain, that augite was originally present in the groundmass. There are some areas now filled by chlorite and magnetite which probably represent *olivine*. A red hematite stain pervades the rock in places and extends into cracks in the phenocrysts.

One section.

Age. Cabotian. U. S. G.

NO. 59. AMYGDALOID.

East Duluth; east of Tischer's creek; small outcrop in the shingle of the beach, having an apparent dip west.
Ref. Annual Report, ix, page 20.

Meg. The amygdules are filled with green epidote, white calcite and quartz, and the rock itself is porphyritic with red feldspars. It is also veined by quartz and epidote, making an attractive rock; contains fragments of a foreign rock, apparently a tuff.

Mic. The large reddened *feldspars* are sometimes zoned, and twinned polysynthetically. The microlites are adjusted to greenish areas, which have apparently resulted from a change of *pyroxene* to *chlorite*. The minerals are all stained with *hematite*.

Age. Cabotian. N. H. W.

NO. 60. PORPHYRYTE. *(Diabase.)*

East Duluth. From a little rocky point and round the bay immediately west of London. This rock forms a high and continuously rocky shore.
Ref. Annual Report, ix, page 20.

Meg. Reddish-brown, finely crystalline, frequently jointed, hardly amygdaloidal or porphyritic, becoming amygdaloidal in patches and coarsely concretionary, containing nests of dog-tooth spar.

Mic. Lath-shaped *feldspars* are abundantly distributed in an ophitic surrounding, which, while possibly originally pyroxene, is now a reddened secondary mineral which polarizes in the aggregate manner characteristic of a mineral wholly wanting. *Hematite,* and especially *magnetite,* have accumulated in these areas, the latter disposed in parallel bars, as if it occupied the spaces of former cleavage openings. Indeed in some places the prismatic cleavage of a *pyroxene* is simulated in the angles presented by these rods of magnetite. The feldspars are also sometimes somewhat colored by a hematitic powder, and usually are much affected by incipient alteration, which renders it useless to attempt to further define them than to say that they are probably *labradorite.*

The *pyroxene (?),* changed as above described, was a very abundant ingredient, on the supposition that the grains which embrace the feldspars ophitically, and are reddened by hematite, are of pyroxene.

Olivine, now wholly serpentinized so as to give a close, greenish, almost opaque, polarization, is quite common in this rock. These grains are uniformly embraced in a coating of magnetite, and sometimes they are colored within by hematite.

One section.

Age. Cabotian.

Remark. The interesting feature about this rock is the fact that instead of chloritic secondary products, as a result of alteration of the pyroxene, the product is reddish and brownish, with very little and often no chlorite visible. It may hence be of the nature of a residuum of the magma. N. H. W.

No. 60A. Calcite.

Duluth. Same locality as No. 60.
Ref. Annual Report, ix, page 20.

Meg. "Dog-tooth crystals of calcite which occur in a finely-jointed or brecciated condition of No. 60, which occurs suddenly, like a dike, extending up and down across the face of the bluff. This breccia is about twenty feet wide and the characters of No. 60 return on the east of it." The crystals contain a considerable amount of impurities. The largest crystal is near two and a half inches in length.

No section.

Age. Calcite crystals in Cabotian porphyryte. U. S. G.

No. 60B. Amygdaloid.

East Duluth. West of London. Same place as No. 60.
Ref. Annual Report, ix, page 20.

This is an amygdaloidal portion of No. 60. Besides abundant calcite the amygdules contain *epidote,* resinous *garnets (?)* and *quartz.*

No section. N. H. W.

No. 61. Tuff. *(Submarine.)*

East Duluth. Six rods west of a massive overhanging bluff, and at the eastern limit of No. 60, two fee thick, in a lot of thin beds, with a definite dip of 24° in a direction N. 60° E.
Ref. Annual Report, ix, page 20; American Geologist, vol. xviii, pages 211-213.

Meg. Evidently a clastic rock of rounded and sub-rounded grains, in a thin or ıaly stratification, some of the individual grains being lighter and some darker than ıe general tone of the specimen, which is a light brown, varying to a grayish, with tint of green. Some of the larger pieces, which are also the darker ones, are ɔparently from some aphanitic rock. Ready effervescence follows the application a small drop of hydrochloric acid.

Mic. The rounded grains are of various composition, but the major part of ıem consist largely of *quartz,* perhaps mingled sometimes with a little mica and a ttle plagioclase. This quartz may be distinguished in two categories:

1. Clear limpid quartz, the grains apt to be somewhat angular, supposed to be primary portion of the grit accumulated to form the rock; not common.

2. Quartz derived from an alteration of volcanic glass. This appears in three ɔnditions:

(a) As clear quartz with a single orientation, constituting a border that surɔunds a more or less confused and cloudy nucleus; some of the larger grains are of ıis character.

(b) As quartz more or less clouded and flecked by minute opaque particles, such uartz occupying the whole area of a grain, and with one or with several orientations.

(c) As microlitic or globular quartz, the minute globules not having crystal utlines nor clearly separate orientation, but crowded and grouped in the central arts of grains which (as in *a*) have clear quartz in their peripheries, or in some ther places.

Calcite forms some of the rounded grains, some of it showing the peculiar, ıarked cleavage characteristic of that mineral. It is also sometimes as an important art of the devitified grains.

Other grains are made up now of a greenish substance, probably some form f *chlorite,* which occasionally has a finely fibrous structure perpendicular to the ircumference of the grain. This, however, is generally destitute of such a structure. t is but slightly less abundant than the silicified grains.

Rarely a grain is simply gray, and semi-opaque, and its nature cannot be etermined.

Magnetite and *pyrite (?)* are not common, though a ferruginous dust which ppears to be of hematite or of magnetite, is scattered generally through, not only ɔme of the individual silicified grains, but more abundantly in the finer matrix.

The most striking feature of the slide, as seen under the microscope, with a low ower, is the non-resolvable nature of most of the grains, though sufficiently ranslucent to show light.

Two sections

Age. Cabotian.

Remark. Two other sections, made very thin, show still further the volcanic origin of much of this rock. It consists almost entirely of devitrified glass and of rhyolitic fragments, the latter showing their fluidal structure and the former a spherulitic. The grains that remain irresolvable in a thick section are found to consist of a crowded aggregate of microlites which never darken as a mass, and give no separate polarization. Their sombre tint indicates that they consist largely of quartz and of feldspar. Some of the grains were evidently in the condition of granulitic quartzes embraced in a mass of apobsidian. Some still show such partial extinctions, the area of their sections being divided between several orientations.

It is probable that this rock resulted from a sand of volcanic glass and a few fragments of augite. The parts are hardly sufficiently angular to be referred directly to volcanic explosive action. In many particulars it agrees with the volcanic breccia described by George H. Williams from the Sudbury district of Canada,* but is rather a clastic accumulation than a breccia. N. H. W.

No. 62. Diabase (?) (*Altered.*)

Duluth. Returns after No. 61; like No. 60, but bedded like No. 61.
Ref. Annual Report, ix, page 20.

Meg. A very fine-grained, compact, reddish-brown rock.

Mic. Rock much altered and reddened as is usual. Section consists of very small lath-shaped feldspars and a confused mass of magnetite, hematite, chlorite, calcite and quartz. What was the original nature of the rock, aside from the feldspars, is uncertain. Resembles No. 65.

Two sections.

Age. Cabotian. U. S. G.

No. 63. Basalt (?) (*Amygdaloidal.*)

Duluth. Overhanging rock which, toward the east, becomes brecciated.
Ref. Annual Report, ix, page 20.

Meg. A dark, much rotted, almost black, aphanitic, earthy rock with numerous small amygdules of chlorite, a few of quartz and less of calcite. Pyrite, in small crystals, is disseminated throughout the rock.

No section.

Age. Cabotian. U. S. G.

No. 64. Basalt. (*Amygdaloidal.*)

Duluth. In a heavy bed three feet thick. Overlies No. 65.
Ref. Annual Report, ix, pages 20, 22.

* *Bulletin of the Geological Society of America*, vol. iii, p. 138; *Geological Survey of Canada*, vol. v (new series), Part I. Appendix I, p. 75F, 1893.

Meg. Almost identical with No. 63.

No section.

Age. Cabotian. U. S. G.

NO. 64A. VEIN MATTER *(from No. 64).*

Ref. Annual Report, ix, page 20.

The specimen shows a vein about half an inch thick, largely consisting of calcite, ut also containing purple and green *fluorite.* When collected this was also said to ontain *bornite,* and it can be distinguished still on the hand sample.

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

NO. 65. PORPHYRYTE (?) *(Diabase.)*

Duluth. Evenly bedded, many jointed, forming bluffs of eighteen to twenty feet, holding large calcite odules.

Ref. Annual Report, ix, pages 20, 21.

Meg. A brick-red, very fine-grained rock holding small, red, porphyritic plagio-lases, which are in part replaced by epidote and chlorite. These two minerals also ccur in the rock in small irregular areas.

Mic. The porphyritic *feldspars* are very highly altered, but in places show the emains of polysynthetic twinning lamellæ. The groundmass of the rock has the sual red color and consists of *chlorite, magnetite, hematite, calcite* and *quartz*; the ast mineral is abundant and forms the ultimate background of the section, frequently ncluding the other substances poikilitically. In the groundmass are also microliths f feldspar. Many of these have no effect on polarized light and can be recognized nly by their form, being now a mass of red material often penetrated by the adja-ent quartz areas.

One section.

Age. Cabotian. U. S. G.

NO. 65A. CALCITE. *(Crystals.)*

[A large collection was made of crystals from nodules lying nearly loose in cavities in No. 65. They were ipped at Duluth, but were never received at Minneapolis.]

Ref. Annual Report, ix. page 20. N. H. W.

NO. 66. PORPHYRYTE. *(Amygdaloidal.)*

A modification of, though probably overlying, No. 65.

Ref. Annual Report, ix, page 21.

Mic. The reddened *feldspars,* their very finely ferrated matrix, the fineness of e texture, the prevalence of *quartz,* as a background for the fine minerals of the atrix, and the quartz fillings of the amygdaloidal cavities, denote that this porphy-yte was originally glassy, and would properly be styled zirkelyte.

No. 67. Apobsidian.

Near London [East Duluth]. Forms the point that is next west of the larger creek; continues thirty-five or forty rods, and is subjected to great upheaval and pressure.

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

Meg. A light red or pinkish specked rock, fine groundmass and some porphyritic and amygdaloidal tendency, appearing as if a siliceous and shaly rock in masses had been embraced in it. Some of these fragments weather dark green, and some purplish red, or fawn color. It also has nests of calcite accompanied by fluorite. It appears like a confused, half-baked, pudding-stone-like rock, or flow breccia. Evidently a continuation of Nos. 65 and 66.

Mic. The groundmass of the rock is reddened by *hematite*, and hardened by poikilitic *quartz*, both being secondary products after *glass*. These, with much *calcite*, are the only identifiable minerals. The quartz is sometimes grouped in interlocking clear grains in what may have been originally vesicles in the glassy mass, but in general it spreads through the whole slide, making a firm rock.

Age. Cabotian. N. H. W.

No. 68. Apobsidian.

PLATE I, FIGURE 3.

Near London, just east of Duluth. A thin-bedded, red or pinkish, hard, condition of No. 67.

Ref. Annual Report, ix, page 21. Annual Report, xiii, pages 100 (No. 152), 102. Bulletin viii, page xxxiii.

Meg. A brown aphanitic rock, with small whitish to pinkish areas which represent porphyritic feldspars. The rock has a laminated appearance and readily splits along parallel cracks, in places splitting into leaves less than one-sixteenth of an inch in thickness. Between the laminæ are very frequently layers or veinlets of quartz, sometimes of almost microscopic width, and sometimes nearly one thirty-second of an inch in width. On a weathered surface these laminæ produce the appearance of flow structure in a lava.

Mic. The characteristic feature of the sections is the presence of large, irregularly outlined areas of *quartz* which contain the other materials of the rock poikilitically. The whole rock is made up of these poikilitic areas and furnishes a most excellent example of the micropoikilitic structure which is so common in the acid rocks of the Cabotian. Scattered all through the quartz are minute grains and specks which, even under a high power, are not clearly shown, of magnetite, hematite and a grayish, almost opaque, substance. The latter is brought out more clearly in polarized light, when it appears isotropic and gives to the section a blotchy "pepper and salt" appearance. Although not now determinable, it seems probable that this substance represents feldspar, now much altered, as is usual with the feldspar of these rocks. In ordinary light the section shows irregular blotches darker than the mass of the rock; these are areas more rich in the iron ores.

The *porphyritic feldspars* are highly altered and reddened and cannot be determined specifically. Frequently the quartz of the groundmass has penetrated these phenocrysts, almost completely replacing them. In such cases the outline of the original grain is shown by the increased deposits of hematite. From the analysis of the rock as a whole, given below, it would seem that these phenocrysts were anorthoclase, or more probably a plagioclase rich in soda.

In sections cut across the laminæ the *quartz veinlets* are very prominent. Most of them are not continuous for great distances, but rapidly decrease in size and disappear. They are recognized easily in ordinary light simply because in them the opaque (feldspathic ?) and iron ore areas are lacking. In the smaller ones the quartz is oriented similar to adjacent areas in the groundmass. But in the larger veinlets the quartz is rather coarsely crystallized, one grain extending across the veinlet, and is usually of orientation independent from the quartz of the surrounding groundmass. In the larger veinlets there is sometimes on each side a narrow layer of clear quartz, then a layer of the feldspathic (?) material, and then the clear centre of the veinlet.

Aside from the appearance of flow structure given to the rock by the veinlets of quartz, there are indications of flowage in other places, especially around some of the porphyritic feldspars, but this flowage is not pronounced.

Three 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. 152):

SiO_2	73.72
Al_2O_3	12.82
Fe_2O_3	2.51
FeO	.22
CaO	1.70
MgO	.35
K_2O	2.40
Na_2O	2.70
H_2O	.94
Total	97.36

Age. Cabotian.

Remarks. This rock is referred without hesitation to a devitrified acid lava. It is very similar to the acid lavas, some of which are yet glassy, found farther east on the north shore of lake Superior at the Great Palisades and at Beaver Bay. Nos. 140, 138, 139, 127 and 129 represent these lavas from these localities, and these rocks will be discussed more fully under these numbers.

The origin of the quartz veinlets is uncertain. They may simply represent cracks in the rock or they may now take the place of old chains of spherulites. These veinlets much resemble such bands of spherulites from the South Mountain area in Maryland and Pennsylvania, and the slides were sent to Dr. Florence Bascom of Bryn Mawr College, who has carefully studied these South Mountain rocks, and she states that it is impossible to reach any other conclusion regarding the rock in question (No. 68) than that it is an ancient acid lava. She also states that the thin seams of quartz are probably cross sections of the former layers of spherulites.*

U. S. G.

No. 69. Diabase.

Near London, forming a point next east of the mouth of the creek, and not more than six rods from it by its position apparently overlying the last, cut by a dike, north 5° east, three feet wide.

Ref. Annual Report, ix, page 21.

Meg. A brown, compact, medium grained, scantily porphyritic rock, with epidotic linings in the seams.

Mic. The poor slide at hand only shows that this is an ordinary diabase, with feldspathic microlites trachytically exhibited. The augite areas are converted to a greenish, probably chloritic substance, and the presence of original olivine can only be predicated on the apparently independent outlines of some of these greenish areas. In general the minerals are all reddened by hematite.

Age. Cabotian. N. H. W.

No. 69A. Laumontite and Calcite.

On the east of the dike cutting No. 69 this rock is roughly amygdaloidal, but subsequently resumes its dense structure and thus continues more than half way to Lester river, cut by occasional dikes.

Ref. Annual Report, ix, page 21.

Meg. With a layer of calcite, next the rock, a second growth of a brick-red mineral is deposited on the calcite. The latter is closely fibro-lamellar and fragile but less so than is usual for laumontite.

Mic. This red mineral gives gelatinous silica in boiling HCl, has low refraction and low double refraction. Its cleavage plates, when examined in fine powder frequently give an oblique optic axis, and it has n_p in the acute optic angle, making it negative. Its angle of extinction with the principal elongation of the fibres is large.

These characters combined indicate laumontite. Its somewhat greater durability and darker red color are to be attributed to a copious cementation by infiltrated iron oxide. The sign of the elongation is positive, but as the angle of extinction measured on the elongation is about 25°, it is necessary to make that allowance for the position of the axis of elasticity.†

Age. Cabotian. N. H. W.

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*Cf. an illustration of aporhyolyte with spherulites in layers. F. Bascom: The ancient volcanic rocks of South Mountain, Pennsylvania. *U. S. Geol. Survey, Bulletin cxxxvi,* pl. 10, 1896.

†*Bull. Société de Minéralogie de France*, vol. viii, 322. The student will find here a useful classification of all zeolitic minerals according to their optic characters, followed by a tabulation of their diagnostic characters. The zeolites having negative elongation are those in which the smaller index of refraction (n_p, a) is parallel, or nearest parallel, with their greatest dimension as determined by the easy cleavages. The direction of this axis is easily observed by crushing fine a small quantity of the mineral and observing the colors between crossed nicols with the quartz plate interposed when the mineral and the quartz plate have their axes at 45° from the principal directions of the nicols. There is a later and improved classification of the zeolites in Lacroix *Minéralogie de la France et de ses colonies*, vol. ii, 1897. In the case of laumontite the axis n_g is nearer parallel with the principal cleavages and the elongation is normally positive.

NO. 70. AMYGDALOID. *(Silicified.)*

Near Lester river, on the west side, forming a prominent point or break in the coast line; overlies No. 69.
Ref. Annual Report, ix, page 22.

Meg. Apparently a fragmental rock, containing rounded pebbles (?) of quartz ;h a dark, fine-grained matrix, in which is disseminated much pyrite in the form of)es, as well as some calcite.

Mic. The matrix proves to be trachytic with *feldspars,* which have independent)ular forms in the midst of the other minerals. The pyroxenic element, which was)bably augite, is changed to secondary products, which are dark, in general, with *gnetite.* There are other areas which now give a blue tint between the crossed :ols *(pennine),* which seem to have consisted of *olivine.* The rounded *quartz* areas ; probably fillings of vesicular cavities in the original rock. They consist of merous interlocking grains of different orientation and sometimes are very finely ınular. Other cavities are filled with *calcite.*

Two sections.

Age. Cabotian. N. H. W.

NO. 71. DIABASE. *(Fine grained.)*

Near Duluth. Just west of the mouth of Lester river. Overlies No. 70. Continues but six or eight rods disappears under the beach, and nothing appears again till at Lester river.
Ref. Annual Report, ix, page 22.

Meg. A fine-grained dark brownish rock, composed of small feldspars and a rker material. Many of the feldspars appear pinkish. A very few small porphy- ic plagioclases are present.

Mic. Small lath-shaped *plagioclases* and an abundance of *augite* and *magnetite.* e augite is largely still quite fresh. A hematite stain has penetrated the rock and more abundant in the vicinity of the magnetite grains.

One section.

Age. Cabotian. U. S. G.

NO. 72. SANDSTONE. *(Pyroclastic grit.)*

Mouth of Lester river, east of Duluth. This river was called Passabika by Dr. Owen.
Ref. Annual Report, ix, page 22.

Meg. Apparently a granular clastic fine-grained rock, of a brown or reddish lor, homogeneous and thinly bedded. The amygdaloidal structure does not pervade ə sandrock, but it pervades the cement or rock which fills the angular openings tween the pieces of the breccia.

Mic. The section made from the clastic rock shows a fine grain, the individual ıins being both rounded and angular, and of different sorts. The most evident d conspicuous are angular limpid fragments of quartz. These are covered with essentially of quartz, are secondary after glass. They are rounded, and are dimmed by many inclusions of opaque substance. Still others are angular plagioclase fragments, their twinning being perfectly apparent by reason of the banded extinctions. These are embraced, over large areas sometimes, by calcite which like the Fontainbleau crystals presents a single orientation.

One section.

Age. Cabotian.

Remark. This rock may be compared with Nos. 17, 24 and 30. It occurs as angular inclusions in a vesicular lava, No. 72A. The rounded outlines and the uniformity of size of the most of the grains seem to be due to beach friction, for it is hardly possible that such forms can be produced by volcanic explosive action. The grains of silicified glass are comparable with the matrix of some of the aporhyolytes of the region. N. H. W.

No. 72A. Amygdaloid. *(Calcitic.)*

Mouth of Lester river, east of Duluth. The cementing material of the foregoing breccia.
Ref. Annual Report, ix, page 22.

Meg. A dull, much changed, fine-grained rock, containing amygdaloidal cavities mostly occupied by calcite.

Mic. Minute trachytic feldspars are distributed throughout the matrix. The ferro-magnesian silicates are wholly changed to serpentinous or chloritic elements, which also fill certain amygdaloidal spaces. No calcite amygdules appear in the section. The chloritic amygdules are blue between crossed nicols, but sometimes have a green border surrounding the blue.

Age. Cabotian.

Remark. It is a common feature to find these clastic masses in the midst of the vesicular lavas of the region. It is as yet unexplainable. Such association may have resulted from the rupture of old clastic strata in the ejection and flow of the lava, or from cotemporary erosion and sedimentary action of the ocean's waters on the lavas of the same or nearly the same date as the amygdaloids in which they are found. N. H. W.

No. 73. Diabase. *(Fine grained.)*

East side of the mouth of Lester river. Becomes brown along some of the joints, and in some large areas. Extends one and one-half miles, with a line of low exposure. Runs under No. 74.
Ref. Annual Report, ix, page 22.

Meg. A fine-grained, compact, dark-gray rock. Small feldspars are the only crystals that can be distinguished.

Mic. The section is composed of small lath-shaped *plagioclase* in a background of *augite, magnetite, plagioclase* and some secondary products. In structure this rock differs some from the usual diabases. The lath-shaped plagioclases are not all idiomorphic, and all gradations can be found from idiomorphic to granular plagioclases; and with these granular plagioclases and between the lath-shaped crystals are grains of augite. Thus the augite is not in the usual plates common to diabases, and in that respect this rock has gabbroid characters. It would seem that after the usual lath-shaped plagioclases were formed there was still a considerable amount of feldspathic material in the magma which crystallized at about the same time, or perhaps slightly previous to the augite. A few areas of magnetite and chlorite are present which perhaps represent old olivines. The augite, which is clear and colorless when fresh, has altered in places to a more or less fibrous greenish substance which often can be distinguished as *hornblende*. There are also some small areas of yellowish or brownish pleochroic hornblende which may be the greenish grains cut in another direction, but these yellowish grains are not so distinctly fibrous as most of the green ones. All of this hornblende is probably secondary after the augite.

One section.

Age. Cabotian. U. S. G.

No. 74. GRANITE. (*Red.*)

Rock next east of No. 73, extending for some distance.
Ref. Annual Report, ix, page 22; Annual Report, xiii, page 100 (No. 153), 102; Bulletin viii, page xxxiii.

Meg. A brick-red, granitic rock of fine grain, composed of red feldspar and quartz. A few cleavage faces of feldspar one-tenth of an inch across are seen scattered through the rock, but the usual grains are much smaller than this.

Mic. Rock composed of *feldspar* and *quartz*, about two-thirds feldspar, which is of the usual red, almost opaque, variety common to the acid rocks of the Cabotian. It rarely shows any effect on polarized light. Judging from the analysis of the whole rock, given below, we would expect the feldspar to be largely *anorthoclase*. Some of the larger feldspars show evidence of an original zonal structure. The quartz is in rather large areas embracing the feldspars poikilitically, and often penetrating and replacing in part the feldspar grains. The rock furnishes a good example of the coarser micropoikilitic structure. The feldspar enclosed in the quartz has frequently a tendency to an idiomorphic development. A few areas of a dull brown, granular, isotropic substance, with dark borders, are present. These may represent an old ferro-magnesian constituent. Scattered abundantly through the rock in grains and specks and stains is *hematite*, and the presence of this mineral is also clearly evident from the analysis.

One section.

Chemical analysis. This analysis was made by Prof. J. A. Dodge and first published in the Thirteent Annual Report, page 100 (No. 153):

SiO_2	65.56
Al_2O_3	10.06
Fe_2O_3	14.40
FeO	.23
CaO	.96
MgO	.73
K_2O	2.88
Na_2O	2.25
H_2O	.86
Total	97.93

Age. Cabotian. U. S. G.

NO. 75. SCORIA. *(Acid, volcanic.)*

East of Lester river. S. E. ¼ sec. 34, T. 51–13. At this locality there has been an unusual disturbanc the strata dipping in different directions, or at a high angle to the north, the strike being nearly east and west This point cannot be far distant from an ancient volcanic crater. (See figure 109, page 576, vol. iv.)
Ref. Annual Report, ix, page 22.

Meg. The rock varies from a brownish red amygdaloid to a flesh-red scoria the latter represented by the samples examined. This is porous, and even spong: but the vesicles are elongated and flattened. Through the rock runs a considerabl calcite in veins and patches.

Mic. The sections show that the rock consists essentially of devitrified glas and of glass, embracing vesicular openings. There are many crystallites which ar apparently biaxial, and others evidently of quartz though they do not exhibi hexagonal shapes. They are clear and quick to extinguish between the nicols. Bu these are embraced, frequently, in a substance which is nearly isotropic. Yet between the nicols other faintly luminous spots appear, indicating the arreste formation of other crystallites. In other words, the glass is but imperfectly devitrified. This fact is in keeping with numerous observations on the tuffaceous rock of the region, in which sub-glassy grains have been seen distributed through a clastic mass.

Two sections.

Age. Cabotian. N. H. W.

NO. 76. DIABASE *(with olivine and thalite).*

Directly overlying No. 75, interbedded in No. 75, but still runs under No. 77.
Ref. Annual Report, ix, page 22. Compare No. 91B.

Meg. Has a trappous aspect, contains laumontite amygdules and nodules o calcite and fluorite.

Mic. The aspect is that of an ophitic rock, the bright microlites of *feldspa* being numerously embraced in some of the large *augites.* There is no evidence o an earlier generation of augite.

The *olivine* is much crowded with magnetite accumulations, and in many grains is so lost that its form is the only remaining evidence of its former existence.

In several irregularly shaped areas occurs a finely fibrous, yellowish green mineral, which has much the appearance of that seen in No. 140 (7). It is in the form of undulatory and mammullated layers, the fibres of which are perpendicular to the layers and have parallel extinction and positive elongation. The name of this mineral is not yet determined, but appears to be thalite. The mineral referred to in No. 140 (7) is much harder than thalite.

One section.

Age. Cabotian. N. H. W.

No. 77. AMYGDALOID *(with laumontite.)*

Overlies No. 76. A coarse amygdaloid, with laumontite and calcite, containing some copper, wrought slightly for copper at one time. Color, brown.

Ref. Annual Report, ix, page 23.

The fragile *laumontite* nests are of various shapes and sometimes two inches in larger dimension, the fibres radiating from points; color, light flesh-red. The fibres are optically negative, and have extinctions at 6° to 24°. The rock is a fine olivinitic diabase in which the augite preceded the feldspar and was then corroded.

One section.

Age. Cabotian. N. H. W.

No. 78. DIABASE.

Forms the bite of Crystal bay east of Lester river. Bluffs fifteen to twenty feet in hight.

Ref. Annual Report, ix, page 23; Annual Report, x, page 38.

Meg. Firm, brownish red, much jointed, disintegrating and falling in large masses, weathering light red or pinkish; containing nests of calcite crystals.

Mic. The section shows a fine-grained diabase now considerably altered and impregnated by iron oxides, apparently both magnetite and hematite. The plagioclase laths are usually still distinct, though clouded. One of these, cut nearly perpendicular to the axis of least elasticity, gave an extinction angle of 21°, indicating *labradorite.* Secondary *quartz* in small grains is common. There are some pseudamygdaloidal areas filled with *chlorite* and quartz.

One section.

Age. Cabotian. U. S. G.

No. 78A. CALCITE. *(Crystals from No. 78.)*

Ref. Annual Report, ix, page 23.

These nests are sometimes eighteen inches across, but generally less than ten. The forms are sometimes perfect, with double terminations. They are impacted in a fine red clay, which doubtless has infiltrated through the loose rock from the surface above, where a continuous sheet of the same red clay covers the country.

No. 79. Porphyryte. *(Amygdaloidal.)*

Eastward from Crystal bay, similar rocks extend for a mile or more. These are brownish or black and basaltiform outwardly, and are doubtless a continuation of No. 78, though exhibiting in the field considerable variation of dip and of structure. They are sometimes compact and sometimes amygdaloidal, and are associated with fragmental rock in a confused manner, the latter being brecciated, and transversely and falsely bedded like some sandrocks. The bluffs are generally low, three to ten feet, with interruptions.
Ref. Annual Report, ix, page 23.

No section.

Age. Cabotian. N. H. W.

No. 80. Prehnite.

From the old copper shaft about a mile up French river. This mineral fills and lines numerous cavities of various ramifying shapes, in the rock No. 81. Rolled pieces of this mineral are found in the gravel of the beach, and metallic particles of copper are frequently embraced in them.*
Ref. Annual Report, ix, page 23.

Meg. This prehnite is associated with another form of gangue, both carrying metallic *copper*. This form of the gangue is a siliceous rock of a light, reddish-brown color, apparently fragmental, which, according to the field descriptions, runs in irregular veins and crevices in No. 81. It is hard, like a quartzyte, and dense, but it plainly embraces fine grains of a darker mineral than quartz. The rock has a color-banding which is somewhat flexuous, simulating a fluidal structure, suggesting the silicification and other devitrification of a glassy eruptive.

Mic. On making a thin section of this peculiar gangue rock, it is seen to be a fragmental rock, consisting very largely of rounded fragments of prehnite, quartz, epidote(?) and of devitrified glass, with an abundant deposition of secondary quartz. Some of the glassy fragments are hardly devitrified, but remain dark constantly between the nicols. They occasionally take the forms of elongated shreds and strings, and show a rhyolitic structure.

Two sections.

Age. Cabotian.

Remark. This rock seems to illustrate, in its origin and manner of occurrence, the clasolyte of Wadsworth. (Report of the State Board [Michigan] of Geological Survey, for the years 1891 and 1892, page 130). N. H. W.

No. 81. Diabase *(with olivine).*

Banks of French creek, from the lake shore northward for about half a mile or more.
Ref. Annual Report, ix, page 23.

Meg. A dark, fine-grained, heavy rock.

Mic. Ophitic, with *augite* and *feldspar*, the *olivine* grains being fine and of a reddish brown color. *Biotite* is also brown and quite abundant. Some of the vesicles are filled with *calcite* and some with *chlorite* of the variety *pennine*, judging from the bluish interference color between crossed nicols.

One section.

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*For an account of this mining enterprise, see *Minnesota Historical Collections*, vol. ii, p. 181, by H. M. Rice.

Age. Cabotian.

Remark. This rock undergoes variations between the lake shore and the old French River mining location, becoming amygdaloidal, and also in other places finer grained, even aphanitic, as if it had been glassy. Of two sections made from the rock at the old mine, on the veinings of which prehnite forms coatings, one is permeated with *prehnite*, as well as having small vesicles that are completely filled with the same mineral. N. H. W.

NO. 82. DIABASE (*with olivine*).

French river, one half mile from the lake. An amygdaloidal portion of No. 81.
Ref. Annual Report, ix, page 23.

Meg. A dark brownish rock of very fine grain. Contains amygdules of laumotite, prehnite and a dark mineral (chlorite). The rock also has small indistinct black areas, which are probably largely of chlorite.

Mic. The section is almost exactly the same as the first section described under No. 81, and so needs no further descriptions. The feldspars are perhaps a little larger than in No. 81.

One section.

Age. Cabotian. U. S. G.

NO. 83. DIABASE. (*Altered.*)

French river.
Ref. Annual Report, ix, page 24.

Meg. There are two hand specimens. One is a dark purplish rock, similar to Nos. 81 and 82. It contains amygdules, veins and geodic cavities of prehnite. The other hand sample is part of a geodic cavity filled with coarsely crystallized laumontite and some prehnite. Part of the rock surmounting the geode is present; this is similar to the other sample, but is redder and decayed.

Mic. The section shows a rock which was undoubtedly originally very similar to Nos. 81 and 82, but is now highly altered. The outlines of the small lath-shaped *feldspars* are sharply preserved, but the whole rock, except the areas of iron ore and some opaque substances, has been replaced by *prehnite*. From the hand sample, which is apparently quite fresh, one would not suspect that so profound a change had been wrought in the rock.

Two sections.

Age. Cabotian. U. S. G.

NO. 84. AMYGDALOID. (*Laumontitic.*)

A mile and a half up French river. Allied to the series of traps and amygdaloids already described at this place.
Ref. Annual Report, ix, page 24.

No section.

No. 85. Diabase. (*Coarse.*)

Two miles up French river.
Ref. Annual Report, ix, page 24.

Meg. Considerably shattered and deeply decayed, but evidently one of the heavier surface flows or sills of the region.

Mic. A coarse ophitic structure is at once apparent. *Olivine* is only shown by the usual independence of the areas that now are filled with the products of decay. *Magnetite*, *quartz*, *chlorite* are conspicuous.

One section.

Age. Cabotian. N. H. W.

No. 86. Diabase. (*Amygdaloidal.*)

French river, two miles from its mouth.
Ref. Annual Report, ix, page 24.

Meg. A dark brownish, medium-grained diabasic rock containing a few small amygdules of *chalcedony* and *quartz*.

No section.

Age. Cabotian. U. S. G.

No. 87. Diabase.

French river, three miles from its mouth.
Ref. Annual Report, ix, page 24.

Meg. A fine-grained diabase with some black blotches, which are pseud-amygdules of chlorite.

Mic. Lath-shaped *feldspars*, *augite*, *magnetite*, *hematite*, *chlorite* and alteration products. The chlorite forms pseud-amygdules. Probably some olivine was originally present.

One very poor section.

Age. Cabotian. U. S. G.

No. 88. Olivine Diabase.

S. W. ¼, sec. 10. From the round point which bounds Sucker bay on the west.
Ref. Annual Report, ix, page 24.

Meg. Fine-grained, dark and heavy trap.

Mic. The feldspars are microlitic and ophitically embraced by the *augite*, which in some cases encloses ten or fifteen of them. The *olivine* is in small grains and much changed to a fibrous substance which is usually green, but which becomes so charged with iron that it is also largely opaque.

One section.

Age. Cabotian.

Remark. The coarse diabases Nos. 85 and 87, and the gabbroid characters of No. 73, are believed to be due to the greater proximity, both areally and chronologcally, of the chief gabbro mass which lies further north. The lavas and clastic rocks along the shore seem to be the more distant representatives of these coarse diabases. How many of the surface outcrops of these coarse rocks away from the lake shore, belong to sills, and how many are of massive surface flows, there is at present no way of knowing. N. H. W.

No. 89. Diabase.

Just east of the creek crossing sections 9 and 10, east of the mouth of French river, and near Sucker bay.
Ref. Annual Report, ix, page 24; Annual Report, x, page 36.

Meg. A massive, homogeneous, fine-grained diabase-like rock, non-amygdaloidal, but having large geodic concretions of calcite, with an interior of laumontite. The joints, as seen in the field, are lined with a mineral Norwood styled heulandite. Compare Nos. 515 and 516.

Mic. An ophitic diabase of the usual characters, lath-shaped feldspars, *pyroxene* much changed, *magnetite, olivine, hematite, chlorite*, a little *quartz*.

One section.

Age. Cabotian. N. H. W.

No. 90. Diabase *(with olivine, coarse)*.

From the east point of Sucker bay; a massive, heavy bedded, dark rock, sloping up from the water's edge, similar to Nos. 1 and 49; continues to Knife river; also forms Knife islands.
Ref. Annual Report, ix, page 24; Annual Report, x, page 139; Proceedings American Association for the Advancement of Science, vol. xxx, page 162; Bulletin ii, page 99.

Meg. A rather coarse-grained, granular "sugary" appearing rock, which is made up of plagioclase, weathering white, and black materials.

Mic. The following is Dr. Wadsworth's description (Bulletin ii, page 99):

"One section is composed of numerous grains of olivine and masses of augite arranged irregularly in the feldspar which is sometimes in aggregations of crystals, and sometimes in divergent lath-shaped blades dissecting the augite. The feldspar contains the remains of an included globulitic base, so commonly seen in the plagioclase of modern basalts.

"The olivine is much fissured and more or less altered to a greenish serpentine. Greenish and yellowish brown secondary products, showing aggregate polarization, are common in the section. In another section of the same rock the feldspar contains much of the altered globulitic base, while that mineral is largely in rounded and tabular aggregations of crystals. The olivine is here altered, not only to the greenish serpentine, but also to a brownish yellow form."

Two sections.

Age. Cabotian. U. S. G.

Remark. This, perhaps, is in continuation of the coarse diabases Nos. 85, 87, and they are probably all closely related with the great gabbro mass seen at Duluth.

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 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_g, 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 1, 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.

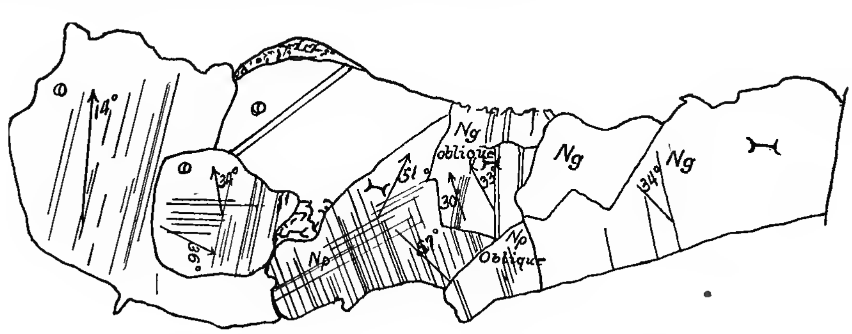

FIG. 6. THE FELDSPAR IN ANORTHOSYTE, NO. 113.

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 supposed 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 labradorites 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:

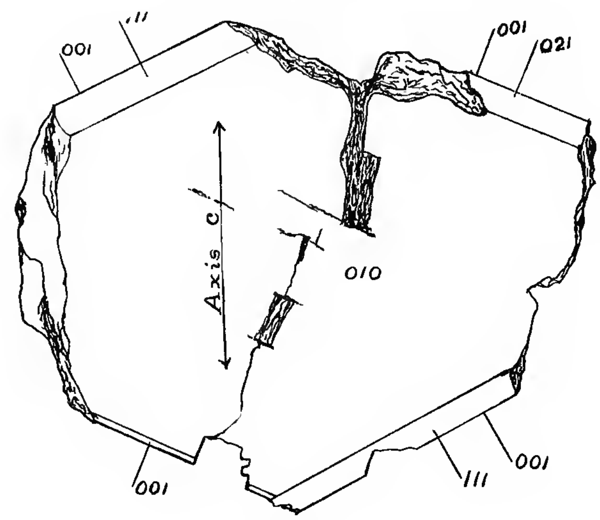

FIG. 7.

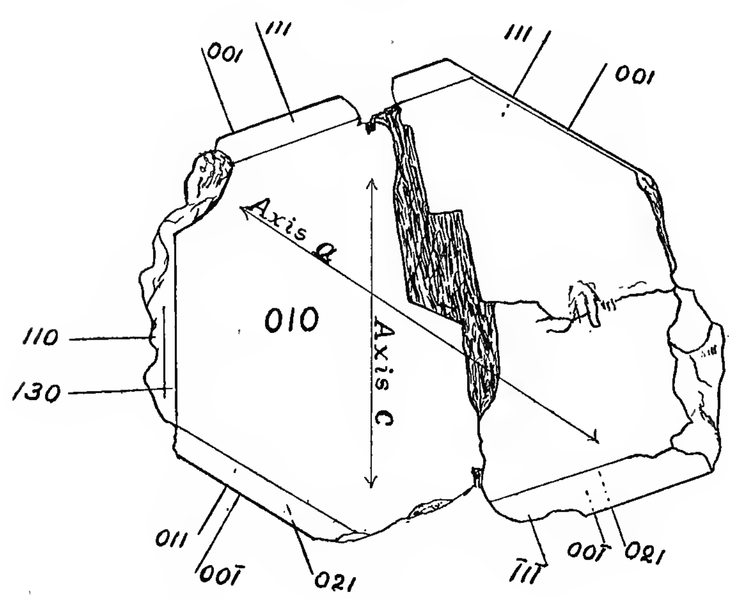

FIG. 8.

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 $\wedge$ 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

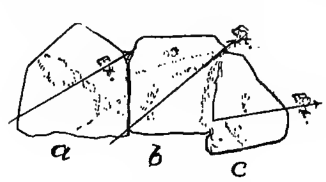

FIG. 9.

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 structures 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_g, 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.*

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* *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.

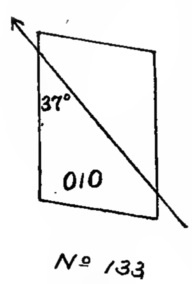


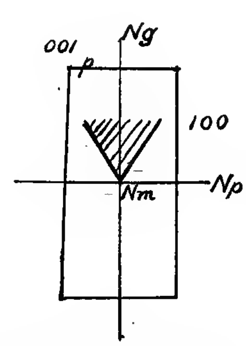
FIG. 10.

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.

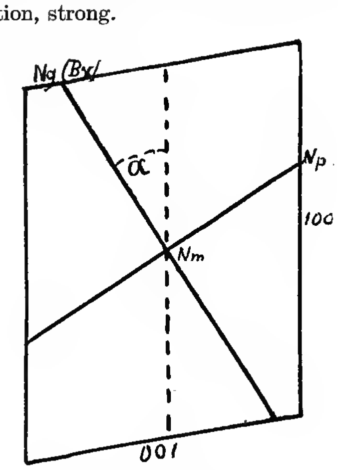
COMPARATIVE CHARACTERS OF ENSTATITE AND AUGITE.

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.

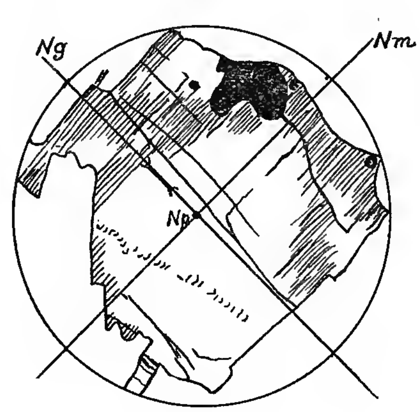


FIG. 13.

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 $\mathfrak{a}$. 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.

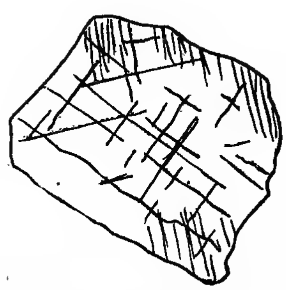


FIG. 14. PRISMATIC SECTION OF AUGITE IN NO. 133.

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):

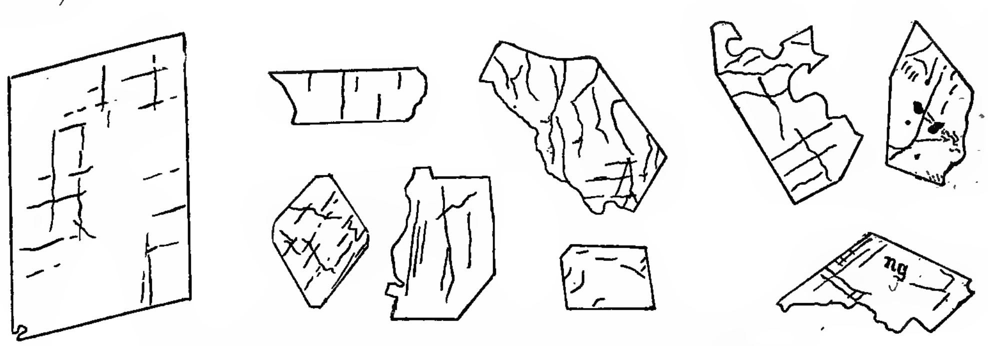


FIG. 15. ANORTHOCLASE IN NO. 140(7) MORE OR LESS RESORBED.

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. 1/4 N. E. 1/4 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.

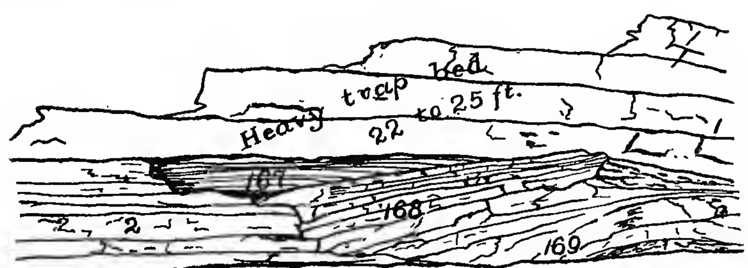


FIG. 16. SANDY, RED SHALE, NO. 167, BETWEEN LAVA SHEETS AT THE MOUTH OF TEMPERANCE RIVER.

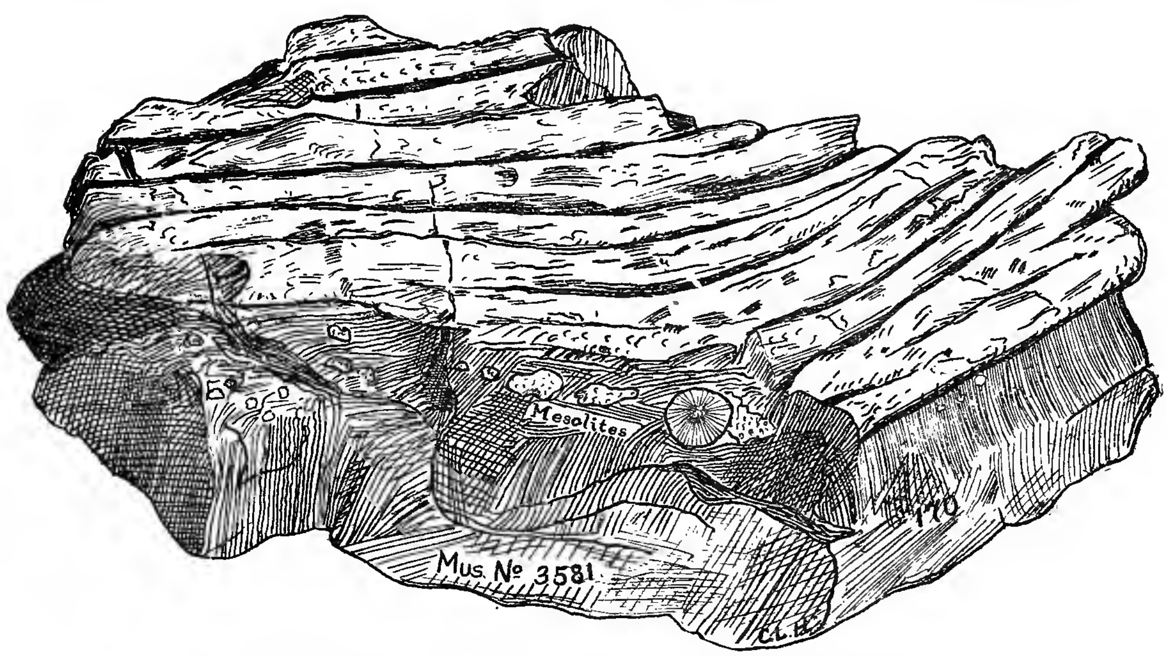


FIG. 17. ROPY WRINKLES ON THE LAVA FLOW OF ROCK NO. 170.

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.

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 summer of 1876, and the face of the rock shows perpendicularly about eighteen feet. It probably exists as a dike." It cuts No. 201.

Ref. Annual Report, ix, page 52; Proceedings American Association for the Advancement of Science, vol. xxx, page 163; Bulletin ii, page 113.

Meg. A medium-grained, dark diabase showing lustre-mottling. Cracks and seams are slickensided, coated with chlorite, or with thin sheets of metallic copper. One hand specimen, marked 200, is a mass of dark-green chloritic material, evidently from one of the layers mentioned above. Along the centre of the specimen are narrow seams of a soft red mineral, perhaps laumontite.

Mic. The rock is composed of *plagioclase* laths, *augite*, which is frequently in plates of large size, *olivine*, now largely altered to a substance which is black, yellowish and brown, and is perhaps *bowlingite*, *magnetite*, *hematite*, *chlorite* and a small amount of metallic *copper*. The olivines in some instances have part of their outlines conditioned by the surrounding feldspar, thus showing that some of the feldspar is older than some of the olivine.

Two sections.

Age. Probably a part of the great Beaver Bay diabase sheet. U. S. G.

NO. 200A. DIABASE *(with thomsonite and copper)*.

Fall River mine, N. W. ¼ sec. 24, T. 61–1 W.; a short distance up Fall river. Near the lake shore.

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

Meg. Inclusions or concretionary masses, apparently within No. 200, of a different color and structure from No. 200 itself.

Mic. Following is Wadsworth's description: "In the least altered and most coarsely crystalline portions the rock is composed of pinkish, divergent, lath-shaped *feldspars*, with interstitial dark material. Irregularly intermingled with this are dark-brown to black or yellowish-brown masses and streaks of decomposed and softened rock with a hardness of about 3. In the coarsely crystalline portions occur segregations of *chalcedony*, *epidote*, *zeolites*, etc.

"The least altered portions of the sections are composed of *augite*, *magnetite* and *feldspar*, with various secondary products. The augite is but little changed to *viridite*, and is of a clear, pale yellow or yellowish brown color. The feldspar, however, has suffered much, being kaolinized, and contains viridite. Along the fissures, and in the patches of *kaolin* and *ferrite* occurs considerable native *copper*, as a secondary product, or else as an infiltration. It was not observed in connection with the augite, and but rarely near the magnetite, although one might naturally expect to find it in connection with that mineral. The *copper*, indeed, appears mainly in the interior of the feldspars during that condition of their alteration in which they are brownish gray, from the dissemination of kaolin with subordinate ferrite, but the copper disappears when the alteration is carried still further, as it often is in the section. The feldspar here is largely replaced by viridite and chalcedonic patches. In the sections of the more highly altered portions of this rock, the augite is changed, for the most part, to a dirty green viridite and chlorite, which show oftentimes a spherulitic structure. In the more highly altered parts many *apatite* needles occur.

"In the portions of the rock which are most altered, the chalcedony forms beautifully polarizing radiating concretions, and the general appearance of the rock is that of granite instead of that which it really is—an altered, coarse-grained diabase."

A Boricky test of the pinkish feldspar gave only lime and soda, the former being in large crystalliths of monoclinic form, and the latter as small hexagonal rods. No signs of potash were observed, and the feldspar may hence be assigned to the prevalent category, viz., *labradorite.*

The mineral, however, which seems to be that called chalcedony, since it is radiated in structure and polarizes in brilliant radiating colors, is certainly a biaxial mineral, and hence cannot be any form of quartz. Quartz, when of the same thickness, would show the same color in all positions and directions when its axis is parallel to the section as in the radiating fibres, and also when parallel to either nicol it would simply be dark. A single test in convergent light confirms this, since the interference figure is either a single optic axis or a curved black bar of a biaxial hyperbola, or occasionally a bisectrix (n_g). The fibres which are cut perpendicular to their longer dimensions show sometimes rectangular shapes. Such forms are found when the centre of a spherule or a radiated mass is cut, and in such case the highest colors of double refraction are found; and such sections show the figure of the optic normal (n_m) in convergent light, indicating the axial plane is transverse to the longer dimensions of the fibres. In other words, the mineral is orthorhombic or tetragonal and has a high double refraction, and its elongation is perpendicular to the axial plane. Further, when the fibres are cut parallel to their elongation, they extinguish parallel. The bisectrix n_g is in the acute angle of the optic axes. Measured in air by the axial goniometer of Lacroix (American Geologist, February, 1896) this angle is found to be about 50°.

These characters, combined as they are, can only be found in *thomsonite*, which is not a very uncommon mineral in the coarse traps of the region, though generally in amygdules of much larger size. This radiated mineral being excluded from that category, there seems to be no free quartz in the sections examined.

Four sections examined, three being the same as examined by Dr. Wadsworth.

Age. Cabotian.

Remark. There is now no doubt, judging from an examination of numerous instances of contacting red rock and the basic eruptives, that the peculiar characters of this rock are the result of small masses of the red-rock series being included in No. 200 at the time of the intrusion, and after complete or partial fusion the dissemination of the elements into the basic rock.

The rock has evidently suffered a great change since its intrusion, giving rise to the zeolites, the "chalcedony" and the copper, and carrying forward the alteration of the feldspars, but a considerable portion of the alteration was probably accomplished before the cooling of the mass. The three sections examined by Wadsworth all contain particles of *metallic copper*. Two others made since show the same. The amount is not sufficient, here, to warrant any economic exploitation. It only shows that the circulating waters at the time of its deposition had access to considerable copper-bearing rock masses, and it is not unlikely that such sources may yet be found in the vicinity. The original source is more likely to be in connection with the reddish-brown felsyte which this basic eruptive cuts than in the eruptive itself—or in some associated detrital rocks.

In further examination of these radiating spheruliths two sections were made by M. Marchand of a thickness as low as 0.015 millimeters. In these the augite shows, between crossed nicols, a light yellow tint, the feldspars are neutral, and the spheruliths, when cut properly, have a yellow color. Some part of the thomsonite shows no color, or only a gray tint, but darkening when parallel with the threads; and some beautiful, perfect, radiated spheruliths, having a negative elongation, have, intermediate between the centre and the periphery, a sharply defined concentric band of fibres parallel with those on either side of the band which are of positive elongation. On the introduction of the quartz plate of the sensitive tint the quadrants are contrastedly colored, and those in this narrow band are contrasted in an opposite direction from those outside and inside of the band.

Some *calcite* also has formed in association with this thomsonite. N. H. W.

No. 201. Aporhyolyte?

From the mine at Fall river. It is cut by No. 200.

Ref. Annual Report, ix, page 54; Annual Report, x, page 141; Proceedings American Association for the Advancement of Science, vol. xxx, page 164.

Meg. A very fine-grained, compact, hard, siliceous rock containing small, reddish feldspar phenocrysts. Quartz phenocrysts are very rare, only two or three being shown on the hand specimen. No section.

Age. Cabotian; red-rock series.

Remarks. This rock seems to be of the same general character as the rock of the Great Palisades—*i. e.*, an acid surface lava—and it is also thought to be of the same age. U. S. G.

No. 202. Diabase *(with olivine)*.

" Green, coarse doleryte, round the east point of Grand Marais; a low exposure in the coast line; with concretions or inclusions of a finer grain. This terminates rather abruptly on the east, somewhat like a dike, when in contact with No. 203; but it is not basaltic, nor is the contact abrupt. Nos. 202 and 203 change colors gradually, and in fragments are mixed through a breccia of three or four feet wide."

Ref. Annual Report, ix, pages 52, 53.

Meg. A black, heavy, rather coarse diabase. There are a few large porphyritic feldspars, one of which is three-fourths of an inch across. The hand specimen also contains a few small areas, aphanitic, and of a dark-brown color. These areas are quite soft. They may be included fragments of a foreign rock or pseudamygdaloidal areas of some soft earthy mineral.

Mic. The section, which is a poor one, shows an ordinary diabase, considerably altered. There are some dirty yellowish areas which represent original olivines.

One section.

Age. Cabotian. U. S. G.

No. 203. Aporhyolyte.

Outcropping in the beach east of Grand Marais. It is the rock that gives red color to the beach for many miles, by reason of the rapid formation of pebbles from the frequent cracks that intersect it. The pebbles also are very durable. They are also abundant in the drift clays of the region. The rock dips 5° to 15° toward the lake, and consequently in some instances, as viewed from the lake, appears horizontal by reason of the coincidence of the coast line.

Ref. Annual Report, ix, pages 53, 54, 55, 57; Annual Report, xiii, pages 100 (No. 162), 103; Bulletin viii, page xxxiii.

Meg. Very much like the Palisade rock (Nos. 138 and 139), and sometimes much resembles the siliceous, slaty, gray rhyolyte of Beaver bay (Nos. 127, 528).

Mic. The specimens bearing this number are rather more crystalline than the Palisade rock. The thin sections show translucent, sharp, rod-like areas, recalling an original feldspathic crystallization, and between them the angular spaces are reddish and sub-opaque; but the whole rock is permeated with silica, which embraces the rest of the undefined mineral contents in a coarse poikilitic nexus which darkens simultaneously over large areas.

Two sections.

Remark. The following analysis has been made of rock No. 203:

SiO_2	73.58
Al_2O_3	13.36
Fe_2O_3	3.78
FeO	.69
CaO	.81
MgO	.18
K_2O	2.48
Na_2O	2.42
H_2O	1.14
Total	98.44

Age. Cabotian; red-rock series. N. H. W.

No. 203A. Laumontite.

From a vein in No. 203. The specimen is in the form of crumbled powder, rather coarse, of a light-pink color.

Ref. Annual Report, ix, page 53. N. H. W.

No. 204. Breccia.

Nos. 204, 205 and 206 are transition rocks, in the order numbered, between Nos. 202 and 203.

Ref. Annual Report, ix, page 53.

Meg. A red, fine-grained, shaly rock, containing much laumontite. The hand sample contains a few apparent fragments of a rock very similar to the rest of the hand sample, but more compact, finer grained and not containing laumontite.

No section.

Age. Cabotian. U. S. G.

No. 205. Diabase. (*Contacting.*)

A supposed transition rock between Nos. 202 and 203, as stated above.

Ref. Annual Report, ix, page 53.

Meg. Compact, fine-grained, brown or gray, with some reddish brown small crystalline angular areas, as if of a rusted feldspar.

Mic. There are remaining some feldspar forms, but they are filled with impurities. They can sometimes be distinguished as twinned triclinic crystals. Narrow, slender, greenish crystals, with feeble absorption, cut across the rock. These extinguish sometimes at a large angle, approximating 26° with the nicols, and have a conspicuous cleavage parallel with their elongation; also an irregular, coarse fracturing, simulating a cleavage, which is oblique to the other. At other times they extinguish nearly parallel to their elongation, but in this case the cleavage is not evident, and the section is obviously not parallel to the edge *m m*. This mineral also has a high refractive index. It is either *hornblende* or *augite*, and the last mentioned character points strongly to augite. The most of the rock is not distinctly crystalline, but poikilitic quartz areas spread through it.

One section.

Age. Cabotian. N. H. W.

No. 206. Diabase.

See under No. 204.

Ref. Annual Report, ix, page 53.

Meg. A fine-grained, dark, diabasic rock. It contains a few small areas, apparently pseudamygdaloidal, of quartz; also of calcite, and along a seam some soft saponite-like material. The hand specimen also contains fragments, not always sharply separated from the rest of the rock, of a very fine-grained, brownish rock.

Mic. The section shows a fine-grained diabase, with *plagioclase* laths, *augite*, *magnetite*, *hematite* and large amounts of confused, dirty, greenish to brownish, alteration products. Some secondary *quartz* is also present. At one edge of the slide is a small area which probably represents part of one of the fragments noticed in the hand specimen. It is composed of quartz, feldspathic material, augite, and confused alteration products. The quartz is in poikilitic areas.

One section.

Age. Cabotian. U. S. G.

No. 207. DIABASE *(with olivine).*

From a dike about 200 feet wide cutting the rock No. 203. There are six such dikes within the distance of a mile. They run E. 15° S.; a short distance east of Grand Marais.

Ref. Annual Report, ix, page 53.

Meg. Coarse, dark-gray diabase.

Mic. Similar to No. 199, of which it probably is a cotemporary. The large augites embrace the earlier feldspars in an ophitic manner.

One section.

Age. Cabotian; probably an apophysis of the great gabbro outbreak which exists in full force in the hills further north. N. H. W.

No. 208. DIABASE *(with olivine).*

East of Grand Marais; just beyond the mouth of the third little creek represented on the Lake Survey chart.

Ref. Annual Report, ix, pages 53, 54, 56.

Meg. Two rocks, or two forms of the same rock, are designated by this number. One is fine grained, brown and heavy, outwardly resembling the Two Harbor rock (compare Nos. 117 and 176), but the other is coarser and has a greenish-gray color. It is less heavy than the former.

Mic. These are both essentially olivine diabases, but the finer-grained one contains much more olivine than the other.

Two sections.

Remark. "This rock occurs much like a dike, at first, with perpendicular jointage, or basaltic structure in beds, but soon larger bedding, crossing these, cuts it and causes the rock to all appear bedded. This is fine grained and brown, and is about twenty-five rods from the last of the dikes already mentioned. This becomes a bedded rock like similar beds seen before, having sometimes the appearance of the Two Harbor rock. It slopes toward the water. Just beyond the mouth of the third little creek (on the Lake Survey chart) these beds become disturbed and brecciated, and even tipped in the other direction (southwest), and are crossed by a dike of doleryte, like No. 207, about eighteen feet wide. Previous to this (further west), they show patches amygdaloidal; but just on the east of this dike there is much amygdaloid with laumontite. Just before reaching the mouth of the fourth creek, another dike like No. 207 crosses these beds, running in the same direction as those before seen, and throwing up the firm heavy beds of No. 208, at a high angle. This dike is basaltic perpendicular to these beds by being cooled by them. This last larger dike is only exposed near the water, and its exact contact with No. 208 is invisible. It is exposed about fifty feet." (Annual Report, ix, pages 53, 54.)

This description of the field appearances seems to show that these beds are older than a series of coarse diabase dikes which cut them, and which is presumably of the same date and origin as the sheet at Grand Marais. It is for that reason that these beds (No. 208) are put in the Cabotian along with the "red rock" of the region. The brown fine-grained rock having this number is allied to Nos. 217–219, but shows little or no glass.

If the foregoing parallelisms are correct, it is necessary to admit that before the Grand Marais diabase, there was a large series of surface eruptives, both basic and acid. If the Grand Marais diabase is the parallel of the Beaver Bay diabase, as believed, and that is the continuation of the Duluth gabbro, as believed, it is also necessary to allow an eruptive epoch which gave origin to basic surface flows at Duluth prior to the advent of the gabbro of that place as well as cotemporary with it.

N. H. W.

No. 209. Diabase *(with olivine)*.

West of the mouth of Devil's Track river. Basaltic perpendicularly to the tilted beds of No. 208. Runs nearly east and west.

Ref. Annual Report, ix, page 54.

Meg. A medium-grained diabase, dark gray in color. There are numerous small grains of a yellowish mineral (olivine) in the rock, and these give a yellowish tinge to the hand sample.

Mic. A medium-grained olivine diabase, the *olivine* being quite abundant. It is altered more or less to a brownish substance. The rock is comparatively fresh, but still has a number of dirty greenish areas and also areas of *chlorite* in radiating masses; perhaps these areas represent, in part at least, interstitial *unindividualized magma.*

One section.

Age. Cabotian (?)

U. S. G.

No. 210. Diabase.

Southeast corner of sec. 8, T. 61–2 E. It forms a low exposure and is a firm, smooth-weathering rock.

Ref. Annual Report, ix, pages 54, 55.

Meg. A rather fine-grained, brown, diabasic rock. It is permeated by small areas of a soft greenish mineral.

Mic. The section shows a fine-grained diabase, with large quantites of *hematite.* The hematite is in large part secondary, filling in the areas between the feldspars and replacing the augite; it also occurs in transparent films in numerous cracks.

Magnetite is present, but is not nearly as abundant as the hematite. The brown color of the rock in hand specimens is due to the abundance of hematite.

One section.

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

NO. 211. DIABASE. *(Lustre-mottled.)*

Cow's Tongue point, the point next west of Kimball's creek, S. E. ¼ sec. 9, T. 61–2 E.
Ref. Annual Report, ix, pages 54, 55; Annual Report, x, page 43.

Meg. Similar to No. 210. The hand sample shows a water-worn surface which is blotched with lighter areas.

Mic. Essentially identical with No. 210, but the augite is in larger plates, and the *magnetite* is more abundant, but *hematite* is present in large quantities.

One section.

Age. Cabotian. U. S. G.

NO. 212. APORHYOLYTE.

In the bay next east of Cow's Tongue point, after a short pebbly beach, this rock forms a low outcrop.
Ref. Annual Report, ix, page 54; Annual Report, x, page 43.

Meg. A red or brownish red rock with scattered porphyritic crystals of some glassy feldspar, but no quartzes.

Mic. This rock much resembles the Palisade rock (No. 139), but in the absence of original quartzes it is probably less acid. It is also the same rock as No. 203.

One section.

Age. Cabotian. N. H. W.

NO. 213. PORPHYRYTE.

From the extremity of Fish Hook point, near the centre of sec. 6, T. 61–3 E.; eleven miles from Grand Marais. Lies as an overflow, and is visible under the water toward the west for some distance, cut by dikes.
Ref. Annual Report, ix, page 54; Annual Report, x, page 43.

Meg. Dark brown, easily splitting rock, which has scattered, light-colored feldspars in a fine matrix. This rock is fissile, horizontally, or obliquely to the main structure, which dips toward the lake. Nos. 213, 214 and 215 may be included in one general description, since they occur on the same general expanse of beach extending from the point westward for nearly half a mile. It is firm against the hammer and against the weather, but is filled with old cracks and joints that make it almost impossible to get a fresh break. It has a red color outwardly, near the water, except in the joints which are iron-shot (so called by Norwood) and blue black. It is finely porphyritic with stellar spangles of feldspar and with isolated crystals that weather nearly white.

Mic. A few *olivines*, numerous *feldspar* microliths and minute *augites (?)* were generated in this rock before the consolidation. There remained, however, a large amount of undifferentiated magma, which now renders the slide dark and obscure between the nicols. This magmatic base is brownish with disseminated *hematite* and surrounds the small microliths. The olivines are probably the oldest crystals in the slide, as they are the largest, but they are wholly altered and are either opaque with ferruginous matter or light green and nearly isotropic with the usual product of such alteration. The plagioclases are small, blurred, apparently broken and so indefinite as to render their specific determination almost impossible. The minute brightly colored points which are presumed to be augite are scattered promiscuously through the slide, but seem to cluster most numerously in the vicinity of the altered olivines, a fact which casts doubt on their supposed augitic nature, but they resemble, except for being much finer, the fine augites that appear in several other fine-grained basic rocks of the region. One section.

Age. Cabotian. N. H. W.

No. 214. Porphyryte. (*Quartziferous.*)

Forms a low inconspicuous outcrop, runs along two or three hundred feet, dipping a little south of east, about one-fourth of a mile west of Fish Hook point.

Ref. Annual Report, ix, pages 54, 55.

Meg. More firm and siliceous than No. 213, and showing a few quartz phenocrysts.

Mic. More completely crystalline, with a little pegmatitic *quartz*; also *calcite* and *epidote*. One section.

Age. Cabotian.

Remark. This rock seems to approach very near the rocks Nos. 127 and 129, at Beaver bay, and perhaps has the same origin and date. The occurrence in the lake, off shore, opposite rocks Nos. 214 and 215, of a basaltic intrusive, may have some bearing on the date and origin of this intermediate rock. N. H. W.

No. 215. Porphyryte. (*Quartziferous.*)

Near No. 214, at Fish Hook point.

Ref. Annual Report, ix, pages 54, 55.

This is also an intermediate rock, there being more or less secondary silica diffused through it, due probably to deep-seated contact with acid rocks.

Age. Cabotian. N. H. W.

No. 216. Diabase.

"It is a greenish-brown rock with curling internal structure, containing quartz and amethystine nests, from the westerly of the two little points west of Brulé river, and before reaching either island, where a little stream enters the lake. It is a short outcrop rising about five feet in the midst of a red beach. This is an igneous rock; and the next point is of the same, also the little island off it, which is in the line of bearing."

Ref. Annual Report, ix, page 55.

Meg. The hand sample shows a rather fine-grained diabasic rock holding a few small areas of chalcedony or of chalcedony and quartz. Along joints a small amount of saponite is present.

Mic. A fine diabase with plates of *augite* which include a number of feldspar laths. The spaces between the augite plates, which are roughly circular in form, is occupied by *feldspar* laths in a dark confused mass composed of *magnetite, hematite* and greenish alteration products. No olivine is now present, but there may have been some original olivine. This dark material between the augite plates perhaps represents an original glassy matrix. Some of the augite plates are comparatively free of feldspar laths. The general structure of the rock is similar to that represented on plate IX of the "Copper-Bearing Rocks of Lake Superior" (U. S. Geol. Survey, Mon. v).

One section.

Age. Cabotian. U. S. G.

NO. 217. BASALT. *(Amygdaloidal.)*

In the midst of a red beach, extending eastward from the easterly of the two little points west of Brulé river, are occasional exposures of this rock which resembles the Two Harbor rock. The specimen collected is from a conspicuous outcrop within the bay between two streams.

Ref. Annual Report, ix, page 55.

Meg. A very fine-grained, brownish-red rock which has irregular streaks and blotches of a greenish color. There are a few rounded amygdules of quartz and chalcedony, and also some of a soft, green chloritic material.

Mic. The section shows plagioclase microliths in a background composed of confused greenish alteration products, *magnetite* and an opaque brown substance. This brown substance, which is bright red in reflected light, makes up the main mass of the rock; it is supposed to represent original *glassy* material. Throughout the section are more transparent areas where this brown substance is lacking. These are, evidently, the greenish blotches seen in the hand specimen. They contain, besides the *plagioclase* microliths, magnetite and greenish alteration products, small, brightly-polarizing grains which are probably *augite.*

One section.

Age. Cabotian. U. S. G.

NO. 218. BASALT *(with olivine).*

From the point near Brulé river off which lie the principal islands.

Ref. Annual Report, ix, pages 55, 56.

Meg. Brown, conchoidally fracturing rock, very fine grained, with small quartz-lined geodes, weathering rough-angular, and black when not under friction. Back from the beach friction, but on the beach, old weathered surfaces are brick red. Similar to No. 217 and to No. 176.

Mic. A fine-grained basalt. The *feldspars* are lath shaped, and sometimes grouped in a radial manner, each consisting usually of two or three albite twins. They do not conspicuously cut any of the other minerals, in the manner of a typical ophitic structure, but occasionally they are seen to interfere with the outlines of the small augites.

The *augite*, though in small grains, can easily be distinguished. Its grains are larger than the olivine grains, and they have a yellowish color, and less refractive power than the olivines. They are comparatively scarce.

Olivine is in very small grains, scattered abundantly throughout the slide, sometimes embraced in the augites and sometimes in the feldspars. It is well preserved considering the minuteness of the grains.

Glass is less common than in No. 176 or in No. 217, but still occurs sufficiently to warrant the designation basalt. It surrounds all the other crystals. It is not so much ferrated as in No. 217.

Occasional *magnetite*, even having its rectangular outline, is also to be observed.

One section.

Age. Cabotian. N. H. W.

No. 219. Basalt.

"A little beyond [east of] the last locality [a point near the Brulé river, off which lies the principal islands], and just as the rock disappears again, it suddenly becomes slaty or closely jointed and laminated, dipping S. 10° E., and more enduring. In this condition it forms some of the islands near the beach, and also rises fifty or more feet near the coast back from the water."

Ref. Annual Report, ix, pages 55, 66.

Meg. A very fine-grained, hard, compact, brown rock. It is of the same general character as Nos. 216 and 217.

Mic. Microliths of *plagioclase* are the most noticeable feature of the section, but between these, and not sharply separated from them in size and shape, are other plagioclases; thus nearly the whole section is composed of feldspar. There are also small, more or less angular grains of *augite*, also *magnetite*, and some alteration products. In structure and composition the rock resembles No. 218.

One poor section.

Age. Cabotian. U. S. G.

Remark. Nos. 217, 218 and 219 seem to be a repetition of Nos. 213, 214 and 215 outwardly, but the latter trio is more acid. It may be that structurally they are nearly related. No. 176 belongs with Nos. 217, 218 and 219.

These beds (Nos. 217–219) seem to have been disturbed by some upheaval, and appear in nearly all respects like those of No. 208 (fine grained), though not so conspicuously exposed. N. H. W.

No. 220. Basalt.

Mouth of Brulé river, forming a dull point.

Ref. Annual Report, ix, page 56; Annual Report, x, page 43.

Meg. A dark-gray, diabasic rock, of fine grain. It contains numerous small black blotches. (Compare No. 539.)

Mic. *Plagioclase* laths are seen distributed in a background which is composed of *augite* in small grains, *magnetite,* chloritic alteration product, and dirty, faintly brownish areas. These areas (which are abundant), except for small bright points, show no effect on polarized light, and they are thus referred to an originally *glassy* condition of the rock. The large amount of this glassy material is noticeable. The black blotches noticed on the hand sample are seen to be pseudamygdaloidal aggregations of the chloritic material.

One thick section.

Age. Cabotian. U. S. G.

Remark. In the field this dark-gray rock is seen to be partly brown, and in some places it is about half brown. It is thus shown to have outwardly, as it has microscopically, a close relation to the rocks Nos. 217–219, in association with which it appears along the beach. N. H. W.

No. 221. DIABASE. *(Coarse.)*

At a distance of about twenty rods east of the mouth of Brulé river.
Ref. Annual Report, ix, page 56; Annual Report, x, pages 43, 140; Bulletin ii, pages 76, 100, 101; American Association for the Advancement of Science, vol. xxx, page 163.

Meg. A coarse rock, rather dark colored and easily rusting. Evidently one of the most recent eruptives of the region, judging by its contents and from the general structural relations. The crystals are all fresh and of large sizes.

Mic. The feldspar is twinned, both on the pericline and albite plans, the lamellæ crossing at varying angles, as cut by the plane of the section. It is very fresh and includes fine needles, apparently of *apatite.* The highest extinction angles on 010 range from 25° to 27½°, indicating *labradorite.* Several sections show a single optic axis in convergent light, the figure consisting of a single straight bar, which rotates in a direction the reverse of that of the rotating stage. Such sections are neither dark nor colored, but show a dim light, and are thus readily recognized in a thick section like the one examined, whose thickness, judging from the colors of the labradorite, compared with Michel Lévy's colored scale (Detérmination des Feldspaths, plate), is about .07 millimeters. The colored fringes on the *augites* indicate the same thickness. When the albite and pericline bands are at or near right angles, as happens sometimes when the crystal is cut in the zone 001:100, the narrow sharp pericline striæ maintain their integrity through the albite bands. The section also shows Carlsbad twinning, the twins themselves being also twinned.

Wadsworth mentions orthoclase and quartz in this preparation, but we can find no orthoclase. There is a little quartz in the altered magmatic remnants.

The *augite* is well preserved, the thickness of the section not producing any dimness in the colors or in the transparency. It is coarsely fissured, but does not seem to pass into diallage. It exhibits a colored striation or banding, occasionally similar to that of the plagioclases, except that the striations are confined to the central portions of the grain. These manifest a kind of multiple twinning sometimes possessed by augite. According to Rosenbusch these twin striations are parallel to 100.

Magnetite is common in large angular grains, apparently of original generation.

Apatite is abundant in the feldspar, in fine needles. These needles are frequently abundant along a side which lies adjacent to the original magma unindividualized as if they projected from the magma into the feldspars. They can also be seen in the unindividualized magma, independent of the feldspars, sometimes forming a loose network. The augite is entirely free from them. This seems to indicate that they were the earliest of the generations from the magma, and that their formation ceased before the augite was generated, or that the augite had a special facility for rejecting them.

If any olivine be present it is in very small amount, and is in such obscured relations to the opaque remnants of the magma that it cannot be distinguished as such. Dr. Wadsworth calls attention to the similarity of this rock to the ovifak basalt of Greenland.

One section.

Age. Cabotian.

Remark. This rock resembles the rocks Nos. 133, 126, 114, 107, 106, etc., and is presumed to occupy a similar relation to earlier eruptives, if not a cotemporary in time with those. It rises back of Sickle and Double bays, and forms an important constituent in the topography as well as in the origin of the Sawteeth hills, both at the eastern and the western extremities of that range. (Compare No. 540; also, Nos. 1813 and 1815.)

It seems to be necessary to trace the outcrop of the basal conglomerate of the Potsdam, seen at Grand Portage bay and in Puckwunge valley, southwestwardly, in order to determine its stratigraphic relation to the great diabase, Nos. 221, 222, 540, and hence to the Beaver Bay and Duluth equivalents of the same, *i. e.*, to ascertain the possible later date of this diabase than that of mount Josephine, etc. N. H. W.

No. 222. Diabase. *(Coarse.)*

Underlies and apparently forms a part of No. 221, the two rising in a bluff about fifteen feet, and forming two or three little points within a mile east of the Brulé. The intervening bays are occupied by large rounded boulders of the same (*i. e.* of No. 221), with little rock exposure.

Ref. Annual Report, ix, pages 56, 57; Bulletin ii, page 77, figure 2, plate VI.

Meg. This is coarse and similar to No. 221. It weathers into a light green, and sparkles all over with what at a distance appears to be mica, but which is, in part at least, due to the glittering cleavages of feldspar, and of pyroxene slightly iron-stained.

Mic. The feldspar shows a curious alteration from one species to another. The original feldspar is altered by the entrance of many kaolinic microliths, and in some instances the twinning lamellæ are obliterated. This has extinction on the brachypinacoid at 64°, indicating *bytownite, near anorthyte.* Intimately ingrown, in irregular areas in this feldspar, is another which is clear and glassy, and which extinguishes not in unison with the other. These areas ramify singularly, like the spreading growth of a mineral that is produced at the expense of another. In some cases the secondary feldspar has wholly replaced the original, so far as seen in the section, and the area appears like quartz.* This secondary feldspar is *andesine,* as indicated by the extinction on n_g at 9°. In another section, the acute bisectrix being n_p, the angle of extinction is 3° on the edge 100:010, indicating *andesine-oligoclase.* In the centre of the same crystal, which is fresh and set off from the border as from a peripheral zone, extinction is 8°, and the acute angle contains n_g, indicating again *andesine.* Thus it appears that this feldspar changes, with the optic angle, from anorthite to andesine and to andesine-oligoclase.

The pyroxene is *diallage,* having a secondary cleavage parallel to 100, characteristic of that species. The grains are not altogether thus affected. It was cotemporary with or slightly preceded the feldspar (*i. e.,* the original feldspar). There are also later pyroxenes that are better preserved and sustain ophitic relations with the feldspars.

Three sections.

Age. Cabotian; Beaver Bay diabase(?)

Remark. No. 222 differs remarkably from 221, although they are in contact, and must be considered the older rock. According to the field description No. 221 is basaltic, further east, and rises into the crests of the hill range which passes inland at Sickle bay.

N. H. W.

No. 223. Gabbro (?)

Four miles east of the mouth of the Brulé river. Rises in a bluff facing Sickle bay toward the east, thirty feet high, and having nearly vertical basaltic structure. Evidently the same rock mass as No. 221. (See No. 540.)

Ref. Annual Report, ix, page 57; Bulletin ii, page 101.

Meg. This rock is much fresher than No. 222. In the sun-light are many reflecting cleavage surfaces of feldspar, but the rock is in general coarse, dark and heavy.

Mic. The feldspars are not earlier than the pyroxene, but these minerals seem to have formed simultaneously. In the large slide examined not an instance of ophitic structure is discernible, but in rare instances the *augite* is entirely enveloped by the *feldspar.* The *augite* has a small optic angle. Considerable amounts of the unindividualized magma were still in the rock when it solidified, but these are now altered to a green and isotropic substance, in the midst of which is rarely seen a little

*Some such small areas were mistaken for quartz, in his description and illustration, by Dr. Wadsworth. *Bulletin ii,* plate VI, figure 2, Minnesota Survey. These areas all give a curved black bar in convergent light.

quartz. No olivine is visible. The augite but rarely shows any tendency to become diallagic. The following extinctions were measured on the feldspar, indicating a *labradorite:* Extinction on n_p, 56°; extinction on n_p, 55°; angle on n_p, between the pericline and albite bands, 81° (Fouqué, Bulletin de la Société de Minéralogie de France, vol. xvii, page 428).

Two sections.

Age. Cabotian; Beaver Bay diabase (?). It is at present impossible to affirm either the Cabotian or the Manitou age of this rock. For the sake of consistence, with what precedes, this is classed Cabotian; but it may be later than the basal conglomerate of the Potsdam. More field work is needed to determine this point.

N. H. W.

No. 224. Aporhyolyte (?)

From the rocky point which divides Double bay into two parts; N. E. ¼ S. E. ¼ sec. 10, T. 62-4 E. This rock is somewhat basaltic like trap, and also rudely bedded.
Ref. Annual Report, ix, page 57.

Meg. A fine-grained, brown rock, very indistinctly mottled with a darker color. Under the lens the rock appears granular, but the only mineral distinguishable is feldspar.

Mic. The section, which is quite fine grained, is made up of *feldspar*, *quartz*, green *hornblende*, *hematite*, *magnetite*, *chlorite* and *augite(?)*. The feldspars are more or less cloudy, are mostly untwinned, and are frequently in short, stout crystals, although many of the grains are allotriomorphic. The quartz is in small grains and sometimes in small poikilitic areas. The hornblende is in small plates, and is evidently secondary. The grains, which are perhaps augite, are minute, greenish to colorless, and polarize brightly. In a few places there is a little greenish to brownish interstitial matter which, under crossed nicols, is dark, except for a few light points. It probably represents *glass*. Other areas, which appear similar to this interstitial material in ordinary light, under polarized light are seen to be largely feldspathic. The rock as a whole is considerably altered.

One section.

Age. Cabotian.

Remarks. See under No. 226.

U. S. G.

No. 225. Gabbro *(with orthoclase)*.

From the most easterly point of Double bay. (See Nos. 5, 263.)
Ref. Annual Report, ix, page 57; Bulletin ii, page 81.

Meg. A coarsely crystalline "orthoclase gabbro" (apparently), as defined by Irving, comparable to that form of the gabbro at Duluth, which is represented by No. 5 of this series.

Mic. The *feldspar* in the sections examined is very much impregnated by quartz and clouded by other alterations, so much so that it is sometimes impossible to state its specific relations. Some of it is certainly triclinic, having yet remnants of the characteristic twinning of the albite type. There are some large plages, however, having more nearly a square outline that are more abundantly supplied with the pegmatitic *quartz*, which may be *orthoclase.* Such acid feldspar, however, cannot be considered an original integral portion of the rock, but only as accessory, and due to the proximity of contact on the clastics. This fact, *i. e.*, the contact with the sedimentaries, manifests itself in many places in a silicification of the other (original) elements of the basic eruptives and in the appearance of orthoclase.

The *augite* seems to have begun its formation from the magma cotemporaneously with the feldspar, its form in some cases being independent of the feldspar, and even being embraced in a certain manner by the feldspars whose outlines give way before it. Yet, in other places, there seems to have been a later generation of augite, which now is seen to fit itself into the interstices between the feldspars. In all cases it is much altered.

The *quartz* is so arranged in the feldspars as to form a microscopic pegmatitic structure, numerous small areas extinguishing at the same moment, each small section sometimes being triangular and aligned with others as if their location had been determined by the cleavage of the feldspar, although, at present, there is no remaining trace of such cleavage. Quartz also appears otherwise as independent, sizable grains.

Magnetite in the usual form and quantity is distributed throughout the section.

Two sections.

Age. Cabotian.

Remark. This is put in the Cabotian because of its obvious association with Nos. 221, 222 and 223, both petrographically and structurally. It is presumed to be a contact phase of the same. This is in keeping with the assignment of No. 5 at Duluth, which is put in the Cabotian because, starting with the gabbro at Duluth as Cabotian, its contact apophyses would also be Cabotian, especially as there we find the upheaved Animikie and red rock associated with it. Still, there would be nothing unreasonable in expecting Manitou contact phenomena similar, if not identical, with those of the Cabotian. N. H. W.

No. 226. Aporhyolyte (?)

From an isolated dike-like exposure on the beach in the next shallow bay east of Double bay; N. W. ¼ S. W. ¼ sec. 12, T. 62-4 E. This rock is closely jointed and basaltic.

Ref. Annual Report, ix, pages 57, 58, 59.

Meg. A fine-grained, reddish-brown rock, which is made up of small, reddish feldspars and a dark substance. It is porphyritic with small, reddish feldspars, and also has a few porphyritic crystals which are fresher than the reddish phenocrys are gray and distinctly polysynthetically twinned.

Mic. None of the gray feldspar phenocrysts are cut by the section. There a however, several of the smaller red phenocrysts. These are much altered a reddened, and show no twinning striæ, but some of them are so much altered th traces of this twinning would probably not remain, even if it was once prese The rest of the section is composed of feldspar, quartz, hornblende, augite, magneti hematite and chlorite.

The *feldspar* is somewhat cloudy, is in small grains and stout crystals, and do not usually show twinning striæ, although simple twins are seen. This feldspar somewhat altered and reddened, is in such small grains, and does not show cleava cracks, that no careful determination can be made. It, however, extinguishes appro imately parallel to the long sides of the crystals, and also parallel to the twinni line, when one is present, and it is thought to be largely *orthoclase.*

The *quartz* is in small grains and is sometimes intergrown with the feldspar form micropegmatyte, and is also in small poikilitic areas.

The *hornblende* is the usual green variety and is quite abundant. It occurs small plates, pleochroic in shades of green and yellowish, and seems to be all of secondary nature. In fact, in some places, it can be seen as an alteration fro pyroxene.

The *augite* is greenish to colorless, and is usually in small grains, many of whi are altered to hornblende. There are a few larger crystal of augite, partially idiomo phic, which are of about the same size as the red sub-porphyritic feldspars of t section.

The rock is considerably altered, and much of the quartz is probably secondar

One section.

Age. Cabotian.

Remarks. This rock and No. 224 are evidently the same, petrographically, a in age, and are thought to be parts of the same mass. Their present condition do not clearly show their original nature, but it seems probable that they were ori inally of the nature of rhyolytes or trachytes. The small amount of quartz, much which is secondary, would perhaps cause these rocks to be more accurately term apotrachytes, but in accordance with the classification of the other rocks of a simil nature and age, they are here referred provisionally to the aporhyolytes. U. S. G.

No. 227. Diabase (?) *(Porphyritic.)*

Same locality as No. 226. A narrow dike-like form, not sharply separated from No. 226. "It is narr and its line of bearing becomes confused, or blends with the rock No. 226, being perhaps a modified form only No. 226, due to different influence in upheaval, or to unseen contact with accompanying igneous rock."

Ref. Annual Report, ix, page 57.

Meg. A fine-grained, compact, heavy, dark gray, almost black rock, looking like a fine-grained diabase. There are some porphyritic, gray to reddish feldspars, which are more common on one half of the hand specimen than on the other.

No section.

Age. Cabotian. U. S. G.

NO. 228. DIABASE. (*Gabbroidal.*)

From the broad point just west of Cannon Ball bay; S. E. ¼ sec. 6, T. 62–5 E. "The east side of this bay is made of the same rock, also the east point, also the island east of it; the coast being rocky and low, or rising from six to ten feet, basaltic. The next island, and the coast along, especially the points of the coast, are of the same. It rises into basaltic beds in a sharp point [S. E ¼ S. W. ¼ sec. 34, T. 63–5 E.] on the west side of Red Rock bay."

Ref. Annual Report, ix, pages 57, 58; Annual Report, x, page 43; Bulletin ii, page 99.

Meg. A rather coarse-grained, heavy, black diabase. There are numerous yellowish grains, which might be taken for olivine, but the section shows no olivine.

Mic. A beautiful section of a rather coarse-grained, fresh diabase. Some of the *augite* has a tendency to an idiomorphic development, and is thus earlier than some of the feldspar, but most of the augite is later than most of the feldspar. There is a considerable amount of a brown alteration product (bowlingite) present. Dr. Wadsworth (Bulletin ii, page 99) regards this as an alteration product of an interstitial basaltic base. It is also apparent that some of it originated from the pyroxene.

One section.

Age. Cabotian.

Remarks. For further description, see under Nos. 222 and 223, which are evidently from the same mass as this specimen. (See, also, under Nos. 133 and 229.)

U. S. G.

NO. 229. DIABASE (*with olivine*).

From Red Rock bay; runs under the Eastern Palisades.*

Ref. Annual Report, ix, page 58; Annual Report, x, page 140; American Association for the Advancement of Science, xxx, page 163.

Meg. This rock greatly resembles No. 228, but is finer grained.

Mic. An ophitic diabase with much fresh *olivine.* The rock is fresher than No. 228, both in respect of the augite and the possession of unchanged olivine. The *augite* appears chiefly in ophitic relation to the feldspar; but there is plainly an older augite which is not diallagic but filled with dark opaque particles scattered like dust throughout their mass. These have independent outlines like those of No. 228.

One section.

Age. Cabotian. N. H. W.

NO. 230. APORHYOLYTE.

Red Rock bay; sec. 34, T. 63–5 E. The rock of the Eastern Palisades. (See No. 620.)

Ref. Annual Report, ix, pages 58, 59; Annual Report, x, page 59.

*The Eastern Palisades are N. W. ¼ S. E. ¼ sec. 34, T. 63–5 E.

Meg. A compact, hard, brownish red, siliceous, aphanitic rock, which hol porphyritic crystals of quartz and red feldspar.

Mic. The porphyritic *feldspars* are much decayed and reddened. The porph ritic *quartzes* are considerably rounded and are sometimes penetrated by litt embayments from the groundmass. The groundmass is similar to that of most the aporhyolytes already described, *i. e.*, a little *magnetite, hematite,* much minu cloudy feldspathic material, the whole section reddened, and all in a background *quartz,* which is usually in poikilitic areas holding the other materials of the groun mass. The section shows some irregular areas of finely crystalline quartz fro which most of the other materials of the groundmass are lacking. In ordinary lig these areas are transparent and colorless.

One section.

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

NO. 231. DIABASE.

From a dike of basaltic doleryte, cutting rock No. 230, a short distance east of the mouth of Red Ro creek, embracing patches of the red rock (No. 230). Compare No. 1818.

Ref. Annual Report, ix, page 58.

Meg. Very fine-grained, nearly black, with isolated nodules of pyrite.

Mic. The slide is too thick for such examination. The *feldspar* is in the for of lath-shaped crystals without distinct terminations. Much *magnetite* is visible small roundish grains.

One section.

Age. Cabotian; probably an apophysis from the great gabbro mass. N. H. W.

NO. 232. BASALT. *(Amygdaloidal.)*

Is the first rock that appears in the pebbly beach east of the rock of the Red Rock point, probably S. W. ¼ sec. 25, T. 63-5 E. Compare No. 1823.

Ref. Annual Report, ix, pages 58, 59; Annual Report, x, page 47.

Meg. A reddish brown, fine-grained, compact or amygdaloidal rock, tl amygdules being white, coated with green or entirely green. Apparently underli No. 230, and resembles some of the compact brown rock seen at Duluth and at mar intermediate points.

Mic. The *feldspars* and all the other minerals are very much stained with ferr oxide, and penetrated by other impurities. The section between crossed nicols nearly opaque.

There are remnants of *olivine,* and of *augite,* and a considerable quantity *magnetite,* the last prevailing in the vicinity of the olivine, and enwrapping it.] general the feldspars are quite perfect in their outlines, the reddened substan which embraces them being probably the uncrystallized remnant of the magm The old olivine grains, entirely altered, sometimes show nearly regular crystalli outlines. The green substance prevailing in the amygdules is opaque between crossed nicols, or nearly opaque, owing to the confused polarization of the crowded, very fine fibres which may be of *thalite*, or of serpentine.

Two sections.

Age. Cabotian; perhaps pre-gabbro. N. H. W.

No. 233. Basalt *(with olivine)*.

From a dike twenty-one feet wide, near No. 232, horizontally columnar, running N. 15° E., projecting into the bay seventy-five to ninety feet.

Ref. Annual Report, ix, pages 58, 59.

Meg. Dark, medium-grained, diabasic.

Mic. This rock is not ophitic, but granitic, so far as concerns the relation of the augites to the feldspars. The *augites* are small and not much altered, considering their comparative date of generation. The *feldspars* are somewhat kaolinized. *Magnetite* rods, or skeleton crystals are disseminated abundantly, and at the same time magnetite is present in the form of angular and irregular masses, probably a replacement of olivine. There is an abundant remnant of a poorly differentiated *magma-glass*, through which the magnetite rods are scattered. In these areas are not only incipient minute crystals which are apparently of augite and of feldspar, but also small secretions of *quartz*, and an isotropic grayish green substance, which represents the final residuum from the glass.

One section.

Age. Manitou (?)

Remark. It is impossible to assign age to the dikes along this part of the shore with any positiveness, since the Manitou may or may not have shared in their production. Considering the fact that the field relation of this rock to No. 234 indicates that it is a part of the same mass as that, it exhibits an interesting variation, which requires different names for the two rocks. The glassy remnant seen in this, and the non-porphyritic structure, are contrasted with the holo-crystalline and porphyritic feldspars of the other. N. H. W.

No. 234. Porphyryte. *(Diabase.)*

"From a dike eighteen feet wide running east and west 'hading' a little to the south, cross-columnar, cotemporary and blending with the dike No. 233, the structure of the two running together; of a brownish-black color."

Ref. Annual Report, ix, page 59.

Meg. A rather fine-grained, apparently granular, dark, brownish-black rock, with porphyritic plagioclases of about the same color as the mass of the rock. Many of the phenocrysts seem to contain the older materials of the rock poikilitically.

Mic. The plagioclase phenocrysts shown in the sections are few and small. They are not poikilitic, as is indicated by the hand specimen, only one of them containing foreign material, *i. e.*, a grain of olivine. It is possible that other phenocrysts would in thin section show this feature more prominently. The groundmass is composed of *plagioclase*, *augite*, *olivine* and *magnetite* as original constituents. The rock, as a whole, has been considerably altered and fissured; the fissures are filled with *hematite* and a greenish yellow serpentine-like material, and these two substances, especially the latter, are developed throughout the rock, replacing the olivines and most of the augites, and also filling spaces which may possibly have been occupied by a glassy residuum; a little secondary *quartz* is also present. The rock is inclined to a hypidiomorphic structure, rather than to the ophitic, but, as the augites are so far gone, the relation of this mineral to the feldspar is not clearly made out. The feldspars, however, while usually in more or less idiomorphic grains, are frequently partly or wholly allotriomorphic.

Three sections.

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

No. 235. Basalt (?)

"A rock similar to No. 232, cut by the dikes, having a slaty structure without any dikes; forms the beach next north of the dike No. 234, which is out in the water."

Ref. Annual Report, ix, pages 59, 60; Annual Report, x, page 47.

Meg. A compact, hard, very fine-grained, almost aphanitic, red-brown rock.

Mic. The section, which is a very poor one, shows microliths of *feldspar* and grains of *magnetite*, in a reddened background whose nature is not discernible on account of the thickness of the section. There is also one sub-angular *quartz* grain present.

One section.

Age. Cabotian.

Remarks. This rock is probably the same as No. 232. U. S. G.

No. 236. Basalt.

"From a dike twenty-one feet wide; a fine-grained, black basalt, running out into the lake about 250 feet, but often in the form of islands that occur a little out of line. The basaltic structure of this is very irregular. In some places it is fine and in others it is coarse; runs N. 15° W., being intersected by the dike No. 234, apparently in the same manner as No. 233."

Ref. Annual Report, ix, page 59.

Meg. A heavy, compact, very fine-grained, greenish, black rock. It contains a little pyrite.

Mic. The section shows microliths of *plagioclase* in a confused, altered background, which is composed of *magnetite*, *chlorite* and cloudy, greenish, or grayish (sometimes with a shade of brownish) areas. These cloudy areas under polarized light, are seen to be sometimes feldspathic, but most commonly show no effect on polarized light, except for a few bright points. The whole background of the rock was evidently originally *glassy*, or nearly so, and it has been considerably altered from its original condition.

One thick section.

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

NO. 237. BASALT *(with olivine)*.

From a curious isolated mound of thin-layered, almost slaty, rock, with curving lamination, which rises eighteen feet on the beach, or between the beach and the lake, a short distance east of No. 236. Shaped like a haystack. (See Nos. 1824–1826.) In structure and lamination reminds of a sedimentary rock, but its amygdaloids show it is an eruptive.

Ref. Annual Report, ix, page 59.

Meg. Compact, fine-grained, brownish diabasic rock. Evidently distorted and curved by pressure.

Mic. The little *feldspars* are mostly idiomorphic, lying in a nearly isotropic brown *glass* which still renders a confused polarization.

Magnetite, in very fine particles, is common.

Olivine appears largely replaced by magnetite, yet, occasionally in the centre of a magnetited grain, a green decomposition product remains. The olivines, thus changed, still show their original idiomorphic outlines. They appear occasionally to break the symmetry of the feldspars, but in general the still mobile magma was so abundant that the feldspars found room to form entire without being trenched upon by the earlier olivines.

Hematite, and apparently *chlorite*, resulted from alteration.

One section.

Age. Cabotian. N. H. W.

NO. 238. BASALT *(with olivine)*.

Same place as No. 237, but from a slaty condition of this rock.

Ref. Annual Report, ix, page 59; Annual Report, x, page 47.

Same rock as No. 237, except that it contains a little quartz, and occasionally a porphyritic feldspar of the first consolidation; entirely reddened by oxide of iron.

One section.

Age. Cabotian. N. H. W.

NO. 239. BASALT *(with olivine)*.

The same rock as No. 238, but non-fissile, firm, weathering brown, rather finer grained.

One section.

Age. Cabotian. N. H. W.

NO. 240. BASALT *(with olivine)*.

From the same place as No. 238, and from the same rock.

Ref. Annual Report, ix, pages 59, 60.

Meg. Finer grained, breaking conchoidally.

Mic. The elements in the slide are hardly differentiated. The *feldspars* are indistinctly combined in the matrix. There are minute polarizing spots, but without the crystallographic outlines of feldspar. This may have resulted from the consolidation of a tuff. In another slide the rock appears the same as in No. 237, but has larger amounts of *hematite*; also *calcite* and *biotite.*

Two slides.

Age. Cabotian. N. H. W.

No. 241. Basalt *(with olivine).*

Same rock, same place, but nearly black. Cannot be distinguished from No. 237, except that the feldspars are not so well formed as to crystalline boundaries. A minutely fine basalt.

One section.

Age. Cabotian. N. H. W.

No. 242. Diabase *(with quartz).*

From a dike cutting Nos. 237–241; 100 feet wide, running nearly east and west.
Ref. Annual Report, ix, pages 59, 60.

Meg. Grain medium in size. Some feldspars being conspicuous and striated. Grayish-brown rock.

Mic. The *feldspar* is of two periods of generation, the earlier one having twinning after the Carlsbad law, the two individuals being twinned after the albite law. A section of such a twin is perpendicular to n_p ($\mathfrak{a}$) and has extinction at 56°, which indicates a feldspar near *anorthite.* Another section is yellow between crossed nicols, and happens to be cut perpendicular to n_m ($\mathfrak{b}$), showing the thickness of the slide at this place is about .0525 millimeters. It varies, however, being in other places .0325 millimeters.

There is considerable *quartz* in the rock, in independent grains, yet in some cases it is minutely distributed through other minerals in the form mentioned in No. 225, forming a micropegmatyte.

Augite is not abundant nor well preserved. It is granular amongst the feldspars rather than ophitic, causing the rock to take on the character of a granular gabbro, and identical with the rock of Nos. 233 and 234.

One section.

Age. Manitou.

Remark. Nos. 232 and 235, and their modifications to No. 241, run under No. 230, the Eastern Palisades, and below the red rock of the point east of the Eastern Palisades. These are basic surface flows, and the Eastern Palisades are of an acid effusive. N. H. W.

No. 243. Basalt *(with olivine).*

From the west point of Deronda bay; N. W. ¼ N. W. ¼ sec. 30, T. 63-6 E.
Ref. Annual Report, ix, page 60.

Meg. Fine-grained, hard, nearly black, homogeneous rock. It is rather bedded, but not basaltic, lying on an amygdaloid (No. 244).

Mic. The thick section is only sufficient to show that this rock is essentially one of the series to which No. 235 belongs. It holds some *calcite* and some *quartz.*

One section.

Age. Cabotian. N. H. W.

No. 244. Diabase. *(Amygdaloidal.)*

From the west point of Deronda bay. A reddish brown amygdaloid with green amygdules, underlying No. 243, passing irregularly into No. 245, which is mainly non-amygdaloidal, but has nests of a lighter mineral; probably of the series represented by Nos. 232-235, 237-242.
Ref. Annual Report, ix, page 60.

Mac. Reddish-brown, rather fine-grained, spotted with fine green amygdules, resembling No. 232 and that series.

Mic. A diabase, with lath-shaped feldspars, magnetite and altered minerals which cannot be determined from the section.

The amygdules are of a green substance, finely radiated, and having a positive extinction, *i. e.*, parallel with the fibres, and seem to belong to *antigorite* (Minéralogie de France, vol. i, page 426), or to *delessite.* The fibres are parallel with n_g. A Boricky test, however, was made to detect the possible presence of potassium, by which celadonite differs from antigorite, with the result that no potassium was found.

One section.

Age. Cabotian. N. H. W.

No. 245. Diabase.

West point of Deronda bay; N. W. ¼ N. W. ¼ sec. 30, T. 63-6 E. Is mainly non-amygdaloidal. Passes into No. 244.
Ref. Annual Report, ix, page 60.

Meg. A dark-gray, compact, fine-grained, diabasic rock. The hand sample shows very fine, indistinct, yellowish to greenish amygdules.

Mic. A fine-grained diabase, with alteration products, mainly *chlorite.* The *augite* is not abundant, but usually occurs in plates of considerable size, including the plagioclases. The rock is very rich in plagioclase, there being considerable areas where the augite is lacking; here the plagioclase is in ill-defined laths and allotriomorphic grains. A few small green areas, probably representing original olivine, are present.

One section.

Age. Cabotian. U. S. G.

No. 246. Diabase *(with olivine).*

About three-fourths of a mile east of Deronda bay, at the mouth of a little creek; near the centre of sec. 19, T. 63-6 E.
Ref. Annual Report, ix, page 60.

Meg. A dark-gray to greenish, fine-grained diabasic rock appearing much decayed. It contains much calcite, some of which is pinkish.

Mic. A diabase with the abundance of *feldspar* and the large plates of *augite* seen in No. 245. There are, however, more of the altered olivines than in No. 245, and what is peculiar is that the interior of these altered grains is frequently a clear, subangular grain of quartz surrounded by the usual decomposition products of the olivine.

One section. [It is possible that the section marked No. 246 is not from the hand sample of that number. The latter appears more decayed than is indicated by the section.]

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

No. 246A. Calcite.

From No. 246.
Ref. Annual Report, ix, page 60.

Meg. A mass of calcite in small, transparent crystals and also massive and flesh colored.

No section.

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

No. 247. Basalt. *(Amygdaloidal.)*

Rock similar to No. 246, but more amygdaloidal.
Ref. Annual Report, ix, page 60.

Meg. A fine-grained, much decayed, dark-greenish gray, diabasic rock. It contains amygdules of calcite, both pink and colorless; also of chlorite and chalcedony. Much chlorite permeates the rock.

Mic. The section, which is too thick, shows *plagioclase* microliths in a dirty, confused mass of alteration products—*chlorite*, *calcite*, *iron ores* and a little *quartz*. It is impossible to tell what the original nature of this groundmass was, but it seems probable that part of it, at least, was glassy.

One section.

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

No. 248. Gabbro. *(Altered.)*

From a dike which has an indefinite width, at least 200 feet, on the third little point east of Deronda bay, after a pebbly beach of half a mile. The second point is like rock No. 246.
Compare rock No. 41, at Duluth, and No. 1855.
Ref. Annual Report, ix, page 60.

Meg. Porphyritic, with a glassy, clear plagioclase, hard and massive, but fresh and rather light colored, owing to the general effect of the feldspars when fractured. The matrix is dark and medium grained.

Mic. The feldspar has an extinction on 010 of 25°, indicating *labradorite.* It is abundant in the rock, and was formed after the augite or cotemporary with it. It is clear and brilliant, but slightly zoned. It shows occasional Baveno and Carlsbad twinning, in addition to the albite and pericline types.

The *augite* is markedly translucent and clear, but not colorless. It has strong prismatic cleavage, but is not diallagic. Its forms are in part independent of the feldspar, and the crystals are not large. They are well preserved, considering the fact that adjoining them are quite commonly seen hornblendic areas which are usually considered the result of alteration of augite.

Olivine is in the rock in small amount, serpentinized in the cleavages, embracing the feldspars. *Quartz* also is not uncommon. It is usually found in the form of small, angular grains embraced in or near those areas that show considerable alteration as from undifferentiated magma, accompanied by brownish or greenish and by opaque substances.

Hornblende is not common, absorptive and yellowish green to brown in natural light. In its immediate vicinity are sometimes small areas of *chlorite*, which seem to be the result of further alteration.

Glass, or glassy remnants from the original magma, seem to have been the instigating cause of all these changes. It appears that, perhaps during the cooling stage after solidification, the remaining portions of the magma were the seat of further differentiation, and that the resultant crystals were hornblende, quartz and chlorite.

Apatite spicules are very abundant. They pierce all the other minerals, and seem to have been the oldest secretion from the molten magma.

Magnetite is present, but not in considerable amount. Another section shows more magnetite.

Two sections.

Age. Manitou(?)

Remark. This is the most westerly known point on the lake shore where this rock, which seems to be a representative of the Grand Portage Manitou dike series, occurs in sight. These dikes constitute a mountain range lying north from the Sawteeth range, and distant from the latter at Double bay from three to six miles. Still, notwithstanding the classification adopted, it is impossible to separate the Cabotian dikes at Grand Portage from those seen at Double bay, and at Deronda and Horseshoe bays.

The field-note (Annual Report, ix, page 60) indicates that this rock cuts an amygdaloid (No. 249). There are two series of surface flows concerned in the Grand Portage region, and at present it is impossible to separate them geographically. There are also, in the same region, two inseparable series of dikes. N. H. W.

No. 249. BASALT. *(Amygdaloidal.)*

Adjoins No. 248. "Third little point east of Deronda bay; probably in N. W. ¼ N. W. ¼ sec. 20, T. 63-6 E.
Ref. Annual Report, ix, page 60.

Meg. A fine-grained, dark greenish to gray, diabasic rock, considerably decayed. Contains amygdules of calcite, quartz, and probably chalcedony.

Mic. Feldspar microliths in a confused, greenish mass of alteration products, which are largely *chlorite, calcite* and *magnetite.* The original nature of this groundmass cannot be determined, but it is not improbable that it once contained considerable *glass.* The section contains part of an amygdule of calcite and *quartz,* in which minerals are a few small grains, with a rather high index of refraction and strong double refraction, which may be *epidote.*

One section.

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

No. 250. BASALT. *(Amygdaloidal.)*

West point of Grand Portage bay; N. W. ¼ N. E. ¼ sec. 16, T. 63-6 E.
Ref. Annual Report, ix, pages 60, 61.

Meg. A fine-grained, brown, diabasic rock, with amygdules of calcite, and with some of quartz and chlorite.

No section.

Age. Manitou (?)

Remark. This is probably the same rock mass as No. 249. U. S. G.

No. 251. DIABASE *(with olivine).*

"Underlying No. 250; an amygdaloidal of a greenish color. These beds (Nos. 250 and 251) dip south at a low angle and do not extend into the bay. They apparently form the coast line between Grand Portage bay and Deronda bay, there being but little outcrop, with a low shore between these places."
Ref. Annual Report, ix, page 61.

Meg. A heavy, compact, rather fine-grained diabase. It is dark gray, with a tinge of yellow. The hand sample is not amygdaloidal.

Mic. The section shows an *olivine* diabase of medium grain. The olivine and *augite,* especially the former, have been largely replaced by a greenish, yellow serpentine like material and *magnetite.* Possibly, some of this secondary material represents an original glassy residuum. There are some pseudamygdaloidal areas, which are filled mostly with what appears to be *thalite,* with some *calcite* and serpentine-like material, and the calcite is also found elsewhere in the rock, especially in the areas once occupied by olivine. One section. U. S. G.

Age. These beds are Manitou, lying above the conglomerate, which is in outcrop a little further north in the hills west from Grand Portage-bay. N. H. W.

No. 252. Slate.

From the Animikie at the village of Grand Portage. The outcrop is near the water along the beach, rising also into short hills a short distance inland.
Ref. Annual Report, ix, pages 61, 62.

Meg. Rather hard and gritty; the slatiness is due to the sedimentation, with occasionally a clay-ball impression.

Mic. Principally of *quartz* and *feldspar*, in angular and sub-angular fragments, with a rare scale of *muscovite.* Some of the feldspar is scantily banded with albite striations.

One section.

Age. Taconic. N. H. W.

No. 253. Gabbro.

From a dike at Grand Portage, near the village, cutting the slates. This dike is thirty-nine feet wide and runs E. 15° S.
Ref. Annual Report, ix, page 61; Bulletin ii, page 112.

Meg. Apparently the same kind of rock as No. 248.

Mic. The composition and grain of this rock are identical with those of No. 248.

One section.

Age. Manitou(?) N. H. W.

No. 254. Conglomerate.

From the base of Portage Bay island, on the northeastern side.
Ref. Annual Report, ix, page 61; Annual Report, x, page 34; American Geologist, xiii, page 437, June, 1894.

Meg. Rather coarse, firm, quartzose conglomerate, but containing fragments of a gray, slaty rock, resembling the slate of No. 252. This lies in large fallen pieces on the shore. These masses are evenly stratified, and show false bedding. The dip *in situ* is S. 10° E., at an angle of 8° to 10°. It shows at least twenty feet, and is cut by a dike nine feet wide. Its color is, in general, gray, but it is spotted sparingly with red pebbles, which can be referred, with the slate fragments, to the hills of the mainland adjacent to this bay, where the red rock of the region appears. It also holds gray quartzyte and flint.

Mic. This conglomerate, consisting largely of vitreous *quartz* grains, yet contains some grains of a triclinic *feldspar* showing the albite twinning, and of *microcline* with its characteristic quadrillage. The cement is *calcite*, but this calcite is so abundant that it serves more than as a cement, and occupies independent areas as if it were rapidly accumulating when the conglomerate was being formed.

In some parts of the thin section examined, indeed in a large part of it, calcite is not so abundant, but in its place, apparently, is an isotropic, greenish, fibrous substance, whose nature it is difficult to determine. There are other sub-isotropic grains, filled with impurities, some of them having a poikilitic quartz background, and some that are derived from feldspathic grains, now much altered. The only plausible interpretation of the isotropic grains, from a petrographic point of view, which presents itself, is to assign them to an original volcanic glass, which may have existed in considerable quantity in the vicinity where this conglomerate was being formed. Structurally, however, there is no warrant for such a supposition, and it seems necessary to refer these isotropic and sub-isotropic grains to alteration from debris derived from some crystalline rock of older date. (See Part I; compare No. 2069.)

Two sections.

Age. Basal conglomerate of the Potsdam.

Four additional sections, from pebbles of this conglomerate, were made subsequently by Marchand. Of these, two were of the "red rock" pebbles. They show a rock consisting largely of *quartz*, but between crossed nicols so dark that it is necessary to allow the existence of considerable isotropic matter. The quartz is in small, irregular grains, sometimes clear and sizable, but for the most part closely intergrown and overlapping, with tortuous outlines. The pebble also embraces *triclinic feldspar* fragments, and *calcite* spreads abundantly through some parts of it. There are also other small, brightly-colored and lamello-fibrous crystalliths which can hardly be named specifically, but may be of muscovite. The aspect is that of a composite, siliceous rock, hardened and partially recrystallized by heat, but not wholly fused. Surrounding this pebble are other, smaller, clastic grains and composite pebbles, some of them being apparently from a rock that would bear the name of quartz-porphyry, with bipyramidal quartzes whose orientation controls the poikilitic quartz that surrounds them and embraces more or less colored and isotropic matter.

Of two other sections made from pebbles from this conglomerate, one is of a granular quartzyte resembling much the rock No. 1838. Mingled with fine, rounded quartz pebbles are some that are clouded with reddish impurities. These last have regular extinctions, and appear to have resulted from a silicification of an older rhyolyte, but on testing them in convergent light they exhibit indistinctly, when cut favorably, the single dark bar of a biaxial mineral which rotates with the stage, but in reverse order. They are therefore clastic grains of *orthoclase.* In the same pebble are other minerals. *Epidote* shows by its high refraction and double refraction. It is rather abundant. A dichroic, fibrous, greenish to brownish mineral, somewhat resembling hornblende, is probably *clinochlore,* as its double refraction, though in the colors of the first order, is but little above that of quartz cut in the same thickness. A single subrounded grain of *zircon* is greenish between crossed nicols, clear and bright, and extinguishes parallel to its greater diameter. Its green color (the section being about .03 millimeters in thickness) is in the third order.

The fourth section, made from a pebble from this conglomerate, is finer grained, but essentially a clastic quartzyte. The grains are interlocked by secondary *quartz* growths, and these growths embrace many clouded impurities which served to make up the original surrounding mass. Hence this interstitial silica is rather dark, especially between crossed nicols. Whether this secondary growth took place prior or subsequent to the incorporation of these grains in this quartzyte is an important question, for it cannot be distinguished from a poikilitic extension of secondary quartz through an aporhyolyte. If it preceded the formation of the conglomerate, there must have been surface rhyolitic rocks to serve as its source. It would not be safe to affirm, on the evidence of this section alone, the existence of such a rock in the Grand Portage region at the date of the formation of this pebble.

Remark. The importance of determining the stratigraphic position of this conglomerate precludes a discussion of the question at this place. It has been supposed to lie at the base of the Keweenawan. It is similar to that represented by No. 1903, which was found about the centre of N. W. ¼ sec. 25, T. 64–4 E., southward from South Fowl lake, and to that seen near Fond du Lac, in the valley of the St. Louis river. It outcrops on the mainland in the hills about a mile west of Grand Portage village, and is illustrated by figure 1 of this volume. N. H. W.

No. 255. Basalt. (*Amygdaloidal.*)

"This overflow comes down to the water at once and hides the conglomerate, and rises perpendicular about twelve feet. It weathers very rough and open angular, from containing fragments, apparently, of rock from contiguous formations, that were not wholly molten." Grand Portage island.

Ref. Annual Report, ix, page 61.

Meg. A very fine-grained, much decayed, greenish-gray rock, which holds small amygdules of calcite. One side of the specimen has some gray shaly material and also some of the underlying sandstone, indicating that this side of the specimen was in contact with the sandstone or that it included a fragment of the sandstone.

Mic. The groundmass of the rock is green, in fact the whole section is, due to the presence of a large amount of *chlorite.* This groundmass is made up of *calcite, chlorite,* small, black spots, and the remains of *plagioclase* microliths. There is also a little *hematite* and *pyrite.* The small black spots are opaque, black in transmitted light and gray in reflected light. There are the outlines of many porphyritic crystals, the crystals having been replaced entirely by calcite, or chlorite, or both. In no case was any of the original material of the crystal discernible. Some of these phenocrysts show eight-sided sections which might be referred to cross-sections of pyroxenes, and others, by the arrangement of the chlorite, suggest olivines. There are also many small amygdules of calcite and chlorite. The peculiar feature of the rock is the large amount of calcite; this mineral not only fills the amygdaloidal cavities and the spaces left by the porphyritic crystals, but exists in large amount in the groundmass of the rock. The calcite evidently makes up more than one-half of the rock mass.

Two other sections show essentially the same features described above, with the additional fact that the rock has included fragments and grains of the adjacent quartzyte. Sometimes rounded grains of quartz are seen in the midst of the basaltic mass.

Three sections.

Age. Manitou. U. S. G.

Remark. Whether this rock be an amygdaloid or a tuff or both (more probably), it is a surface rock, and not an intrusive; and as it is overlain by a sandstone it indicates an interrupted volcanic action in the near vicinity during the accumulation of the fragmental rocks at the base of this island, and it therefore makes more plausible the suggestions of glass in the conglomerate No. 254. N. H. W.

No. 256. Gray Sandstone.

"Sandstone; of even grain and bedding, lying between layers of trap-rock immediately over No. 255." Grand Portage island.

Ref. Annual Report, ix, page 61.

Meg. A light-gray, fine-grained sandstone or quartzyte. It contains a few small red grains—feldspar. The hand sample shows a few dark-gray, or greenish-gray, spots roughly circular in outline and about a quarter of an inch in diameter. This spotted character is somewhat similar to the spotted rocks of the Animikie on Pigeon point (see description of future rock numbers, and also W. S. Bayley, Bulletin cix, U. S. Geol. Survey).

Mic. The section is composed almost entirely of interlocking, angular grains of *quartz.* A few semi-rounded grains are seen, but the most of them show no evidence of having been rounded. Practically no cementing material is present. The various grains fit into each other, and some of them by their outlines show that they could not have had this form as original fragmental grains. It seems evident that they have been enlarged by the addition of secondary silica, but no distinct examples of this were seen. There are also a few grains of feldspar—*orthoclase, microcline* and *plagioclase*—and some areas composed of very minute grains, probably of quartz.

One section.

Age. Potsdam.

Remarks. The rock has been changed somewhat from its original fragmental state and would, perhaps, better be styled a quartzyte than a sandstone. The change in the rock has most probably been induced by the eruptives which are in contact with it, as is evidently the case with the quartzytes of the Animikie just to the east on Pigeon point. However, the change from sandstone to quartzyte (by the growth of the quartz grains) sometimes occurs in beds that have not been subjected to the influence of any eruptive or to any "metamorphosing" action. There is, in this section, one conspicuous grain of *zircon*. It is highly refractive and doubly refractive, showing red of two orders, the highest color being green. It is thus distinguished from rutile. It has parallel extinction. U. S. G.

NO. 257. QUARTZYTE. *(Micaceous.)*

"Gray, thinly-bedded, hard, quartzyte, styled *siliceo-argillaceous* shale by Norwood; at a short distance having the aspect of a bedded slate, probably belonging to the slate formation of No. 252; from the west side of Hat point [sec. 11, T. 63-6 E.] near the extremity, overlain by the next. On the east side of the point can be seen numerous dikes cutting this rock, which probably has a thickness of 500 feet."

Ref. Annual Report, ix, pages 61–63.

Meg. A hard, compact, very fine-grained quartzyte, dark gray in color. It contains a considerable amount of a silvery micaceous mineral.

No section.

Age. Animikie. U. S. G.

NO. 258. GABBRO *(with olivine).*

East side of Hat point, overlying or cutting No. 257 (Animikie slate). Basaltic trap-rock, rising at least 150 feet, and finally culminating in the summit of mount Josephine further north. (See No. 1829.)

Ref. Annual Report, ix, page 62; Bulletin ii, page 105.

Mic. The feldspar is quite pure. A grain cut nearly perpendicular to n_p has extinction 55°, according to the method of Fouqué for determining the feldspars cut perpendicular to the axes of elasticity.* If the section were exactly perpendicular to n_p this measurement would indicate anorthite, but, allowing for the slight obliquity, it is only an evidence of a very basic feldspar, and can safely be named *labradorite* or *labradorite-bytownite.*

There is some difficulty in distinguishing the *olivines*, which preceded the feldspars in origination, from those augites which also preceded or accompanied the feldspars, since the cleavages of the latter are not always evident. They both possess irregularly rounded outlines, independent of the forms of the feldspars, and are similarly refractive and doubly refractive. The olivines, however, when perpendicular to an axis of elasticity, have very indistinct cleavage parallel to one or both of the threads of the ocular when in extinction; in other positions their cleavages are very irregular, while the augites, on the other hand, always show some straight cleavages, and occasionally a diallagic structure. They frequently manifest those

*In the employment of this method the extinction angle is always read from the vertical thread of the ocular after bringing the optic plane into agreement with it. This is conventionally chosen by M. Fouqué in order to make the readings comparable and consistent. This feldspar, on n_p, has an extinction angle on the horizontal thread of 34°. *Bulletin de la Société de Minéralogie Française*, 1894, vol. xvi, p. 428.

peculiar included plates, coincident with cleavage, which gives them a specked or spotted aspect. Another peculiarity of the augite in this rock is its including poikilitically a number of smaller augites which have different orientation. This is shown in the upper portion of the figure below.

The *olivine* in this rock is abundant, and, like the augite, is quite light colored, indicating its low content of iron, and concordant with its lateness in date. It uniformly embraces the feldspars ophitically, but is embraced by the augites. This is not a usual structure for olivine. One of the larger grains is represented below. In this figure those areas marked *a* are of olivine and have simultaneous extinction in the direction shown by the arrow. Those marked *b* are of augite and have extinction in various positions, while those marked *c* are of labradorite-bytownite. This was also photographed. (See plate I, figure 7.)

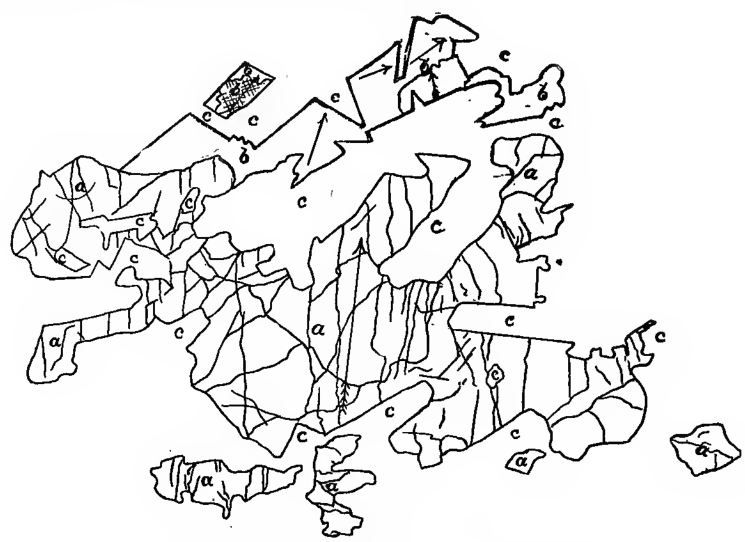


FIG. 18. OPHITIC STRUCTURE OF OLIVINE.

In the upper part of the figure, where four orientations of augite are shown, the mineral contains numerous inclusions. It appears as if the crystallizing force in the augite, the last mineral to be generated from the magma, had embraced the remnants of the glass and undifferentiated magma. In the small isolated figure at the top of the figure a distinctly cleaved augite, evidently corroded, is surrounded by a later augite having the same orientation, the whole exactly filling an angular interstice between feldspars. In other cases two augites, similarly situated, have different orientations.

One section.

Age. Cabotian.

Remark. This is a beautiful rock in thin section, owing to the good preservation of the elements, even the olivine being nearly intact. The section examined by Wadsworth is very thick, and the feldspars appear fissured and darkened. N. H. W.

No. 259. Quartzyte. *(Gray.)*

From the east side of Hat point, underlying or cut by the rock No. 258, forming a part of the slate formation at Grand Portage.

Compare Nos. 257, 270.

Ref. Annual Report, ix, page 62.

Meg. This rock is largely composed of *quartz* in sub-angular grains with an occasional fragment of *plagioclase*, the cement being of smaller grains of the same and of feldspathic (?) material and of *mica*; occasionally a grain appears to consist of much kaolinized feldspar, but still charged with impregnations of iron oxide.

This rock is illustrated by several other numbers, which afford better facilities for description. It contains globular masses or colored spots which, on a fractured surface, give the rock a spotted aspect, the spots being lighter than the rock in general, and often reddish. These reddish spots consist apparently of the indigenous elements stained at their borders by an accumulation of ferric oxide which here permeates the feldspars. A thin section, made so as to cut one of these spots, appears to have a different matrix for the quartz grains, consisting largely of *calcite*. This calcite is in crystals which embrace, under one orientation, many of the grains of the sandstone. Throughout the rest of the rock no calcite is seen, but the section is singularly dark between crossed nicols, as if it contained considerable devitrified *glass*.

Two sections.

Age. Animikie. N. H. W.

No. 260. Diabase *(with olivine)*.

Near the head of Wauswaugoning bay. From a dike cutting the Animikie slates and quartzytes, and running S. 45° W.

Ref. Annual Report, ix, page 62; Bulletin ii, pages 115, 116.

Meg. A compact, heavy, dark-gray diabase of medium grain.

Mic. A diabase composed of *plagioclase* laths, *augite*, *olivine* and *magnetite*. The rock has been considerably altered. The olivine is all replaced by a brown material *(bowlingite?)*. The feldspar is also altered, and the section has much dirty greenish chloritic material and some magnetite, *hornblende* and a little *biotite*, all of which seem to be alteration products from the augite. The augite is light violet brown in color and some of it is slightly pleochroic, varying from the usual color to a pale straw color.

Two sections.

Age. Cabotian. U. S. G.

No. 261. Diabase *(with olivine)*.

From the summit of the hill on N. E. ¼ sec. 25, T. 64–7 E. Northeast of the head of Wauswaugoning bay. Represents the rocks of the hills about Grand Portage.

Ref. Annual Report, ix, pages 63, 66, 70; Bulletin ii, page 106; American Association for the Advancement of Science, vol. xxx, page 163.

Mac. Medium-grained basic, uniform in color and composition, rather dark gray.

Mic. The *feldspar* is ophitically embraced by the pyroxene. It is not much altered. It constitutes about one-half of the rock.

The *pyroxene* is abundant and contains not only the feldspar but also *olivine*, which is in granules rounded before the generation of the pyroxene. These grains are sometimes isolated, but frequently are grouped in clusters. The olivine is easily distinguished from the augite by the difference in colors. It is yellowish, while the augite is reddish-brown in common light.

The *magnetite* is not secondary, in the sense that it is derived from the alteration of the other minerals. It is sometimes closely associated with the augite, but it is also embraced in the feldspars. Still more frequently, it is plainly the latest of the generations of the magma, since it fills the angles between the other elements. There is a brownish-red mineral occasionally associated with the magnetite which has been called biotite by Dr. Wadsworth. It has, however, the appearance of the brown mineral mentioned already as possibly *bowlingite*.

One section.

Age. Cabotian(?)

This rock differs from the rock of mount Josephine in having an ophitic structure in place of a granitic one. N. H. W.

No. 262. Quartzyte. (*Gray.*)

"Below the outcrop of No. 261 can be seen slaty red quartzyte beds with slate, in the southern slope of the hill, dipping toward the north, or into the hill, at a low angle. The hill [in N. E. ¼ sec. 25, T. 64–6 E.] is largely made up of this kind of rock".

Ref. Annual Report, ix, page 63; Annual Report, xiii, pages 100 (No. 163), 103; Bulletin viii, page xxxiii.

Meg. A fine-grained, gray quartzyte. It contains numerous red grains (feldspar) and small black grains.

Mic. The section shows rounded and subangular grains of *quartz* and *feldspar*. The larger of these grains appear rounded or water-worn in ordinary light, but in polarized light their peripheries are seen to be jagged, as if the original rounded grains had been enlarged and filled up the spaces between the grains. These larger grains are surrounded by a very fine-grained aggregate of quartz and feldspar, but there is no sharp distinction between large and small grains, as all intermediate sizes can be seen. The feldspar, except for a very few plagioclase grains, is much clouded and reddened and often shows very little effect on polarized light; it is probably *orthoclase* and *anorthoclase*. This cloudy feldspar is quite abundant and even seems to pervade the rock in the nature of a cement, although this feature is not so marked as in some of the other quartzytes from this immediate vicincity (especially No. 264). There are a few small flakes of greenish *biotite* in the section, also minute flakes of *chlorite*, and small opaque gray spots.

Chemical Analysis. The following analysis of this rock was made by Prof. C. F. Sidener, and first published in the Thirteenth Annual Report, page 100 (No. 163):

SiO_2	81.86
Al_2O_3	9.87
Fe_2O_3	1.44
FeO	2.36
CaO	.46
MgO	.81
K_2O	.45
Na_2O	1.61
H_2O	1.43
Total	100.29

In comparison with the other analyses of quartzytes, both altered and unaltered, published by Bayley (U. S. Geol. Survey, Bulletin cix) from Pigeon point, this rock is seen to be especially low in the amount of alkalies present.

Age. Animikie. U. S. G.

No. 263. Gabbro (*with hornblende*).

N. E. ¼ sec. 30, T. 64–6 E.; east side of Wauswaugoning bay. Lies between sedimentary sheets, in the form of a sill. It forms the straight high coast which makes a sharp angle in Wauswaugoning bay. When followed toward Birch island it becomes overlain by layers of quartzyte which are curved and twisted as if by heat from below. Angular pieces from this quartzyte are enclosed in No. 263, changing the weathering color and the composition in spots, reminding one of the "red rock" embraced in the gabbro at Duluth.

Ref. Annual Report, ix, page 63; Annual Report, x, page 142; Bulletin ii, page 81, plate VII, figure 2, plate IX, figure 1; American Association for the Advancement of Science, xxx, page 164.

Meg. Has the appearance of No. 5, at Duluth, showing a *striated feldspar*, *quartz*, *magnetite* and a red feldspathic or siliceous ingredient irregularly disseminated. The rock is therefore spotted with red, although in general a dark basic eruptive. Some of the dark mineral has the elongated habit of *hornblende*. Small amounts of *pyrite* and of *calcite* are visible.

Mic. Dr. Wadsworth has carefully and fully described this rock and illustrated the same by three figures. (Figure 2, plate VII, and figures 1 and 2, plate IX; Bulletin ii, page 81, 1887.) His description is as follows:

"A dark grayish and reddish brown crystalline rock, composed macroscopically of reddish and grayish feldspar, pyroxene, hornblende, biotite, magnetite, quartz and calcite.

"The section has its pyroxene largely altered to biotite, hornblende and viridite. Much secondary feldspar of a plagioclase type occurs, but the primary feldspar appears to have been largely, if not entirely, replaced by the graphic or eozoön quartz and fibrous kaolinized feldspathic material. Secondary quartz in irregular grains, besides the graphic form, is quite abundant, while both the quartz and the feldspar are filled with microliths (apatite ?).

"Plate VII, figure 2, shows the structure of one of the altered diallage crystals. The diallage is in the form of a core surrounded and penetrated by a greenish viridite which traverses the irregular cracks of the diallage. The viridite passes on its outer edge, into a greenish hornblende which is the second step in the diallage alteration. Apatite and magnetite are common and some biotite was observed.

"Figure 1, plate IX, indicates the graphic or eozoon stage in the alteration of this rock, while figure 2 of the same plate shows a more highly altered or a biotite-hornblende-granite form. The quartz contains microliths and fluid cavities."

Remark. The foregoing is substantially the same that the writer would give as a description of the appearance and composition of this rock. He would, however, call attention to the unusual conditions which surround this rock in its structural relations. It is evident that this altered condition is due to the contact with quartzytes of the region and not to any normal or widespread change which could give rise to such a rock. The plagioclase therefore is more likely to be original than secondary. The alteration which pervades the reddened areas, permeated with micropegmatitic quartz, seems more likely to be the residue of the quartzyte inclusions which did not respond to the crystallization which affected the quartz. As the quartz of the pegmatyte darkens over considerable areas simultaneously, it is plain that one orientation prevailed throughout areas which were not actually in contact, but were separated by a "feldspathic" ingredient which did not crystallize. Whether that ingredient was an original feldspar, which now has lost its power to crystallize, as believed by Dr. Wadsworth, or was simply the rejected impurities left after the quartz was regenerated, is a question worthy of consideration. That the circumstances of injection of a molten basic rock between the layers of an acid one would be favorable for the absorption of silica throughout the region of contact by the basic rock, and for the rearrangement of crystalline orientation of those portions of the quartzyte included in the zone of greatest heat, cannot be questioned. Heated alkaline waters would be generated. These would seize on the quartz and would transform it readily into such shapes as the adjacent surroundings permitted. Several other members illustrate the same transformations. The viridite is probably penninite. It has a distinct cleavage and a hexagonal form. In a new section the plagioclase is seen to be posterior to both augite and olivine. Three sections examined.

The field description, published in the Ninth Annual Report, page 63, makes it plain that this rock is an intrusive in the Animikie along the bedding, being the first published observation of an actual intrusion in that manner in the Animikie. The intruding rock here is evidently a spur from the great dikes of the region, and is of Cabotian age. N. H. W.

No. 264. Quartzyte. *(Altered.)*

From the shore of Wauswaugoning bay due north (by compass) from Birch island; near the centre of E. ½ sec. 36, T. 64-6 E. Sample shows changed quartzyte enclosed in the gabbro (No. 263).

Ref. Annual Report, ix, page 63; Annual Report, x, page 141; Proceedings American Association for the Advancement of Science, vol. xxx, page 165.

Meg. A fine-grained, pinkish quartzyte, composed of quartz, feldspar and a black mineral. It is indistinctly mottled by gray and pink, the gray areas being composed almost entirely of quartz, and the pink areas of quartz imbedded in feldspar. Along one side of the specimen, and in drusy cavities the minerals of the rock exist in small crystals. The hand sample is sharply divided into a pink and a dark gray portion. The above description is of the pink portion; the dark gray part is essentially the same except that the quartz is much decreased in abundance, and there is a corresponding increase of the black mineral.

Mic. The section, which was made from the pink part of the hand specimen, is composed of *quartz* and *feldspar* with a little *chlorite* and green *biotite*. The quartz is in sub-angular and more or less rounded grains, and a noticeable feature is the tendency of many of these grains to assume bipyramidal outlines. The outlines, however, are not perfect, but approximate to the perfect bipyramidal form. In some cases these crystals are short and stout, and again they are ragged and irregular, but still show an indication of crystal outlines. This form of the quartz has been noted by Bayley (U. S. Geol. Survey; Bulletin cix), and figured (see figure 12, page 86; plate XII, figure a; figure 13, page 93). Some of these imperfect quartz crystals are shown in the accompanying figure. The quartz is also in the form of more or less rounded grains with no indication of crystal planes, and sometimes several of these grains, separated by veins of feldspathic material, are seen to have the same optical orientation.

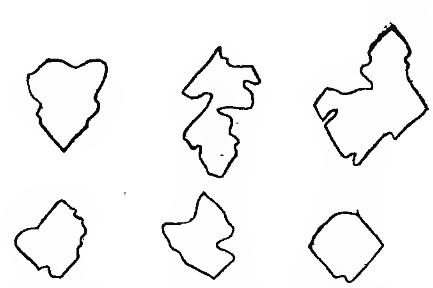


FIG. 19. OUTLINES OF IMPERFECT QUARTZ CRYSTALS FROM QUARTZYTE.
Crystallographic c in each case is vertical.

The *feldspar* is clouded, as in No. 262, and its peculiar feature is that it exists as a *cement* between the quartz grains. It does not occur in distinct grains, as in No. 262, but two or three clear plagioclase grains are seen. The feldspar sometimes extinguishes simultaneously over considerable areas.

One section.

Age. Animikie.

Remarks. This rock, and a number of others from Pigeon point and vicinity, are similar to those described by W. S. Bayley in Bulletin cix, U. S. Geol. Survey, where detailed descriptions, illustrations and analyses are given. U. S. G.

No. 265. DIABASE. *(Contacting alteration.)*

From the upper (altered) part of No. 263. Wauswaugoning bay, where in contact with the quartzyte at the coast due north by compass, from Birch island.

Ref. Annual Report, ix, page 63; Annual Report, x, page 141; American Association for the Advancement of Science, vol. xxx, page 165.

Meg. Principally reddish, rough rock, with geodic cavities containing quartz and a softer, greenish substance.

Mic. Similar to some parts of No. 263. Throughout the reddish matrix is much *quartz*, which is in the form of *graphic quartz*, polarizing simultaneously over considerable areas in the same manner as in No. 263. The quartz has been subjected to a common orientation. Much of the remaining material of the slide is dark between crossed nicols, being made up of finely crystalline elements. Yet it has sometimes a layered structure, lying between the quartz bands as if it occupied the place of some cleaved mineral, perhaps an original feldspar, whose skeleton remains in the form of its original cleavage. Very rarely, also, may be seen a grain which shows still a characteristic plagioclase striation. The rock in general, then, is to be considered a silicified eruptive.

It contains, however, many other minerals secondary or accessory to the minerals of a basic eruptive, viz., *biotite*, *penninite*, *sphene*, *rutile* (and apparently *zircon ?*) as detected by Prof. Lacroix.

The *biotite* is sometimes closely interwoven with the chlorite, but also sometimes they both fill considerable areas entirely separate. The former is also disseminated widely throughout the rock. It is hardly perceptible in ordinary light, being uncolored, but by lowering the condenser its fibrous and cleaved structure becomes apparent. It is sometimes in radiating and intersecting plates which, as cut by the section, show star-shaped spangles and confused knots of fine fibres. Between crossed nicols it polarizes in blue, red and yellow, even in a section having no greater thickness than 1.5 millimeters. There is evidence of this mineral changing to the next. This consists of the remnants of its polarizing colors in the midst of the contrasted-gray colors of the chlorite.

The *chlorite* has a pale, yellowish-green color in ordinary light. It is fibrous and linear, with extinction parallel to the fibres, which are parallel to n_p. It is the principal mineral in the open geodes. It shows well the characteristic colored aureoles or round dark spots. When cut parallel to the base it has hexagonal outlines, and is not distinctly fibrous.

Sphene appears as small, yellowish and yellowish-green, isolated grains of irregular shapes and not abundant. Sometimes the grains are nearly colorless and have the characteristic high refractive index.

Rutile, twinned and crossed, appears in isolated, darker-yellow grains than the sphene. The twinning or lamellation forms a network within the central part of the grain, but is invisible about the exterior, owing to the total reflection which darkens the peripheries of the grain. The general contour is pear-shaped. Both rutile and sphene are doubtless results of change from titaniferous magnetite contained in the original rock.

Two sections examined.

Age. Cabotian. N. H. W.

NO. 265A. QUARTZYTE. *(Dark gray.)*

Birch island, Wauswaugoning bay; S. E. ¼ sec. 36, T. 64–6 E. Darker and firmer parts, appearing somewhat like dikes. "Birch island is caused by four hardened belts in the quartzyte and slates, from five to ten feet wide, which run east and west, making the slates darker and in spots basaltic, and yet showing in other spots their bedded slatiness. These belts resemble dikes of igneous rock, and they run as a reef almost to the shore northwardly."

Ref. Annual Report, ix, page 64.

Meg. A fine-grained, hard, heavy, compact, dark-gray, impure quartzyte, looking almost like a diabase. Quartz grains, and a few of feldspar, are seen embedded in a darker background.

No section.

Age. Animikie. U. S. G.

NO. 265B. QUARTZYTE.

Birch island. Shows peculiar fractures due to glaciation (?).

Ref. Annual Report, ix, page 64.

Meg. Sample not found.

No section.

Age. Animikie. U. S. G.

NO. 266. DIABASE.

South shore of Pigeon point, east of Birch island; probably in S. ½ sec. 31, T. 64-7 E. From a dyke which cuts the quartzyte and contains scattered pyrite.

Ref. Annual Report, ix, page 64.

Meg. A rather-fine grained, dark-gray diabase.

Mic. The rock is considerably altered. In structure it is ophitic. The original minerals are *plagioclase*, *augite* and *magnetite*. The secondary minerals are magnetite, a greenish chloritic substance and a dirty brownish opaque material. These alteration products seem to have come from the augite, although some unindividualized material may have been present. Minute needles of *apatite* are common, penetrating all the minerals of the rock except the magnetite. One small porphyritic plagioclase, having minute twinning lamellæ which are seen only with a high power, is present.

One section.

Age. Cabotian. U. S. G.

NO. 267. DIABASE.

"Basaltic rock from the main vein, containing a calcite centre, and which is about twenty-five feet wide." A dike. South shore of Pigeon point, east of Birch island; probably in S. ½ sec. 31, T. 64-7 E.

Ref. Annual Report, ix, page 64.

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

Mic. The section is too thick for careful study. The rock is composed of small *plagioclase* microliths, plagioclase in allotriomorphic grains, subangular, more or less rounded grains of a greenish mineral regarded as *augite*, and *magnetite*.

One section.

Age. Cabotian(?)

Remarks. The structure of the rock is different from that of the usual diabase dykes in this vicinty. It is possible that this is a facies of the usual diabase, but it is also possible that this dyke is really of later age than the rest of the dykes (Cabotian) and represents a later intrusion (Manitou). U. S. G.

No. 267A. Calcite and Chalcopyrite.

From No. 267.
Ref. Annual Report, ix, page 64.

Meg. A mass of these two minerals.

No section.

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

No. 268. Quartzyte. *(Dark.)*

"Blackened quartzyte, with red (hematitic) specks; from near the dike No. 267. This is of a dark color, but represents the prevailing color."
Ref. Annual Report, ix, page 64.

Meg. A fine-grained, greenish-gray, impure quartzyte. Quartz grains and a few of feldspar occur in a dark background. The hand sample contains a few red spots of hematite.

Mic. The section is composed of distinctly rounded and subangular grains of *quartz* and some of *feldspar* in a dirty, greenish cement. The distinctive feature of the rock is its clearly sedimentary nature, as shown by the worn quartz grains. Another feature, which is shown very clearly, is the secondary enlargement of the quartz grains. The feldspars are much clouded and decayed. The cement is quite abundant; it is composed very largely of *chlorite* with some finely crystallized quartz and feldspar, and much dirty undeterminable substance.

One section.

Age. Animikie.

Remarks. This rock, although so near the eruptive, is very little altered. Bayley has shown (Bulletin cix, U. S. Geol. Survey) that the clastic nature of the quartz grains is not evident, even in the slightly altered portions of the quartzytes of Pigeon point. U. S. G.

No. 269. Diabase.

"From Island No. 2, being the easterly of the first two islands near the coast; a porphyritic doleryte, the larger crystals being of a triclinic feldspar. The whole rock is gray, and has small grains of pyrite, The whole island is formed by a dike of No. 269, flanked by a little quartzyte and slate near the water. The dike is about fifty feet wide, and the island is not much more." This island is at the S. E. corner of sec. 31, T. 64–7 E.

Ref. Annual Report, ix, pages 64, 65, 66; Bulletin ii, pages 47 (as No. 169), 118.

Meg. A gray diabase of medium grain. A few porphyritic plagioclases are present. One of these is three-fourths of an inch across, but the rest are much smaller. A little pyrite is present. The feldspathic part of the rock is gray and the rest of the rock is darker and apparently decayed.

Mic. A much-altered diabase. The original minerals are *plagioclase, augite, magnetite* and *apatite*. The first two are much changed. The secondary minerals are *hornblende, chlorite, biotite, magnetite, pyrite, quartz* and a brown almost opaque material. The feldspars contain flakes of a micaceous (kaolin?) mineral.

Two sections.

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

No. 270. Quartzyte. *(Graphitic.)*

Pigeon point, S. W. ¼, sec. 32, T. 64–7, nearly on the axis of the peninsula. (Compare No. 552.) This rock, at large, is charged with graphite. Some pieces twelve inches and more in diameter have been extracted in the shallow working which has been accomplished. The rock also contains a little native copper and pyrite. It embraces also irregularly angular patches of quartzyte. The graphite occurs most plentifully in the quartzyte, over a belt twenty to thirty feet wide.

Ref. Annual Report, ix, pages 62, 65; Annual Report, x, page 48; Bulletin vi, pages 123, 420.

Meg. A gray, medium-grained, irregular rock, rusty, yet sparsely specked with pyrite, and giving the dark metallic lustre of graphite, which seems to be disseminated throughout it. It is evidently the product of the mutual reaction of the sedimentaries on the basic eruptives of the region, and it is, in many cases, hence, not possible to state the greater alliance of a hand specimen, whether with the sedimentaries or the eruptives. Yet, this has uniformly been considered as a modified portion of the quartzytes and slates of the Animikie of the region.

Quartz is abundant, probably the most abundant element of the rock, though it hardly constitutes one-half. It is all in secondary form, usually in angular grains, not generally pegmatitic, but micro-granulitic.

Biotite is common, some of the larger plates being brown and giving a uniaxial interference figure. When cut perpendicular to the cleavages, or at least when not parallel to them, this mineral is alternately brown and light green, or greenish brown when, with one nicol in use, it is rotated on the stage. The brown color appears when the direction of the edges of the cut plates agrees with the principal section of the nicol in use. When it is not brown and is cut oblique to the cleavage, it gives colored polarization, approaching that of muscovite.

Graphite, which resembles magnetite, even in reflected light, is common. It is an element of the sedimentary strata.

Penninite, having nearly the same appearance as in No. 265, but in less amount, seems to exhibit a gradation in color from the "aureoles" mentioned under No. 265 to the characteristic brown of the biotite, at the same time fading out in the opposite direction to green. These aureoles have usually quite distinctly a nucleus of very dark color, as if a foreign substance provoked the change or centralized it, or retarded it, and that hence the aureoles are remnants of biotite not wholly converted to pennine. The aureoles, moreover, are not always aureoles, but patches that spread irregularly, sometimes shading into the brown of the biotite.

Titanite (sphene) in small, generally roundish, light yellow grains.

Rutile, in rods, closely associated with dark, opaque grains, resembling magnetite.

Pyrite and hematite, the latter in very small amount. The rock might be considered a changed eruptive.

Two sections examined.

Age. Animikie.

Remark. This rock is completely changed, but there is no apparent generation of secondary plagioclase. There are various areas in the section occupied now by sub-opaque or kaolinic substances which are perhaps the remnants of original plagioclases. N. H. W.

No. 271. Quartzyte. *(Graphitic.)*

"Finely graphitic quartzyte; from the same place as the last."
Ref. Annual Report, ix, page 65.

Meg. A rather fine-grained, gray quartzyte. It consists of grains of quartz and feldspar in a darker mass which is mostly graphite. The rock is indistinctly mottled with gray or pinkish, this being due to small areas where the graphite is much decreased in amount or is almost absent.

No section.

Age. Animikie. U. S. G.

No. 272. Barite, Calcite, etc. *(Vein material.)*

From the vein on S. W. ¼ sec. 32, T. 64–7 E. Pigeon point.
Ref. Annual Report, viii, pages 15, 16; Annual Report, ix, page 65.

Meg. The hand sample is a coarsely crystallized mass of calcite, barite and quartz.

No section.

Age. Embraced in the Animikie rocks; crosses a dike running N. 60° E.

U. S. G.

No. 273. Diabase.

From a dike running N. 60° E., crossed by the vein No. 272, situated in S. W. ¼ sec. 32, T. 64–7 E.
Ref. Annual Report, ix, page 65.

An ordinary diabase, with quartz and much apatite, considerably altered, spotted with reddish brown.

One section.

Age. Cabotian(?) N. H. W.

No. 274. Gabbro.

From near the trail to Parkerville.* About three-quarters of a mile north of the lake shore, near the north line of sec. 32, T. 64–7 E. This rises in a low hill, just north of the point where the trail runs over a stony beach fifty-two feet above lake Superior.
Ref. Annual Report, ix, pages 66, 69, 70.

Meg. Coarsely crystalline with porphyritic glassy feldspars. Sample much decayed. Probably a hornblende gabbro, like the rock at the extremity of Pigeon point (No. 291). The section is worthless for examination.

Age. Cabotian. N. H. W.

No. 275. Diabase *(with olivine)*.

From the dike at the brink of Pigeon River falls, running north 50° E.
Ref. Annual Report, ix, page 66; Annual Report, x, page 140; American Association for the Advancement of Science, vol. xxx, page 163.

This rock is an ordinary ophitic diabase, with considerable magnetite.

One section.

Age. Cabotian(?) N. H. W.

No. 276. Diabase *(with olivine)*.

From a dike just below Pigeon River falls, running east 10° north. These two dikes seem to converge toward the hill where No. 261 was obtained.

This rock is not different from No. 275, as evinced by the thin section with that number. Yet the specimen bearing that number is coarse and rough with the ophitic augites. N. H. W.

No. 277. Diabase. *(Porphyritic.)*

"Porphyritic basalt, from a small island west of Governor's (or Susie)† island, south of the island which furnishes No. 269. This island is caused by this dike, but has the country quartzyte on the flanks. On the east and north side, it dips a little east of south, or as the slates at Pigeon River falls. It rises about twenty-five feet." This is from the island called Oley island, in the northwest corner of sec. 5, T. 63–7 E.
Ref. Annual Report, ix, page 66.

Meg. A fine or medium-grained diabase, black and heavy and apparently somewhat altered. It contains small porphyritic plagioclases and a few reddish areas.

No section.

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

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*Parkerville was the name given originally to a settlement at the mouth of Pigeon river. It embraced but two or three buildings and has now entirely disappeared.

† The islands of the Lucille group have received two sets of names; one by Dr. Hanchett, state geologist in 1864, and the other by the officers of the U. S. Lake Survey in 1870. The former having priority have the first claim to acceptance.

No. 278. Diabase.

"Is from the east end of the long island west of Governor's (or Susie) island, next south of No. 277; from the main dike of the island." From the long island in N. E. ¼ sec. 6, T. 63–7 E.

Ref. Annual Report, ix, page 66.

Meg. A fine or medium-grained diabase, somewhat altered and containing much red, feldspathic material.

No section.

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

No. 279. Diabase.

From a dike west end of Governor's (or Susie) island.

Ref. Annual Report, ix, page 66.

An ordinary gray, rather fresh diabase, in which, in thin section, an ophitic structure is evident, and in which is a very small amount of olivine.

Age. Cabotian(?) N. H. W.

No. 280. Diabase. *(Porphyritic.)*

"Rock like No. 269, and in its bearing. Forms the north point that encloses the long bay on the east end of Governor's (or Susie) island, cutting the quartzitic slates that dip south on each side." S. E. ¼ S. E. ¼ sec. 32, T. 64–7 E.

Ref. Annual Report, ix, pages 66, 67.

Meg. A fine-grained, dark-gray diabase with some red material. A few porphyritic plagioclases are present.

Mic. The section shows a considerably altered diabase, quite similar to No. 269.

One section.

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

No. 281. Bornite *(and vein matter).*

About half a mile from the east end of Governor's (or Susie) island. From a vein which runs north and south. This vein has since been extensively exploited, but without finding copper or silver in paying quantities (see Nos. 1851, etc.) The vein is about three feet wide and is probably in continuation from one of the veins of the mainland of Pigeon point. There are several other such veins in the vicinity.

Ref. Annual Report, ix, page 67.

N. H. W.

No. 282. Diabase. *(Altered.)*

From the main dike of the north part of Governor's (or Susie) island.

Ref. Annual Report, ix, page 67; Annual Report, x, page 142; American Association for the Advancement of Science, vol. xxx, page 165.

Mic. This is a diabase in which the augite has become changed to chlorite and hornblende. Otherwise it is similar to several others already described, but has an occasional feldspar of an earlier consolidation.

One section.

Age. Cabotian(?) N. H. W.

No. 283. Porphyryte. *(Diabase.)*

"From the larger little island at the west end of High (or Lucille) island." N. W. ¼ sec. 8, T. 63–7 E.
Ref. Annual Report, ix, page 67.

Meg. A fine-grained, dark-gray, diabasic rock, with porphyritic plagioclases, some of which are over half an inch across. Some of these phenocrysts show, especially at their edges, a pinkish color; otherwise they are glassy and gray in color.

Mic. The porphyritic *plagioclases* are imbedded in a groundmass which is composed of plagioclase laths in an abundant background of secondary minerals. These secondary minerals are almost entirely *chlorite*, *hornblende* and *magnetite*. It is probable that most of this secondary material, especially the hornblende, originated from augite, although no augite is now present. It is also possible that part, at least, of the areas filled with alteration products, were originally *glassy*. There are a few green areas which suggest olivines, especially as some of these areas interfere with the outlines of the plagioclase phenocrysts.

One section.

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

No. 284. Gabbro. *(Porphyritic.)*

"From the main dike (?) of High (or Lucille) island, on the south side. The dike itself is horizontally basaltic toward the west end of the island; and a part of the hight of the island is caused by a heavy overflow, but perhaps not from this dike. This dike "hades" to the south, and is a coarse porphyritic greenstone. The samples are from that part that is dike-like."
Ref. Annual Report, ix, page 67; Bulletin ii, page 118.

Meg. A fine-grained, gray rock, consisting of small gray feldspars in a darker background. It contains porphyritic crystals of a gray to glassy plagioclase.

Mic. The section shows but one phenocryst; this is considerably clouded. The groundmass is much altered, even the feldspars being much altered. In structure this groundmass is granitic and is composed essentially of *plagioclase* and *hornblende* with some *quartz*, thus justifying the name quartz dioryte applied to this rock by Dr. Wadsworth (Bulletin ii, page 118). It seems quite evident, however, that the rock was originally a gabbro and is here so-called, the hornblende and quartz being regarded as secondary. Some iron ore occurs in the section and this in places is seen adjoining a gray opaque substance evidently derived from it; the iron ore is thus *ilmenite* or *titaniferous magnetite*, rather than magnetite. One section.

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

No. 285. Quartz Keratophyre.

From the first island northwest of Magnet (or Belle Rose) island. The south side of this island is conspicuously red with this rock, but the north shore appears of the usual color. This rock is embraced between two or three narrow basaltic dikes running east and west. As the dikes crumble by reason of their more close jointage the surfaces of this red rock stand out to view. The island next further northwest (Little Brick island) appears reddish in the same way on the south side.

Ref. Annual Report, ix, pages 67, 68 (rock No. 1845); Annual Report, xiii, pages 100 (No. 164), 103; Bulletin viii, page xxxiii; Bayley, Bulletin cix, U. S. Geol. Survey.

Meg. The rock is brick red, imperfectly crystalline, with a few spots or specks of greenish color and some quartzes. There is also occasionally visible a glittering reflection, evidently from the cleavage of a feldspar.

Mic. The reddened section is occupied almost entirely by a network of spheruliths, some of which have bipyramidal quartz at the centre. These spheruliths are but rarely true spheruliths. The reddened matter, it is true, is almost always arranged in a radial structure about the quartzes, but it is observable that the quartz background usually embraces this reddened matter poikilitically and extinguishes in conjunction with the *quartz* which occupies the centre or in patches which have no relation to the rays of the spherulith. In other places there is evidence that a feldspar form has become reddened and occupied by silica in a micropegmatitic manner. In still other parts, which sometimes are quite large, there is a closer grouping of individual quartzes similar to those which lie at the centres of the spheruliths, but their surroundings are more finely granular and complex, with a liberal supply still of pegmatitic quartz. The dark portions of the slide are occupied by *chlorite* and by magnetite. One of the slides also shows *epidote.*

Three sections.

Chemical analysis. An analysis of this rock (No. 285) gave the following results:

SiO_2	73.91
Al_2O_3	14.89
Fe_2O_3	2.27
FeO	1.70
CaO	.27
MgO	trace
K_2O	2.78
Na_2O	2.64
H_2O	1.01
Total,	99.47

Age. Cabotian.

Remark. This rock is strictly identical with the rock forming the knob on Pigeon point peninsula from which was obtained rock No. 1845. It has been discussed at length by Bayley, and is again referred to in Part III, in the treatment of the "red rocks" of the state. (Compare, also, Part I of this volume.) N. H. W.

No. 286. Diabase (?)

"Black, basaltic rock, from the narrow dike adjoining No. 285."
Ref. Annual Report, ix, page 68.

Meg. A compact, fine-grained, very dark, diabasic rock containing a little pyrite.

Mic. The section shows a much altered rock. It is composed of *plagioclase,* much altered, *hornblende, magnetite,* a dirty greenish product, and *quartz.* It is impossible to determine whether augite was originally present, but it seems quite probable that it was and that the rock was a fine-grained diabase. The section shows one grain of *pyrite*.

One section.

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

No. 287. Diabase.

From the big dike (like No. 274), the axis of Pigeon Point peninsula, near the location of Kindred and Baker's barite vein. (Compare No. 1843.)

Ref. Annual Report, vii, pages 16, 17; Annual Report, ix, page 69; Bulletin ii, page 96.

Of this rock Wadsworth says: "Has a section composed of *plagioclase, diallage, magnetite*, altered *olivine*, and other secondary products. The olivine is replaced by reddish and yellowish brown *serpentine*, showing the usual network or 'maschen-structur' of serpentine, replacing olivine along a network of fissures. The diallage has suffered considerable alteration, is of a cloudy, brownish color, and is in part replaced by *biotite, chlorite*, etc."

The feldspar, which, having on 010 an extinction angle of 20°, seems to be labradorite, appears to have embraced, in some instances, small amounts of the uncrystallized magma, which is now converted to a greenish and grayish substance which gives the interference figure of a possible monoclinic mineral, but charged, for the most part, with *magnetite*. In some cases the result of change in the olivines is a highly absorptive, brownish yellow, cleaved mineral, which may be the same that has been referred to already as *bowlingite*. Augite distinctly ophitic.

Two sections examined.

Age. Cabotian.

Remark. In another section of this rock, there is much less decay; the augite is ophitically related to the feldspar, and no olivine is apparent. N. H. W.

No. 288. Diabase.

"Fine, green rock from the shaft at the barite vein," Pigeon point; probably in S. E. ¼ sec. 28, T. 64-7 E. Baker and Kindred's location.

Ref. Annual Report, vii, pages 16, 17; Annual Report, ix, page 69.

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

Mic. The section shows small lath-shaped plagioclases, considerably altered, in a groundmass of greenish and yellowish alteration products, which are *hornblende, chlorite* and *magnetite*. No augite is now present, although it probably was originally. Some unindividualized interstitial material may have also occurred.

One section.

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

No. 288A. Barite, etc. *(Vein material.)*

From the shaft. Same locality as No. 288.

Ref. Annual Report, vii, pages 16, 17; Annual Report, ix, page 69.

Meg. A coarsely crystallized mass of barite, with a few specks of pyrite, *chalcopyrite* and *sphalerite.*

No section.

Age. A vein in Animikie rocks. U. S. G.

NO. 288B. BARITE, ETC. *(Vein material.)*

From another vein adjoining No. 288A.
Ref. Annual Report, vii, pages 16, 17; Annual Report, ix, page 69.

Meg. A coarsely crystallized mass of *barite,* with *calcite,* some earthy material and decayed rock.

No section.

Age. A vein in Animikie rocks.

Remarks. The age of these veins is not known. They are, however, probably of the same age as No. 272, which is clearly later than the dike No. 273. U. S. G.

NO. 289. QUARTZYTE.

"The country rock at the barite vein." Same locality as No. 288.
Ref. Annual Report, ix, page 69.

Meg. A very fine-grained, greenish-gray quartzyte, showing quartz grains in a darker greenish background.

Mic. The section, which is a poor one, shows the rock to be essentially the same as No. 268.

One section.

Age. Animikie. U. S. G.

NO. 290. QUARTZYTE. *(Brownish.)*

"Fair samples of the quartzyte of the region—the chief rock of Pigeon Point peninsula, as exhibited on the south shore; obtained three miles west of the extremity. This is a dark-red or brownish quartzyte, becoming black near the dikes, and in some places having red orthoclase mixed with the quartz grains."
Ref. Annual Report, ix, page 69; Annual Report, x, page 49.

Meg. Quartzyte, fine-grained and brownish. Small quartz grains and red feldspars are discernible in a greenish cement.

Mic. The section is essentially similar to No. 262 except that the greenish chloritic material is in much larger amount.

One section.

Age. Animikie. U. S. G.

NO. 291. GABBRO *(with olivine).*

From the extremity of Pigeon point. (Compare Nos. 274, 287, 1843.) Forms the main axis of the peninsula.
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, pages 57, 140; Bulletin ii, page 105; American Association for the Advancement of Science, vol. xxx, page 163.

Meg. Two consolidations are apparent, the first embracing the feldspars and probably olivine, and the second the bulk of the rock. This structure is visible, however, only in one of the sections. The other, and the rock sample from which it was taken, do not show any porphyritic structure. The rock is otherwise coarsely and evenly crystalline, gray and gabbroloid in aspect, and not much decayed.

Mic. The later *augite* embraces both *olivine* and augite ophitically. *Magnetite* and brown and greenish *biotite*, sometimes in contiguous masses, each color showing the darkened aureoles, accompany the augite, and brown-yellow *serpentine* occupies fissures in the olivine. It is evident that these aureoles are not imperfectly biotitized remnants of chlorite remaining in the biotite mass, since they are equally distinct in both places. Their cause antedates both minerals.

The earlier augites seem to have been affected, in some cases, in such a manner by the vicissitudes through which they have passed as to become nearly uniaxial. At least, in one grain, cut perpendicular to n_g, the optic angle 2 E is so small that the mineral was at first taken to be some other than a monoclinic pyroxene on account of the black cross presented by the interference figure. After more careful examination, it was noticed that the hyperbolas separate about 5°. This is an unusual optical anomaly for augite.

Magnetite has shapes similar to those of the augite, but is occasionally embraced by the latter in the characteristic ophitic manner.

Quartz appears as isolated grains of good size, and also as pegmatitic filling in some of the plagioclase.

Two sections.

Age. Cabotian.

Remark. The brownish substance above referred to as serpentine, which is sometimes brownish red, may be the same that has been alluded to before as a product of a very ferruginous olivine in process of decay. (M. Hannay, Mineralogical Magazine, vol. i, page 154, 1877.) The methods of distinguishing this mineral from antigorite, and a summary of all its characters, are given by Lacroix (Minéralogie de France, vol. i, pages 442–445.) See under No. 162. N. H. W.

No. 292. Granite *(with biotite)*.

"The next rock just west of the canoe portage, on the north shore of the peninsula; forms a similar kind of coast; also is heavily jointed and bedded like No. 291, but it is red with orthoclase. The microscope reveals also hornblende and quartz; occasionally, also, is a grain of milk-white, foliated, soft mineral. This is a granular rock, derived from the fusion and crystallization of the associated sedimentary beds. It weathers and parts as if a conglomerate near the water. This rock continues but a short distance, making one blunt point, when the features and color of No. 291 return again. (See the notes on Nos. 604–613.)" S. E. ¼ N. W. ¼ sec. 26, T. 64–7 E.; north side of Pigeon point.

Ref. Annual Report, ix, page 70; Bulletin ii, pages 81–83.

Meg. A medium-grained red granite, composed of red feldspar, quartz and a soft dark green mineral, probably chlorite. There are some drusy cavities on the sides of which are crystals of the minerals of the rock and calcite.

Mic. The section shows a granular rock composed mostly of *quartz* and reddened *feldspar.* The other minerals present are *biotite, chlorite, epidote, calcite, pyrite, magnetite* and *hematite.* Quartz is in grains and also in pegmatitic intergrowths with the feldspars, especially around the peripheries of crystals of the latter mineral.

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

SiO_2	61.09
Al_2O_3	15.34
Fe_2O_3	5.74
FeO	3.69
CaO	3.10
MgO	1.33
Na_2O	3.41
K_2O	3.65
H_2O	1.80
Total	99.15

The analysis shows a lower percentage of silica than would be inferred from the large amount of quartz in the sections. In chemical composition this rock is more basic than the granular red rock described by Bayley from this locality,* and probably this hand sample would belong with the rock intermediate between the granular red rock and the gabbro. A considerable part of the lime shown in the analysis can be accounted for by the presence of calcite, and with this in mind it seems probable that the feldspar is largely *anorthoclase,* the feldspar common to the granular red rock.

Age. Cabotian. U. S. G.

No. 293. Gabbro (*with olivine*).

From the north side of Pigeon point a mile and a half east of the mouth of Pigeon river. This rock forms the coast line, which rises sometimes fifty feet above the lake, nearly all the way from the extremity of the point and is doubtless in continuation from No. 291 and from No. 287.

Ref. Annual Report, ix, pages 50, 70.

Mic. The thin section made from this rock presents a fresher appearance than those from No. 291, and contains much fresh *olivine,* a little *biotite* and *chlorite* with characteristic aureoles. The *augite* is more frequently ophitic than in No. 291,—indeed it is generally ophitic, and at this point therefore this rock hardly deserves the name gabbro.

Two sections.

Age. Cabotian. N. H. W.

No. 294. Gabbro (*with olivine*).

From the hills next north of the glacier plain on the Grand Portage trail, probably S. E. ¼ sec. 30, T. 64–6 E., near the point where the Arrow River trail crosses them. This rock is identical with rock No. 293.

Ref. Annual Report, ix, pages 72, 73.

No. 295. Quartzyte.

Near upper end of the Grand portage; probably in N. E. ¼ sec. 29, T. 64–5 E.

Ref. Annual Report, ix, page 73. (See, also, rock No. 772 [W.] from this same locality.) Annual Report, xvi., page 291; Final Report, iv, page 510.

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

Meg. A fine-grained, rather light greenish, gray quartzyte.

Mic. The section is composed of rounded and subangular *quartz* grains, sometimes showing secondary enlargements, and a few *feldspar* grains in an abundant cement, which is composed largely of *chlorite*, and quartz and feldspar in minute grains.

One thick section.

Age. Animikie. (Grand Portage graywacke.) U. S. G.

NO. 296. DIABASE *(with olivine).*

From a dike near the brink of Partridge falls in Pigeon river. The axis of a hill range, supposed to be the same as that from which was derived No. 294. This dike runs W. 5° N.; at least 110 paces wide.

Compare No. 774 (W.), Annual Report, xvi, page 291.

Ref. Annual Report, ix, pages 73, 74; Bulletin ii, page 106.

Meg. Apparently an olivine diabase of a dark color, and of uniform grain.

Mic. This rock has the same characters as No. 293. The rock is fresh, and the olivines even are well preserved.

One section.

Age. Cabotian. N. H. W.

NO. 297. GABBRO *(with olivine).*

English rapids (upper end), near the centre of the N. ½ sec. 21, T. 64-4 E.

Ref. Annual Report, ix, page 74; Annual Report, x, page 140; Bulletin ii, page 106; American Association for the Advancement of Science, vol. xxx, page 163.

This rock, which also comes from a dike, again illustrates these great dikes, which cut so numerously the Animikie slates of the region. The augite is both ophitic and idiomorphic, and the whole rock is fresh, making a beautiful microscopic slide. In one of the ophitic augites the same character is observed as seen in No. 291, *i. e.*, the optic angle round n_g is abnormally small, in this case being about 20°.

Two sections.

Age. Cabotian. N. H. W.

NO. 298. DIABASE *(with olivine).*

Top of the hill on the east of the portage trail, at the foot of South Fowl lake. This lies on the slates, and was probably injected as a sill between the slates originally, the overlying slates having been destroyed. It has a perpendicular basaltic structure.

Ref. Annual Report, ix, pages 74, 75; Bulletin ii, page 108.

Mic. This rock is undistinguishable from Nos. 293, 296 and 297, except that the minerals are all more decayed. Macroscopically, much pyrite is apparent in this rock.

Two sections.

Age. Cabotian. N. H. W.

NO. 299. SLATE.

"Fragment of the slate from below No. 298; ten feet below the contact." Same locality as No. 298.

Ref. Annual Report, ix, page 75; Annual Report, xvi, page 72.

Meg. A very fine-grained, gray or greenish gray, fissile slate. Contains some micaceous mineral along the cleavage planes.

No section.

Age. Animikie. U. S. G.

No. 300. GABBRO *(with hornblende and quartz).*

From a hill S. W. ¼ sec. 30, T. 65-3 E. South of Moose lake (of the international boundary). Rises 485 feet above Moose lake. One of the common coarse eruptives of the region.

Ref. Annual Report, ix, page 76; Annual Report, x, page 84; Bulletin ii, page 80, plate VII, figure 1.

Mac. Coarse, gray, apparently altered basic irruptive, containing hornblende.

Mic. The *feldspar* is changed by the entrance of micropegmatitic quartz; in some crystals the *quartz* occupies one-third of the total area. Micaceous and ferruginous products of decay cloud the feldspar, but in some grains its triclinic character is still manifest. Extinction on 010 indicates a labradorite near *andesine.* Extinction on a section perpendicular to n_g is 22°, indicating labradorite adjoining andesine. (Fouqué.)

In the decay of the augite, it seems to have changed first to "*diallage,*" and then to *hornblende.* In the diagram presented by Wadsworth, this transition is well shown. (Bulletin ii, plate VII, figure 1, and page 80.) The cleavages of the augite are all parallel, indicating a section in the prism zone. These lines are marked and continuous, though not rigidly straight. The fibrous intercalation, however, which marks the progress of decay and the orientation of the "diallage," as shown by him, forms an angle of about 72° with the cleavage of the augite, which is very near the angle β, *i. e.*, the angle between the base and the orthopinacoid. It appears, hence, that the fibrous disintegration, which follows certain coarse cracks, is parallel to the base of the augite crystal. Its origin, in this case, therefore differs from that which is assigned to the diallagic schillerization by Judd, not only in its cause, but also in its direction in the crystal (Quarterly Journal, Geology Society, xlii [1886], page 82). This change is here probably one that results from weathering. The whole section indicates a weathered condition of the rock from which it is obtained. The diallagic parting which is found in the older augites of the gabbros is seen in numerous cases, and is parallel to the orthopinacoid. It is a strong cleavage-like parting, not fibrous nor lacking in transparency. Such crystals are found, not where weathering has affected them, nor dynamic pressure, but in the deep-seated and most protected portions of the gabbro masses. This parting coexists with the prismatic cleavage. It seems probable that two different forms of alteration in augite may have been confounded, one due to the cooling stage of the rock, when gases and hot solutions permeated it, and the other due to ordinary weathering. They seem to differ not only in the direction in which the lamellation grows in the original crystal, but in the cause which produced them, and also in the degree of integrity which is preserved by the crystal in general. The true diallagic structure does not destroy the orientation of the augite, but in this case the fibrated mineral has an orientation different from that of the original augite.

Another section was made of this rock for the purpose of studying more fully the changes undergone by the augite. There are four facts that appear distinctly in the course of this change: (1) The augite changes to what may be called diallage, by the loss of the prismatic cleavages and the acquirement of a cleavage parallel to 100. This can be seen in a single grain, in which the centre is still augite with its prismatic cleavages at right angles, and in which the surrounding mass is still augite, having the same extinction but only the cleavage 100. (2) A cleavage is developed parallel to the base 001 which appears at first imperfectly and in short cracks. (3) Parallel with this basal cleavage is a finely fibrous alteration product, called diallage by Wadsworth (Bulletin ii, plate VII, figure 1), which is the so-called *viridite* of numerous authors. (4) This substance, which has no longer the orientation of the augite and cannot be considered diallage, is further altered, by a new crystallization, into amphibole whose cleavages, in the section represented by Wadsworth, are parallel to the prismatic cleavages of the original augite.

Biotite can be distinguished by its pleochroism, though it is not always brown.

The *chlorite* is decorated with the characteristic dark halos. It is about hexagonal, and gives a black cross in convergent light.

Bowlingite seems to have been generated in abundance, the product of changed olivine, which is now wholly wanting.

Hornblende, a uralitic product of change from the pyroxene is scattered in grains that vary much in size. It is prevailingly of a faint green color, distinctly cleaved and pleochroic.

Quartz is common both as individual grains of considerable size, of secondary origin, and as pegmatitic growths in the feldspars.

Apatite is seen in the quartz grains and in the altered feldspar.

Two sections.

Age. Cabotian. N. H. W.

No. 301. Calcite, Quartz, etc. *(Vein material.)*

"Vein matter from Kindred and Baker's shaft on the White Rose vein, near Arrow lake in Canada. This is about one and a quarter miles north of the east end of the first lake [Rove lake] west of Mountain lake."

Ref. Annual Report, vii, page 17; Annual Report, ix, pages 77, 78.

Meg. Calcite and quartz with some chalcocite (?) and pyrite and rock fragments.

Mic. The section shows *calcite* and *quartz* with particles of the rock which is black and opaque. One section.

Age. Vein in Animikie rocks. U. S. G.

No. 302. Quartz and Quartzine. *(Vein matter.)*

From the Baker shaft on the White Rose vein near Arrow lake (in Canada).
Ref. Annual Report, vii, page 17; Annual Report, ix, page 78.

Mic. Consists largely of *quartz* and *quartzine*, the latter differing from chalcedony only in having its fibres elongated parallel with n_g instead of n_p. The fibres are coarse and readily pass into pyramidal quartz.

There is, besides this siliceous element, apparently a large amount of altered rock material. *Pyrite* is visible macroscopically. The colored ingredients are *hornblende*, alteration of augite, *biotite*, *magentite*, and a few isolated grains of *titanite*.

Four sections.

Age. Vein in the Animikie rocks. N. H. W.

No. 303. Quartzyte. *(Vein material.)*

Apparently auriferous quartzyte from the large quartz vein near the north shore of Pine lake; S. E. ¼ sec. 31, T. 65-2 E.
Ref. Annual Report, vii, page 21; Annual Report, ix, page 79.

Meg. A gray, cherty mass, holding small fragments of a darker material. There is also some pyrite in the rock.

Mic. The section, which is very thick, shows finely crystallized *quartz* and much of an opaque gray substance.

One section.

Age. Vein in Animikie rocks. U. S. G.

No. 304. Taconyte.

Point in North lake; N. E. ¼ sec. 16, T. 65-2 W.
Ref. Annual Report, ix, pages 80, 81.

Meg. A cherty rock which varies in color from gray to greenish and to pinkish. A few small spots of finely crystallized *quartz* are seen; also some small dark spots which have a little pyrite on their peripheries.

Mic. The section shows numerous small rhombs of *siderite* in a *cherty* groundmass. The section is too thick to enable the exact nature of this groundmass to be determined, but it is probably made up of a very finely crystallized mass of *quartz* grains.

One section.

Age. Animikie.

Remarks. This rock is similar to those described as sideritic cherts, by Irving and Van Hise, in Monograph xix, U. S. Geol. Survey. For a full discussion of these rocks, see that work, and also "The Mesabi Iron Bearing Rocks" (Bulletin x, Geological and Natural History Survey of Minnesota), by J. E. Spurr.

No. 305. Dioryte(?)

North lake, Canadian side, just east of the first narrows in the outlet of North lake. (If the United States survey were extended over this point it would be found in N. W. ¼ sec. 16, T. 65–2 W.) This rock is the same as No. 744W.

Ref. Annual Report, ix, pages 81, 83, 107; Annual Report, x, page 85; Annual Report, xvi, page 270, Bulletin ii, pages 83, 85, 86, plate VIII, figure 1.

Meg. Black and white, or pepper-and-salt rock, composed largely of hornblende, quartz and one or more white feldspars, granular, rather coarse, sharply crystalline and fresh. It forms low irregular knolls, veined and blotched with irregularities of composition.

Mic. This rock has been carefully and fully described by Wadsworth, who shows that the original *pyroxene* has undergone great alteration, passing from diallage to green hornblende, thence to brown hornblende, showing its prismatic cleavage, and also into *biotite*, with which last is associated a little *magnetite*. The quartz he considers secondary. There is a little *titanite* (sphene) and *epidote*, as well as *apatite*, and doubtfully *zircon*. He says:

"The steps in the alteration shown by the different diallage cores irregularly interlocked with the hornblendic substance, and gradually passing into it, are as follows: (1) A palish green substance, not dichroic, and destitute of cleavage. (2) A deeper green substance, having a longitudinal cleavage, but not dichroic, or only slightly so. (3) The same dark green substance (all being connected), but of a somewhat darker green color, and dichroic, varying from a slight yellowish green to a dark green. (4) A well marked light hornblende, with not only the hornblende cleavage in a longitudinal direction, but also across the longer or vertical axis. This is dichroic, varying from a yellowish brown to a dark brown color. These changes resemble those shown by Williams in the Baltimore gabbro. The first three stages are to be seen united about a single diallage core, as are also the third and fourth stages."

One section.

Age. Archean. N. H. W.

No. 306. Granite *(with biotite)*.

Same locality as No. 305, in which it occurs somewhat in the manner of a vein.

Ref. Annual Report, ix, page 81.

Meg. A rather fine-grained, gray granite, composed of quartz, gray to glassy feldspar and biotite.

Mic. The section shows a granite composed almost entirely of quartz and feldspar. The feldspar seems to be *orthoclase* and a *plagioclase* showing fine twinning striæ and a low extinction angle,—probably near *oligoclase*. A little *biotite* is present, and also some *chlorite*, and a few small grains of *sphene*. Some of the quartzes and feldspars are set in a mosaic of finer grains, probably caused by peripheral granulation of the larger grains; the section, however, is too thick to show this point with certainty.

One section.

Age. Archean. U. S. G.

No. 307. Tuff (?)

At a point about a mile west of the last, on the south side of the Gunflint river, west of the "narrows."
Ref. Annual Report, ix, pages 81, 83.

Meg. Apparently an irony and carbonaceous shale, pyritiferous, firm and heavy, with flinty nodules, exposed perhaps two feet, nearly black.

Mic. The rock is fragmental and confused, of varying texture and grain, a considerable percentage being opaque black. The aspect is that of a finely vesicular or scoriaceous, mainly fragmental, rock whose cavities have become filled with *calcite*, or with *hematite* and calcite set in a dark, even opaque, ground work. Some rounded areas are much finer than others, and some of the fragments are very fine and scarcely polarize light. Sometimes *quartz* shares in the fillings of the minute cavities.

Three sections.

Age. Taconic (near the base of the Animikie).

Remark. The nature of this rock cannot be determined from the data at hand, except that it may be affirmed that its origin was through the accumulation of a peculiar fragmental debris. It is more nearly like a Carboniferous tuff of King's county, Ireland (No. I, 1397 of the series of the Survey of Great Britain), of which thin sections have been made from samples furnished by Sir Arch. Geikie, than any rock with which it is now possible to compare it. It is darker than that, and its ground work is less greenish. There are, however, isotropic, apparently glassy, portions which have a finely fluidal structure.

It is comparable, stratigraphically, with the glassy breccia described by Williams at Sudbury, Canada,* and with the tuffs of the Penokee range described by Van Hise.† N. H. W.

No. 308. Gabbro.

"The trap of the country; south side of Gunflint lake; sec. 24, T. 65–3 W.
"Compare Nos. 721–727."
Ref. Annual Report, ix, page 81; Annual Report, x, page 86.

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

Mic. The section shows a gabbro of rather fine grain, and considerably altered. The feldspar is much kaolinized, but a number of comparatively fresh grains remain. Some of these show equal extinction angles on each side of the albite twinning line running up as high as 30°, thus indicating *labradorite.* The *augite* is in part fresh, and part altered, the alteration products being *chlorite, hornblende* and *biotite.*

* *Bulletin of the Geological Society of America*, vol. iii, p. 138.
† *Bulletin of the Geological Society of America*, vol. iv, pp. 435, 436, 1893.

Apatite is also present, as is also *magnetite*, both secondary and original. In structure the rock approaches granitic; the augite, while in some cases later than the feldspar, is mostly of about the same date as the feldspar, and the rock is a gabbro.

One section.

Age. Cabotian.

Remarks. This rock is from one of the Logan sills of the Animikie (see A. C. Lawson, Bulletin viii). In general these sills are diabases, but the section of this rock can properly be called a gabbro. The evidence, however, is not conclusive that it is an apophysis from the gabbro of the great gabbro mass which lies just to the south of this area of Animikie. U. S. G.

No. 309. Slate.

North side of Gunflint lake, about half way from the eastern extremity.
Ref. Annual Report, ix, pages 81, 82; Annual Report, xvi, page 68.

Meg. An aphanitic, dark, greenish-gray slate or schist.

Mic. Under a low power the rock shows a few grains and crystals of *magnetite* and *pyrite*, small specks of an opaque substance which is black in transmitted light and gray in reflected light, and numerous black dust-like particles, all imbedded in a minutely crystalline groundmass. Under a high power, this groundmass appears to be made of minute grains of *quartz*, scales of *chlorite* and a few minute *muscovite* scales.

One section.

Age. Archean (Keewatin). U. S. G.

No. 310. Graywacke.

North side of Gunflint lake, half way from the eastern extremity; associated with vertical slates into which it graduates.
Ref. Annual Report, ix, pages 82, 85; Annual Report, x, page 17; Annual Report, xvi, page 68.

Mac. Firm, harsh, siliceous rock, with grains of free quartz, of a light green color; evidently also contains much feldspathic material.

Mic. A fragmental, slightly schistose rock, the grains all much altered. *Quartz* is the most conspicuous element, in sub-rounded grains, some of them being composed of several individual grains, as if from a sandstone or a conglomerate originally. *Feldspar*, clouded and semi-opaque between crossed nicols, but occasionally showing albite twinning, is very abundant, in sub-angular fragmental grains. The matrix for these two consists of finer grains of the same and a little coloring matter such as *hematite*, *biotite* and *chlorite*. The fibrous and laminated minerals are mainly arranged in one direction.

One section.

Age. Archean (Keewatin). N. H. W.

No. 311. QUARTZ-PORYHYRY (?) *(Consolidated debris, porphyrel.)*

Greenish, "porphyritic," schistose and fibrous, with free quartz, embraced in the slate No. 310, parallel with its bedding, running E. 20° N., standing vertical.

Ref. Annual Report, ix, pages 82, 85, 97, 102; Annual Report, xvi, page 68. (Compare No. 1283.) This rock is the same as No. 731 (W.), Annual Report, xvi, page 256, and No. 1008 (G), Annual Report, xxii, page 85.

Meg. The fibrous structure is characteristic of a pressed rock. The larger elements form knots, round which the fibres are compelled to shape themselves. The quartz and the feldspar seem to be intact, but the former is sub-rounded.

Mic. The *feldspar* belongs to the acid series. It is twinned on the Carlsbad and albite plans. A section in the zone of symmetry,* shows, accidentally, an optic axis, vertical on each side of the line of an albite twinning, which, according to the épures of Michel Lévy (Détermination des feldspaths dans les plaques minces, planches 3 and 4) can happen only with *oligoclase* and *andesine*. Another section, nearly perpendicular to n_p has extinction, according to Fouqué's method, at 81° or 82°. As this is much too high for andesine, and yet as the feldspar cannot be albite, it must fall on the oligoclase side of oligoclase-albite of Fouqué's table (Bulletin de la Société de Minéralogie de France, vol. xvii, page 428), *i. e.*, between oligoclase and andesine-oligoclase. If the section were strictly perpendicular to n_p, it is therefore certain that the extinction would be about 88°, in agreement with the table, and the feldspar is thus shown to be *oligoclase*.

The feldspar has a great many inclusions, the most frequent and conspicuous of which, owing to its polarization colors, is *muscovite* in minute isolated scales. *Apatite* also occurs in this situation, elongated parallel with the twinning. Spots, which in the feldspars are nearly isotropic, are probably of *chlorite*, cut parallel to the base. Much *calcite* occurs, both in the feldspar and throughout the section.

The outlines of the feldspars are plain. No granulation is perceptible. The edges, whether crystalline or fragmental, are abrupt and distinct.

Throughout the matrix, which is fine and made up of angular pieces, no feldspar fragments can be distinguished readily, since unless albite twinning is apparent, they would have a strong resemblance to quartz, which is abundant.

Quartz is in porphyritic masses and is finely disseminated through the largely isotropic matrix. The larger grains sometimes show a cloudiness which shifts about on rotation between crossed nicols, indicating a distortion produced by pressure.

Apatite, as already stated, is found in the feldspars. It is also in the matrix in larger though microscopic crystals. These are distinguished when cut parallel to their elongation by parallel extinction, by conspicuous shagreen on lowering the polarizer, and by the conspicuous transverse cleavages. Usually but a single crystal is found alone, but in a few instances two or three are associated lying parallel.

*That is, in the triclinic feldspars, to the zone perpendicular to 010, and nearly to the vertical axis.

Chlorite gives color to the rock, which is a greenish gray. In a section parallel with the laminated structure, the chlorite scales overlap each other and give a general isotropic appearance to the matrix between crossed nicols, relieved by the sprinkling of angular grains of quartz and a few other minerals.

Age. Archean (Keewatin).

Remark. This rock has had a long history and no name can properly be assigned to it in its present form. It is equally impossible to state what its original nature was. In many respects it resembles some of the "porphyritic" fragmentals near the base of the Upper Keewatin, and its intimate structural association with, and petrographic alliance to, the graywacke (No. 310) in the midst of which it occurs, point to its original fragmental nature. It would then be a porphyrel. N. H. W.

No. 312. Limestone.

Matrix of a flint conglomerate or breccia. Occurs on both sides of Gunflint lake, most conspicuously on the north side, west of No. 311, on the points of the peninsula.

Ref. Annual Report, ix, page 82; Annual Report, x, page 87; Annual Report, xvi, page 69; Annual Report, xix, pages 126, 127; Bulletin vi, pages 121, 129, 130, 420.

Meg. This rock is gray, finely crystalline, and covered with a coating of iron rust, from which fact it has been supposed to consist essentially of siderite. The angular pieces embraced by it are of gray flint. It has a fine color-banding due to sedimentation, and occasionally fragments of rock other than flint are scattered in it, some of which is nearly black, resembling the dark rock of No. 307, and some is quartz, the latter being quite rare. Some of the dark rock is apparently a calcite amygdaloid.

Mic. The shimmering iridescence of *calcite*, or *dolomite*, is the most pronounced feature between crossed nicols, in convergent light, due to the high double refraction which is capable of giving the different colors even for roughness of the ordinary grinding and especially for the varying thicknesses in the individual grains of the rock as left by the slicing. There are a few other substances in the slide for the most part opaque, and too fine for determination. They are not pyrite. The section does not cut any of the vesicular dark ingredient of this rock.

In another section, made so as to cut one of the darker portions, the darker portion is seen to be made up largely of fine angular *quartz* with a matrix of finer grains of the same. There is also a considerable percentage of *chlorite*. Between the nicols the darker portion is so much darkened as to indicate the presence of an isotropic substance, perhaps of *glass*. The slide still does not show the vesicular portion mentioned above.

In still another sections made by Marchand, there are occasional areas which, sprinkled with a few minute opaque specks, are for the most part transparent, but between crossed nicols are either wholly dark or are indistinguishable from a devitrified *glass*.

Prof. C. F. Sidener, who analyzed this rock, obtained the following result (Bulletin vi, page 121):

Silica,	2.70	per cent.
Alumina,	.35	"
Ferric oxide,	17.23	"
Ferrous oxide,	8.35	"
Calcium carbonate,	49.80	"
Magnesium carbonate,	19.65	"
Potassium oxide,	.04	"
Sodium oxide,	.20	"
Water,	.47	"
Total,	98.79	per cent.

Age. Taconic, near the base of the Animikie, or perhaps Upper Keewatin.

Remark. The stratigraphic horizon of this limestone is much below that of the calcareous conglomerate of Grand Portage island (No. 254) and of the nondescript somewhat vesicular calcareous rock (No. 255) which overlies it. Further examination has shown that the latter was cotemporary with a volcanic epoch in the Keweenawan near the bottom of the same, while the former is near the base of the Animikie, or belongs in the Keewatin. N. H. W.

No. 313. Granite.

N. E. ¼ sec. 24, T. 65-4 W., south shore of Magnetic lake (a part of Gunflint lake north of the narrows).
Ref. Annual Report, ix, page 83.

Meg. A light-colored, micaceous, medium-grained rock.

Mic. With much *quartz* is mingled *microcline* and perhaps *orthoclase*, *biotite* and *chlorite.* Some of the feldspar is finely twinned on the albite plan and probably comes near *oligoclase.*

One section.

Age. Archean (igneous). N. H. W.

No. 314. Granite *(with hornblende).*

North shore of Magnetic lake; S. E. ¼ sec. 13, T. 65-4 W.
Ref. Annual Report, ix, page 83. Compare No. 650 (W.), Annual Report, xvi, page 237.

Meg. A rather coarse pinkish granite, composed of quartz, pink feldspar usually not showing twinning striæ, and *hornblende.* There is some *epidote* present, and also probably *chlorite* and *biotite.* A noticeable feature of the rock is the presence of several good sized crystals of a cinnamon brown mineral, most probably *sphene.*

No section.

Age. Archean (igneous). U. S. G.

No. 315. Granite *(with hornblende).*

First falls north of Gunflint lake, on the international boundary; N. E. ¼ N. E. ¼ sec. 13, T. 65-4 W. Compare Nos. 800, 1318; also, No. 649 (W), Annual Report, xvi, page 233, and No. 62 (G), Annual Report, xvii, page 160.
Ref. Annual Report, ix, page 83; Annual Report, x, page 106.

Meg. This is similar to the rock No. 305, but has generally less amphibole and more quartz.

Mic. The thick section is composed of *quartz* with shadowy extinctions, a clouded *feldspar* that cannot be determined, *chlorite, epidote* and a little *hornblende.*

One section.

Age. Archean (igneous). N. H. W.

No. 316. Granite (*with hornblende*).

Saganaga lake, N. E. ¼ sec. 4, T. 66–4 W. A few rods below the rapids.
Ref. Annual Report, ix, page 84; Annual Report, x, page 106.

Meg. A rock in general similar to the last, but having large quartzes.

Mic. Consists of much *quartz, microcline, orthoclase(?)* and *oligoclase.* The last is indicated by the fine, uniform striations, and the constant parallel, or nearly parallel, extinction. At the same time the striations are not fine enough to be characteristic of anorthoclase. The section also shows *epidote, chlorite* and *sphene*, the chlorite no doubt a result of decay of the hornblende common in the rock.

A feldspar grain cut nearly perpendicular to n_p has extinction at 75°, which agrees tolerably well for oligoclase, according to the table of Fouqué.* In general the feldspar is much kaolinized. The quartz grains, which appear larger in the hand sample, are seen under the microscope to consist of many parts, the result of a crushing to which they have been subjected. A shadowy extinction passes over them, and many fragments sometimes have nearly the same point of extinction, but so removed that a slight rotation in the same direction brings them successively into darkness. Two sections.

Age. Archean (igneous). N. H. W.

No. 317. Granite (*with hornblende*).

Small island in Saganaga lake, sec. 5, T. 66–4 W.
Ref. Annual Report, ix, page 84.

Meg. A medium-grained, pinkish granite, composed of approximately equal amounts of pink feldspar, quartz and hornblende. There are two small hand samples, one of which has a rude banding due to excess of hornblende in rough layers.

Mic. A granite composed of feldspar, *quartz, green hornblende* and some *chlorite.* The feldspar has a tendency to an idiomorphic form, is much decayed, but sometimes shows traces of fine twinning striæ and of zonal structure. When the twinning striæ (albite) are present the extinction on either side of the twinning line is low, indicating most probably *anorthoclase* or *oligoclase.* There is also a little *magnetite* and *epidote* in the section. One section.

Age. Archean.

* *Bulletin de la Société de Minéralogie de France*, vol. xvii, p. 428 (1894).

Remarks. No careful study of the feldspar of the great Saganaga granite has yet been made. This mineral is usually too much altered for a satisfactory optical examination. It is, however, clear, from the sections examined, that a considerable part of the feldspar is plagioclase. This shows fine twinning lamellæ according to the albite law; in grains showing an equal extinction angle on each side of the twinning line the extinction angle is very low, indicating that the feldspar is most probably oligoclase.

An analysis of a characteristic specimen (made by Mr. A. D. Meeds) of the Saganaga granite from the S. W. ¼ N. E. ¼ sec. 22, T. 66-5 W. [see Annual Report, xx, page 88; Annual Report, xxi, page 43, No. 686 (G.)] is as follows:

SiO_2	69.34
Al_2O_3	17.25
Fe_2O_3, FeO	2.46
CaO	3.43
MgO	1.18
K_2O	.71
Na_2O	4.33
H_2O	1.17
Total	99.87

From the analysis it is seen that very little potash feldspar is present, and in this case the rock might properly be called a quartz dioryte. It is possible that other samples of this rock from different parts of the lake would show a much higher percentage of K_2O; at any rate, on account of the large quantities of quartz and the general character of the rock as a whole, it seems best to refer the great Saganaga mass of coarsely crystalline quartz-feldspar-hornblende (or biotite) rock to the granites rather than to the dioryte. U. S. G.

No. 318. Quartz. *(Vein matter.)*

Northeast side of a small island in Saganaga lake; S. E. ¼ N. W. ¼ sec. 14, T. 66-5 W.

Ref. Annual Report, ix, page 84. (Compare No. 835W.) Annual Report, xvi, page 215. (For a description of this island, on which is a fluorite granite, see A. Winchell, Annual Report, xvi, pages 215, 216; U. S. Grant, Annual Report, xx, page 89; N. H. Winchell, Annual Report, xxiv, page 22, No. 2046.)

Meg. Coarsely crystalline, pure, milk-white quartz. There is also a very little purple fluorite.

Mic. The section shows a large mass of clouded *quartz*, with similar orientation throughout. The cloudiness is due to innumerable minute cavities filled with liquid, and frequently containing a bubble.

One section.

Age. A vein in Archean rocks.

Remarks. From the field descriptions, reference to which is made above, it appears that this island contains an irregular quartz vein. The surrounding rock, which is the usual Saganaga granite, has been much decayed and silicified, and in some places penetrated with purple *fluorite*, forming a beautiful *fluorite granite.* It seems that a fissure of some depth must have existed here, and that from it have come solutions bearing silica, and also gases. See rocks Nos. 835–841 (W.), Nos. 676–680 (G) and No. 2046. U. S. G.

NO. 319. GRANITE. *(Decayed.)*

Saganaga lake; southwest corner of an island just north of that on which No. 320 was found; S. W. ¼ N. W. ¼ sec. 14, T. 66-5 W.
Ref. Annual Report, ix, page 84. See, also, under No. 318.

Meg. Apparently a highly siliceous rock, containing some feldspar and pyrite, and in spots stained brownish yellow.

Mic. The section is composed of *quartz* and much decayed *feldspar*. There are also numerous small rhombs of what appears to be *siderite*, and some *pyrite* crystals. The siderite is seen in connection with a brownish yellow material (*limonite*), and this same substance is common throughout the section. It seems most probable that all of the limonite is an alteration from the siderite.

One section.

Age. Archean.

Remarks. This rock is regarded as part of the decayed granite mentioned under No. 318. U. S. G.

NO. 320. GRANITE. *(Decayed.)*

Saganaga lake; N. W. ¼ sec. 10, T. 66-5 W.
Ref. Annual Report, ix, pages 84, 85.

Meg. A coarse-grained rock composed of large, sometimes roughly rounded, areas of quartz, and feldspar which is much decayed and is pinkish, gray or yellowish in color. There are also small areas of a rather soft greenish-yellow material.

Mic. The section is composed largely of *quartz* and very much decayed *feldspar*. There are areas which are now opaque and greenish or gray in color, which seem to represent old *chlorite* areas; these are probably the greenish-yellow material seen in the hand sample. A few small grains of a green mineral are seen; the nature of this cannot be determined owing to the thickness of the section. Two rusty, reddish brown spots are also seen, possibly an alteration product from some ferruginous mineral.

One section.

Age. Archean (igneous). U. S. G.

NO. 321. GRANITE.

Lake Saganaga. Probably near the northwest corner of sec. 16, T. 66-5 W.
Ref. Annual Report, ix, page 85.

Meg. Greenish-gray, with quartz and a pinkish feldspar, and a chloritic mineral.

Mic. Essentially composed of *quartz* and a saussuritized feldspar which cannot be determined on account of the loss of cleavage and twinning lines.

One of the variations of the rock of the region.

One section.

Age. Archean (igneous). N. H. W.

No. 322. Arkose.

Oak portage, on the international boundary at the west end of Saganaga lake; S. E. ¼ N. E. ¼ sec. 24, T. 66-6 W.

Ref. Annual Report, ix, page 85. Same as No. 565 (W.); Annual Report, xvii, page 213; Nos. 2031-2045, Annual Report, xxiv, pages 18-22.

Meg. Rather fine grained; composed of angular grains of quartz and feldspar in an apparently feldspathic background.

Mic. The section shows angular grains of *quartz*, also some of much decayed *feldspar*. Between these grains is a dirty, almost opaque, isotropic, gray or yellowish material. It in part appears like decayed feldspar and sometimes the feldspar grains are not sharply set off from this material but seem to grade into it. A little *pyrite* is present.

One poor section.

Age. Archean (Keewatin).

Remarks. This rock is regarded as an arkose, whose elements have been obtained from the adjoining granite, and it may thus be termed a recomposed granite. This is not the place to discuss the relations of the Saganaga granite to the surrounding rocks. It may, however, be stated that here (west side of Saganaga lake) the rocks change from granite to clastics (slates, graywackes and recomposed granite). These clastics are of a later date than the granite and the rock here described (No. 322) represents part of the base of the clastics composed of debris derived immediately from the adjoining granite, and not water-worn. The granite may have been in a semi-decayed state when this rock was formed from it. U. S. G.

No. 323. Quartz Schist.

Oak lake, north side, which is the first lake west of Saganaga lake on the international boundary. The shores of this lake are composed of this rock.

Ref. Annual Report, ix, page 85.

Meg. Gray or greenish-gray schist, having a structure which is due apparently to pressure and shearing.

Mic. The section is largely made up of microgranulitic clastic *quartz*, in the midst of which is strewn a large amount of *chlorite*, which, being in shreds or fibro-lamellar, renders the field nearly dark constantly between crossed nicols. There is also some *calcite* and some *hematite*. The structure may have been produced in part by shearing, but the rock is evidently a clastic one.

Two sections.

Age. Upper Keewatin.

No. 324. Graywacke. *(Fine.)*

From the portage from Oak lake to Otter Track lake, on the United States side. Said to be a condition or variation of rocks Nos. 323 and 311.

Ref. Annual Report, ix, pages 85, 86.

Meg. Very fine grained and dense, of a slate color, massive (*i. e.*, not sheared), and homogeneous.

Mic. The section (which is too thick) consists of angular fragments of various minerals, but the most evident is *quartz*. This is perhaps also the most common. A few similar fragments of a striated *feldspar* are also observable. These lie in an abundant matrix of translucent grains, which seem to be darkened between crossed nicols by mutual overlapping and by a little *chlorite*. In a thinner section the clastic origin of the rock is evident. A few grains still give colored polarization. These are in part *muscovite*, and in part *epidote*. Between crossed nicols the slide is rather dark, except in the areas occupied by the quartz and feldspar grains.

Two sections.

Age. Upper Keewatin.

Remark. The fine debris of which this rock is composed is essentially granitic, and was doubtless derived from the Saganaga granite, on which this series of strata is seen to lie about one-fourth of a mile east of the portage from Oak lake to Saganaga lake. (Compare No. 322; also Nos. 2031–2045.) N. H. W.

No. 325. Arkose.

East end of Knife lake, on the international boundary, S. E. ¼ S. W. ¼ sec. 32, T. 66–6 W. From the slate series of the region which extends from the portage from Saganaga lake to Oak lake. This member is an important one in the series, as it represents the rock which continues a good part of the distance from the east end of Knife lake, at least to the narrows of the same lake (between sections 11 and 12). The rocks all have a greenish color, but are not always slaty.

Ref. Annual Report, ix, page 86.

Meg. A non-slaty, much greener variety of a rock similar to No. 324.

Mic. This rock is very similar to rock No. 322 and doubtless had the same origin. It is coarser than Nos. 323 or 324.

Age. Archean (Upper Keewatin).

Remark. It is an interesting fact that the coarser parts of the Upper Keewatin, about Saganaga lake, are not at the contact on the granite, but at a considerable distance from it. (See Part I.) N. H. W.

No. 326. Slate. *(Pyritiferous.)*

Ontario; north side of Knife lake, about three-fourths of a mile east of the portage to Maple Leaf lake. (Maple Leaf lake is a small lake, not more than a mile across, lying in Ontario between the north bay, near the west end of Knife lake, and the northward extension of Carp lake; Carp lake is called Pseudomesser lake in the fifteenth and sixteenth annual reports. The usual canoe route between Knife and Carp lakes is through Maple Leaf lake.)

Ref. Annual Report, ix, pages 86, 87.

Meg. A dark gray, rather coarse-grained slate or schist, containing cubes of pyrite. It is rather soft and not decidedly siliceous.

Mic. The section shows a coarse band lying between two finer ones. The coarse band has numerous rough rhombs of *siderite*, a few angular *quartz* grains and a little *pyrite* in a finely fibrous groundmass. This groundmass is made up largely of minute greenish fibres or flakes, which have very little influence on polarized light, much of the section remaining practically dark between crossed nicols; these greenish flakes are regarded as *chlorite*. There are a few brightly polarizing flakes, probably *muscovite*, and a few minute quartz grains. The finer bands lack the siderite and angular quartzes, and are practically similar, although somewhat finer grained, to the groundmass of the coarser band. Throughout the section is much black dust-like material, and also specks, which are opaque, black in transmitted light and gray in reflected light.

One section.

Age. Archean (Keewatin). U. S. G.

No. 327. Flint.

Knife lake end of the portage between Knife lake and Maple Leaf lake; in Ontario.

Ref. Annual Report, ix, page 86. Compare rock No. 1429; also No. 973 (A. W.), Annual Report, xvi, page 210.

Meg. Flint, nearly black, but weathering light, with conchoidal fracture and sharp edges which gave name to Knife lake, about whose shores it is common. It is only local or in beds, or sometimes in ridges.

Mic. The rock is a very fine-grained clastic, of the nature of Nos. 322 and 324. With a high power, numerous angular fragments of quartz can be seen lying in a matrix, which, between crossed nicols, is rather dark, and which consists, probably, of much decayed feldspathic debris, in which, however, are sprinkled a few scales of muscovite.

One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 328. Slate.

Ontario. Maple Leaf lake end of the portage between Maple Leaf and Carp (Pseudomesser) lakes.

Ref. Annual Report, ix, pages 86, 87.

Meg. From the roofing slate series of Knife lake. The sample shows alternations of fine and coarser-grained rock.

Mic. The section, evidently made from the coarser part of the specimen, embraces conspicuous angular *quartzes* and a few striated *feldspars*, lying in a matrix similar to the matrix of several already mentioned (Nos. 324, 325, 326) which is semi-isotropic between crossed nicols, the exact nature of which it is difficult to decide but which may have been derived from a devitrification of volcanic glass. It is grayish to greenish, or even clear and translucent in natural light. In some cases a fibrous or scaly structure like chlorite is visible, but in most of the grains of this sort, the clear parts are simply the background for many microliths, some of which are opaque and some transparent and capable of polarizing light.

The slide also contains areas of *calcite*, and one cubic section of *pyrite*, in the vicinity of which is some *chalcedony*, at least a minutely fibrous glass-clear mineral in which the elongation is sometimes negative and sometimes positive.

The slide also shows variations in the relative abundance of the opaque grains. These are sometimes so grouped as to suggest that fragments of some different rocks were involved in the accumulation of this. These fragments are not vesicular, distinctly, but seem to be composed of rock similar to the rock in which they lie.

One section.

Age. Archean (Keewatin). N. H. W.

No. 329. Schist. *(Hornblendic.)*

East end of Bassimenan (Basswood) lake, near Prairie portage; probably in N. E. ¼ S. E. ¼ sec. 2, T. 64–9 W.
Ref. Annual Report, ix, page 87.

Meg. A rather soft, dark-green rock, slightly schistose. The rock is too fine-grained to allow the components to be distinguished. Along seams some calcite is deposited.

Mic. The section shows green *hornblende*, *calcite*, *quartz*, *plagioclase*, *epidote*, *chlorite* and *pyrite*. The hornblende, which is the most abundant mineral, is elongated in one common direction, thus giving a decided schistose structure to the section —much more pronounced than would be thought from an examination of the hand sample. The hornblende is wrapped around quartz and plagioclase grains which show no clastic features, but are fresh and interlock with each other. Scattered through the section is abundant calcite (probably in part siderite) and small flakes of chlorite.

One section.

Age. Archean (Keewatin).

Remarks. This rock is part of the "greenstones" of the Keewatin. From the field notes, the hand sample and the section it is impossible to draw any definite conclusion as to the original nature of the rock. It shows no indication of structures which are definitely characteristic of either clastic or igneous rocks. It seems probable that the rock represents a sheared and recrystallized diabase or basic ash.

U. S. G.

No. 330. Granite *(with hornblende).*

Bassimenan (Basswood) lake, N. E. ¼ N. W. ¼ sec. 2, T. 64–9 W.
Ref. Annual Report, ix, page 87.

Meg. Rock varies from rather dark to lighter colored, as the hornblende and micaceous elements vary.

Mic. The rather thick section only permits the determination of the essential minerals present, which are *quartz*, *feldspar*, *chlorite* and *hornblende.*

One section.

Age. Archean (igneous). N. H. W.

No. 331. GRANITE *(with hornblende).*

"The rock of the country at Basswood lake, taken from an island two miles northwest of the eastern extremity." Perhaps in sec. 34, T. 65–9 W.

Ref. Annual Report, ix, page 88.

Meg. A gray granite of medium grain, composed of quartz, white feldspar which rarely shows twinning striæ and hornblende.

Mic. The section is composed of *quartz*, *feldspar*, *hornblende* and a little *epidote.* The quartz shows undulatory extinction. The feldspar is apparently *orthoclase*, *microcline* and *plagioclase* which seems to be near *oligoclase.*

One section.

Age. Archean. U. S. G.

No. 332. GRANITE *(with hornblende).*

"Near the portage landing, west end, in a low exposure; a fine chloritic (?) gneiss, the bedded structure sloping south at a high angle." Bassimenan (Basswood lake); west end of portage from the main lake to a narrow arm; sec. 5, T. 64–10 W.

Ref. Annual Report, ix, page 88.

Meg. Fine-grained, gray granite, composed of quartz, white feldspar and hornblende.

Mic. The most noticeable feature of the section is the large crystals of feldspar, which, however, are not idiomorphic. These feldspars are in a groundmass of finer grained *quartz* and *feldspar.* The *feldspar* of the rock is frequently considerably altered, but much of it is comparatively fresh. Some of it appears to be *orthoclase*, but much of it is *plagioclase* with low extinction angles—probably *oligoclase.* One grain, which was cut almost perpendicular to the positive bisectrix, gave an extinction on the cleavage of about 4°; this indicates *oligoclase* or *andesine-oligoclase.* (M. Fouqué, Bulletin de la Société Minéralogique de France, tome xvii, 1894.) The large feldspars frequently show a zonal structure. There are some small green *hornblendes* in the slide; also a few small *sphenes* and a little *epidote.*

One section.

Age. Archean (igneous). U. S. G.

No. 333. DIORYTE.

Same place as No. 332.

Ref. Annual Report, ix, page 88.

Meg. The abundance of hornblende in this rock gives it a dark aspect.

Mic. This only differs from No. 332, so far as can be seen, in the relative amount of *hornblende* it contains. The *sphenes* are sometimes large for microscopic crystals. Slender spicules which are associated with the feldspar seem to consist of *apatite*, while *epidote* is quite common.

The existence of quartz in this rock is very rare. The feldspars have the appearance of quartz, being clear and limpid in extinctions as the stage rotates. These grains, when tested for the characteristic interference figure, uniformly give a biaxial sign, and on lowering the nicol they are seen to contain numerous enclösures, and sometimes show a cleavage or a structure indicating feldspar. In one such instance the bisectrix (n_g) gave an extinction angle of 8°, which is near *andesine*. Another exactly perpendicular to n_p gave an extinction angle of 66°, which exactly agrees with *andesine*.

One section.

Age. Archean (Coutchiching).

Remark. The transition from the igneous rock of the "Laurentian" of the region of Bassimenan lake to the Coutchiching at this place is no less noticeable petrographically than it is outwardly. The abundant quartz of the light colored igneous Laurentian disappears almost entirely, and the clouded, semi-saussuritized oligoclases, microclines and orthoclases, give place to a glass-clear andesine.

N. H. W.

No. 334. Dioryte.

Same locality as No. 332. "Chloritic hornblende schist, conformable with No. 333."
Ref. Annual Report, ix, page 88; Bulletin ii, pages 87, 88, plate VIII, figure 2.

Meg. A dark, almost black, medium-grained rock composed very largely of hornblende, with some gray feldspar.

Mic. The section shows *hornblende* in abundance, feldspar, *epidote* and *sphene*. The feldspar is sometimes very highly altered and sometimes quite fresh. In the highly altered portions much epidote has been developed. The fresher feldspar frequently shows fine twinning lamellæ and a low extinction angle—and probably is near *oligoclase*. Many of the smaller grains do not show twinning, but still seem to be plagioclase. An untwinned grain cut almost exactly perpendicular to the positive bisectrix shows an extinction angle of about 3°, indicating *andesine-oligoclase*. (A section of orthoclase cut parallel to the brachypinacoid would show the positive bisectrix and a low extinction angle, as would also a similar section of andesine-oligoclase. In this case, however, it is probable that no orthoclase is present.)

Remark. In Bulletin ii, a quartz-pseudomorph after plagioclase is described and figured. This very grain, however, seems to be feldspar and so do the surrounding smaller grains. This grain and many others which seem to be quartz on casual examination, were tested and many of them were found to show a distinct biaxial character, and *not one* showed clearly a uniaxial nature. There were, however, a number of grains whose characters could not be determined positively. It thus seems that quartz is very rare, if not entirely lacking, in this section.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 335. Mica Schist.

"Biotite mica schist, separated from No. 334 by a recurrence of rock like No. 332, conformable in dip with the last. This includes irregularly shaped masses or agglomerations of Nos. 336 and 337; also has thin, irregular, interrupted and contorted interlaminations of the same. They are certainly interstratified." Same locality as No. 332.

Ref. Annual Report, ix, pages 88, 89.

Meg. There are two hand samples. The first is a gray mica schist of fine grain. The second is a darker, greener rock, and seems to be a hornblende schist.

Mic. The section, which is remarkably thick, was evidently made from the first hand sample. It shows *biotite* and *quartz* (with possibly feldspar) in fine grains. The biotite is in flakes lying approximately parallel, and to this is due the schistose structure of the rock.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 336. Granite (*with hornblende*).

"Biotite(?) hornblende gneiss, of a light-gray color, alternating along the beach two or three times, conformably with No. 335." Same locality as No. 332, but along the beach further south.

Ref. Annual Report, ix, pages 88, 89.

Meg. Fine-grained, gray granite, composed of gray feldspar, quartz and hornblende.

Mic. The section is closely similar to No. 332.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 337. Granite (*with hornblende*).

Same locality as No. 332, near No. 336.

Ref. Annual Report, ix, page 89; Annual Report, x, page 95.

Meg. A rather fine-grained, gray granite, composed of gray feldspar, hornblende, (with probably some biotite) and quartz. No section.

Age. Archean (Coutchiching). U. S. G.

No. 338. Gneiss (*with hornblende*).

Same locality as No. 332, still further south, near the beach and island.

Ref. Annual Report, ix, page 89.

Meg. A rather fine-grained, dark-gray granitic rock having a somewhat schistose structure due to the arrangement of the hornblende. Composed of hornblende, gray feldspar and apparently quartz.

Mic. The section is composed essentially of green *hornblende*, feldspar and quartz, the last two in rather small grains. The feldspar seems to be similar to that of the other rocks from this locality—*i. e.*, near *andesine-oligoclase;* many of the grains are clear and glassy. Quartz is not as common as at first sight would be supposed, but still is present. The other minerals of the rock are biotite, epidote, sphene and apatite.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 339. Hornblende Schist.

"Hornblendic schist, from the shore of the same lagoon, on the north side, where the same interstratified condition of the same kinds of rock appears again." Near the same locality as No. 332, etc.

Ref. Annual Report, ix, page 89; Annual Report, x, page 95.

Meg. A dark rock, very rich in hornblende. Besides this mineral there is a fine-grained granular aggregate of glassy grains.

Mic. The section shows much green *hornblende*, sometimes very dark and practically opaque. Between the hornblendes and sometimes in them are fine grains of *feldspar.* This is sometimes cloudy and sometimes quite clear. The section is very thick and no careful determination of the feldspar could be made, but it seems to be of the same nature as the feldspar of the associated rocks. Quartz may be present in small amount, though none was determined.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 339B. Dioryte. *(Coarse.)*

"From the shore near Nos. 337 and 338, not in place, but supposed to be from these beds."

Ref. Annual Report, ix, page 89.

Meg. A very coarse-grained aggregate of green hornblende, biotite and gray to pinkish feldspar.

Mic. The section shows large plates of more or less fibrous green *hornblende*, large and small grains of feldspar and some *biotite.* The feldspar is mostly cloudy. One grain which gave a positive bisectrix almost exactly perpendicular shows an extinction of 6°. This might indicate *oligoclase-andesine* or *orthoclase*, but in this case the general characters of the mineral and its similarity to the feldspar of the associated rocks make it more probable that the feldspar is of the oligoclase-andesine series. Considerable *sphene* is present, and one peculiar feature of the section is the abundance of large stout prisms of *apatite.* This mineral occurs in the hornblende, biotite and feldspar, but more especially in the last. A little *calcite* is present.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 340. Mica Schist.

"A little further west from No. 339, on the north side of this little water, the rock appears as a micaceous quartzyte, which also varies to No. 341."

Ref. Annual Report, ix, page 89.

Meg. A very fine-grained, hard, dark greenish-gray micaceous rock, somewhat schistose.

Mic. The section shows the schistose structure of the rock finely. It is composed of *biotite*, *feldspar*, *quartz*, *chlorite* and *pyrite*. The feldspar is very abundant; it is quite clear, but often inclined to become cloudy; it rarely shows twinning, and then the twinning lamellæ are minute. The feldspar rarely shows any trace of cleavage. A number of grains showing bisectrices were found, but only one of these showed cleavage; in this grain the cleavage was not pronounced, it gave a negative bisectrix and an extinction of 76°, indicating *andesine-oligoclase*. Quartz is not nearly as abundant as the feldspar, although it is present.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 341. Mica Schist. *(Tuff?)*

Same locality as No. 340; a variation of No. 340.

Ref. Annual Report, ix, page 89.

Meg. A dark, fine-grained rock, hardly schistose.

Mic. This is a fragmental rock, and in the slide all the elements have a prevailing elongation in one direction. The sparse *quartz* and abundant *feldspar* are so nearly alike that they cannot be distinguished except by the closest scrutiny at high power, and in convergent light. They are in angular small bits, and, with a little *pyrite*, they are set in a loose and scant frame-work of *biotite*. The feldspars are nearly always destitute of cleavage, and the most of them present a deceptive, limpid appearance, with double refraction lower than quartz. Some of them have a a shadowy extinction, indicative of dynamic deformation. Other grains of feldspar are probably of another species, for they are much clouded with saussuritic particles; so much so, that an effort to determine them is fruitless.

Throughout much of the slide, instead of evident mica there is a greenish, clouded, semi-isotropic (perhaps chloritic) ingredient. It is probably this element that gives the rock its dark color.

Two sections.

Age. Archean (Coutchiching). N. H. W.

No. 342. Gneiss.

"A gneissoid quartzyte, and makes a high bluff, the beds in all cases dipping to the south." Near the same place as Nos. 340 and 341.

Ref. Annual Report, ix, page 89.

Meg. A fine-grained, siliceous rock, showing gray to pinkish feldspars in a fine groundmass.

Mic. The section is very similar to Nos. 332 and 336, *i. e.*, it contains large cloudy feldspars *(oligoclase)* in a finer groundmass. The groundmass is made up largely of feldspar (near oligoclase), with some *quartz, biotite, chlorite, epidote, magnetite* and *apatite.*

One section.

Age. Archean (Coutchiching). U. S. G.

No. 343. Syenyte.

Bassimenan lake. East end of the portage, E. ½ sec. 6, T. 64–10 W.
Ref. Annual Report, ix, page 89.

Meg. A light-colored, granitoid, medium-grained rock.

Mic. The greater part of this rock consists of a feldspar which greatly resembles quartz, along with another that shows albite striations. The latter is *oligoclase,* as it gives an extinction angle of 88°, in a section cut perpendicular to the bisectrix n_p. An occasional large feldspar seems to be of *microcline,* but the peculiar cross-hatching of that species is not conspicuous, and cannot be relied on. Hence this peculiar rock may be said to consist essentially of *andesine* and *oligoclase,* with a few conspicuous *epidotes* and a very little *chlorite.*

One section.

Age. Archean (Coutchiching). N. H. W.

No. 344. Mica Schist *(with hornblende).*

"At the other end of this portage, and at one or two spots on the trail, the rock is a tough mica schist. This here also embraces strips of syenyte and of quartz. These appear mainly as interlaminations, but also as veins crossing the laminations." Bassimenan (Basswood) lake; west end of portage; W. ½ sec. 6, T. 64–10 W.
Ref. Annual Report, ix, page 89.

Meg. There are two hand samples. One is a fine-grained, dark, greenish-gray hornblende schist, with perhaps some biotite. The other is a fine mica schist in contact with a gray, granitic rock composed almost entirely of white feldspar and quartz.

No section.

Age. Archean (Coutchiching). U. S. G.

No. 345. Granite *(with hornblende).*

Bassimenan lake. Probably in N. E. ¼ S. E. ¼ sec. 1, T. 64–11 W. "The rock along the shore, passing up this long bay, is syenyte [granite ?], but the sample of this number is taken from the place where the first view is presented up the long bay southwest. Here it is evenly bedded, dipping west, and is of pinkish or red color. This continues past one or two small points, when it is seen to dip in the opposite direction; then, on the next, it dips again southwest."
Ref. Annual Report, ix, pages 89, 90.

Meg. Red granite of medium grain.

Mic. The section consists largely of non-striated and striated feldspars, one of the latter giving on n_p an extinction of 79°, indicating a feldspar between *andesine-oligoclase* and *oligoclase.* The non-striated feldspar is probably *andesine,* and would show striations if the section were thinner and the grains were properly cut. The presence of evident grains of *microcline,* however, rather favors orthoclase instead of andesine. *Quartz* is quite common, and *hornblende* is sufficient simply to warrant the name hornblende-granite.

One section.

Age. Archean (Coutchiching). N. H. W.

No. 346. Mica Schist *(with epidote).*

"Passing to the north side of this bay, within a half mile, or perhaps more, the whole changes to a fine, tough gneiss, which has a coarse schistose structure that makes it resemble the schists, being probably only a variation of the schists." Bassimenan (Basswood) lake; perhaps in sec. 11, T. 64–11 W.

Ref. Annual Report, ix, page 90.

Meg. A fine-grained, dark greenish schistose rock, composed of much biotite (with some chlorite) and gray to pink feldspar.

Mic. The section shows a decided schistose structure due to the approximately parallel "streams" of *biotite* and *epidote.* Besides these minerals there are *feldspar, quartz, chlorite, calcite* and a micaceous mineral due to alteration of the feldspar. The feldspar is often much altered, and this and the quartz are often in very fine grains.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 347. Granite or Gneiss *(with hornblende).*

"A little further along, across the bay, the syenyte returns; but here a schistose structure can be seen on weathering, parallel to that seen all along. This forms the coast for some distance on the north side, at least to within one-half mile of the next portage." Bassimenan (Basswood) lake; perhaps in sec. 11, T. 64–11 W.

Ref. Annual Report, ix, page 90.

Meg. A gray, rather fine-grained, granitic rock, consisting of hornblende, gray to pinkish feldspar, quartz and epidote.

Mic. The section shows feldspar, *hornblende, quartz* and *epidote.* Part of the feldspar is very highly altered; a large part of that which is fresh shows the characteristic *microcline* grating in polarized light. One of these grains, showing but one set of twinning striæ and thus cut parallel to the brachypinacoid, gave a positive bisectrix and an extinction angle of 9°, all of which corresponds closely to microcline. Sometimes the larger feldspars include the other minerals poikilitically. The *epidote* is abundant, especially in minute grains and crystals in the immediate vicinity of the hornblende.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 348. Actinolite Schist.

Ridge and rapids at the mouth of Pipestone river, where the water comes down to the level of Bassimenan lake, the descent being about ten feet. S. W. ¼ sec. 22, T. 64–11 W.

Ref. Annual Report, ix, page 90: Annual Report, x, pages 89, 95; Annual Report, xv, pages 104, 105.

Meg. A tough greenish schist, crushing under the hammer like a chloritic schist; irregular and broken by jointage planes in different directions, and confused by a slight schistose structure, rather fine grained.

Mic. The slide is composed, almost entirely, of a network of spicules of green *hornblende*, which are not so compactly interwoven but that in their meshes can be seen grains of *feldspar* and of *quartz*. They do not have any prevalent direction of elongation, but overlap and cross each other as if accidentally thrown together. They show usually very faint dichroism, or none, but occasionally a marked dichroism is observable; a little *sphene* is also seen.

Two sections.

Age. Archean (Lower Keewatin).

Remark. This is a common rock in the Lower Keewatin, lying next above the igneous portion of the Kawishiwin. It is probably derived from an ancient sediment in which volcanic debris and erosion products were mingled. It is the horizon which contains elsewhere the most of the Keewatin jaspilyte. N. H. W.

No. 349. Serpentine.

Pipestone rapids, a short distance above the rapids, in the right bank which rises about two feet above the river. S. W. ¼ sec. 22, T. 64–11 W.

Ref. Annual Report, ix, page 91; Annual Report, x, page 95; Annual Report, xv, pages 104, 105; Annual Report, xvi, page 111; Bulletin ii, page 29.

Following is Wadsworth's description of this rock *(op. cit.)*:

Meg. "The hand specimen is a compact, dark-green rock, traversed by veins of talc and dolomite and coated in places by a limonitic deposit.

Mic. "The section shows a pale grayish and yellowish green groundmass, traversed by a reticulated network of *magnetite*, and cut by a dolomite vein. The magnetite preserves in part the outlines and fissures of the original *olivine* grains, while the groundmass itself is composed principally of a pale greenish isotropic *serpentine*, *talc* scales and fibres and *magnetite* granules. The talc is in single plates and in aggregations of fibres. The general character of the rock is similar to the serpentines of Michigan, New Jersey and Massachusetts."

Having had another section prepared we are able to add to the foregoing description. The term "serpentine" here may be employed in a general sense, somewhat as suggested by Lacroix,* indicating a rock rather than a mineral, consisting essentially of the products of alteration of the magnesian schists, which

* *Minéralogie de France et de ses Colonies*, part I, p. 417.

may be separated into distinct types on their differing optic properties. In this sense the entire rock is essentially a serpentine, retaining still a sort of porphyroidal microscopic structure, such as mentioned by Dr. Wadsworth.

In the section examined there are five minerals, not including magnetite.

1. An isotropic, pale green or yellowish mineral, which occupies areas of considerable size, entirely different and distinct from the other areas. This mineral is very finely fibrous, or structureless, and cannot be distinguished from that frequently seen in the centres of decayed olivines in the Keweenawan eruptives.

2. *Calcite* (or *dolomite*) is present, not only in microscopic veins, but more or less disseminated in the mass of the rock.

3. A highly bi-refractive mineral, which occasionally is in distinct fibres, but for the most part is in flakes or scales, and which occurs scatteringly in the porphyroidal areas of the original olivines referred to by Dr. Wadsworth. They do not probably consist of antigorite, owing to their high double refraction. They have positive elongation and parallel extinction, and with a thickness of .03 millimetres, their highest colors are in the second order, viz.: red, yellow and green. They appear, therefore, to be *talc*, of which there is a microscopic vein visible on one end of the hand specimen.

4. The most of the space of the supposed old olivines is occupied by a much less bi-refractive mineral. Its highest colors are a faint yellow, and most of it does not rise above the white of the first order. It is also in fine scales and is probably *antigorite*. The network which occupies these areas renders it impossible to get a uniform darkness.

5. There is also a noticeable amount of a fibrous or fibro-lamellar mineral, whose double refraction is still lower, viz., in the grays below the white of the first order, which is referable to *pennine*.

The rock is therefore a serpentine with a considerable amount of *steatite*.

Two sections.

Age. Archean (Lower Keewatin). N. H. W.

No. 350. Chlorite Schist (?)

"Chloritic (?) slate from Pipestone rapids, just above the pipestone rock. The slate stands nearly vertical, but dips to the south." S. W. ¼ sec. 22, T. 64-11 W.

Ref. Annual Report, ix, page 91; Annual Report, x, page 95. For description of this locality see, also, Annual Report, xv, pages 104, 105.

Meg. A very fine-grained, soft, fissile, greenish-gray schist. It has minute laminæ, green in color and probably composed largely of chlorite; also gray or flesh colored laminæ perhaps composed of feldspathic material.

No section.

Age. Archean (Keewatin). U. S. G.

No. 351. Sericite Schist.

"About three-fourths of a mile above the rapids the slates dip northwest." Newton lake; probably in N. E. ¼ sec. 27, T. 64–11 W.

Ref. Annual Report, ix, page 91. Same as No. 257 (W.), Annual Report, xv, page 104.

Meg. A very fine-grained, light greenish gray, rather fissile schist. Occasionally a small grain of feldspar can be seen,—otherwise the rock is almost aphanitic.

Mic. The schistose structure is finely shown in the section; there are irregularly parallel streams of fine gray opaque material, and the scales of *sericite* and *chlorite* are elongated in a common direction. The rock consists of sericite, chlorite, *quartz*, *feldspar*, the gray opaque substance, *calcite* and a brownish stain. The sericite (or what is so regarded) and the chlorite are in minute flakes or scales; the former polarizes brightly. With these scales is a very fine-grained aggregate of *quartz* and apparently feldspar also. The section shows also larger grains of *feldspar*, which are broken and show undulatory extinction. Usually several grains of almost parallel orientation, and separated by growths of sericite, are close together, suggesting that the several grains are from one broken crystal. In this respect they are closely similar to the "stretched" grains of feldspar figured by G. H. Williams in Bulletin lxii, U. S. Geol. Survey (figure 2, plate IX; figure 2, plate XIV). These feldspars very rarely show twinning; they are somewhat altered, sericite being developed in them, and do not as a rule show cleavage, so their species was not determined. They are, however, probably *orthoclase*. The opaque gray material, spoken of above, under a high power is seen to be made of minute highly refractive grains and crystals which seem in part to be epidote. One section.

Age. Archean (Keewatin).

Remark. What this rock was originally cannot be determined from the single specimen and section at hand. It may not be amiss, however, to suggest that it represents an advanced stage of shearing and stretching in a quartz-porphyry or similar rock, the broken and almost obliterated feldspars being the only original grains left in the rock. It may also be a sheared debris derived largely from quartz-porphyry.

U. S. G.

No. 352. Quartz. *(Vein.)*

"At the upper end of the second rapids, or a little distance above, near the portage landing, is a large white quartz vein in the chloritic rock that makes the rapids. This runs S. 30° W., and coincides with the slate in dip, which is toward the northwest. This quartz embraces rusted pyrite, and has an auriferous aspect." Near the S. E. ¼ sec. 22, T. 64–11 W.

Ref. Annual Report, ix, page 91. This vein is illustrated by figure 1, plate AA, vol. iv.

Meg. Milk-white *quartz* enclosed in a green, fine-grained chloritic schist. The schist contains rusty spots probably due to the decay of a ferruginous mineral—*pyrite*.

No section.

Age. Vein in Archean (Lower Keewatin) rocks.

U. S. G.

Remark. A section of the rock embracing the vein is almost wholly dark constantly between crossed nicols, but affords scattered scales of a highly bi-refractive mineral which seems to be of *sericite,* besides a little *calcite* and a few grains of secondary plagioclase.

It also contains a single microsopic crystal of a rare mineral, viz.: *tourmaline.* This exhibits a longitudal section whose absorption is very strong, bi-refraction strong and single refraction weak. It is crossed by many transverse irregular fissures, but is otherwise without cleavage. It has a dark gray color, and its elongation is negative, and its extinction parallel. N. H. W.

No. 353. Sericite Schist.

"Slate, soft, greenish (talcose or chloritic), from about two miles further up the lake, on the south side. There is not much exposure, but sufficient to show the formation extends to here, at least." South end of Newton lake, at the portage to Fall lake; probably near centre of sec. 3, T. 63-11 W.

Ref. Annual Report, ix, page 91.

Meg. Soft, light greenish-gray, sericite schist. Resembles, though more fissile and apparently less siliceous, No. 351. Contains a little pyrite and rusty spots probably from the decay of this mineral.

No section.

Age. Archean (Keewatin). U. S. G.

No. 354. Chlorite Schist (?)

"A less slaty, chloritic slate, from the same place. The slates here run S. 30° W., standing nearly vertical, sloping south. Indeed, this direction is about that of the narrow, long lake (Newton) in which the route lies." Same locality as No. 353.

Ref. Annual Report, ix, page 91.

Meg. A soft, fine-grained, dark, greenish-gray schist, apparently containing much chlorite.

No section.

Age. Archean (Keewatin). U. S. G.

No. 355. Tuff (?) (*"Greenstone."*)

South side of Fall lake, east of the falls. Probably in the S. ½ sec. 17, T. 63-11 W.

Ref. Annual Report, ix, pages 91, 92; Annual Report, x, pages 89, 95.

Meg. A massive, yet coarsely schistose, siliceous light-green, fine-grained rock, with white quartz veins, apparently the same continuous rock mass as at Kawasachong falls (No. 356), but more like a graywacke. The single (poor) section at hand shows a fragmental rock composed of shreds of triclinic *feldspar* and much semi-opaque material, amongst which can be recognized, with greater or less certainty, *epidote, mica* and some *chloritic* mineral. Quartz has been generated so as to embrace the other minerals poikilitically.

Another section, made by Marchand, shows a general composition essentially of a basic débris, the original elements of which have been much altered. It contains *hornblende, epidote, feldspar, quartz,* isotropic (chloritic?) substance, and is similar to the next.

Two sections.

Age. Archean (Kawishiwin of the Lower Keewatin). N. H. W.

No. 356. TUFF (?) *("Greenstone.")*

Kawashachong falls, forming the brink, and the bluffs below the falls; south side sec. 17, T. 63-11 W.

Ref. Annual Report, ix, page 92; Annual Report, x, pages 89, 95; Annual Report, xv, page 319; Annual Report, xix, pages 126, 127; Bulletin ii, page 123; Bulletin vi, pages 37-40, 420. This is also the same rock as Nos. 997, 998, 999 and 138 (W.).

Meg. Appears similar to the rock at Pipestone rapids. It contains narrow, white quartz veins and deposits, some of which are two or three feet wide. This rock is neither bedded, jointed nor distinctly schistose, but it breaks in a very coarsely schistose manner, and each piece runs to blunt points lenticularly. Chlorite permeates and colors it. It seems to be closely seamed in all directions, but not with any regularity, if we except the general schistoid fracture, which coincides with the slates in being nearly perpendicular, and yet in sloping to the south. It abounds in talcose(?) or chloritic and hematitic slickensides. It is everywhere rough superficially and mashes under the hammer before breaking, and then breaks toughly and roughly.

Mic. The sections do not show any schistosity, but that may be owing to being parallel to the structure. That the rock is fragmental is evident, as remarked by Wadsworth, and it has undergone not very much deformation since its deposition. Along with a few fragments of triclinic (probably secondary) *feldspar* and much *clinochlore,* indicating a basic source for the ejection which supplied the materials of this rock, are numerous quartzes which, also, to some extent, have been enlarged so as to embrace the surrounding rock material. The chloritic element is sometimes *pennine,* and is sometimes also isotropic. A considerable amount of the green color of the rock is also due to the presence of *hornblende* which appears in the thin section with higher double refraction than any other mineral. This mineral is sometimes in large grains with reeded extremities, but occurs in some places quite abundantly as finer grains and fibres. Its alteration is to clinochlore and to an isotropic chloritic substance. *Calcite* is common, as is also a gray, *leucoxene*-like substance. *Hematite* and *pyrite* are rarely seen. *Magnetite* is questionable.

Two sections.

Age. Archean (Kawishiwin of the Lower Keewatin).

Remark. The hornblende in this rock has a very varied aspect, and it is often difficult to distinguish the finer grains from epidote. Their index of refraction is sufficiently near that of epidote and the overlapping produces a darkness that likens the aggregate to the obscure upper colors of the third order as required by *epidote* of the same thickness. Hence we are disposed to consider that a portion of the higher polarizing mineral may be epidote. Such grains are abundant and not fibrous, but subangular and constitute an important element in the rock. N. H. W.

No. 357. Sericite Schist.

"A chloritic slate, running nearly southwest and sloping to the southeast." Fall lake, at end of portage to Long lake; N. E. ¼ sec. 24, T. 63–12 W.

Ref. Annual Report, ix, page 92.

Meg. A soft, fine-grained, fissile, greenish-gray, sericite schist.

Mic. The section does not show any schistose structure and was thus cut parallel to the cleavage. The rock is very fine grained, being composed essentially of very minute grains (most probably both quartz and feldspar) and of flakes of *sericite* and *chlorite.* There is also considerable *epidote* in minute grains and crystals, and also a few *hornblende* fibres, and *calcite.* A number of larger *quartz* and *feldspar* grains occur in the rock; these are not sharply angular, nor rounded, but they interlock with the minute surrounding grains. The rock in general is quite similar to No. 351, but the feldspars are more numerous and do not so much suggest that one larger grain has been broken up to form smaller ones.

One section.

Age. Archean (Keewatin). U. S. G.

No. 358. Tuff (?) (*"Greenstone."*)

Island near the west end of Long lake. Perhaps N. W. ¼ sec. 29, T. 63–12 W.

Ref. Annual Report, ix, page 93; Annual Report, x, pages 89, 95; Bulletin ii, page 119.

Meg. Light green, scarcely schistose, evidently decayed deeply, fine-grained, with veins of quartz, resembling No. 356.

Mic. This rock is one of the tuffaceous parts of the Kawishiwin, the minerals being very indefinite. Still, there may be seen a considerable amount of *calcite,* a secondary *feldspar*, which shows no cleavage and can hardly be distinguished from quartz, *quartz* broken by pressure and with shadowy extinction, an isotropic substance, and a *leucoxene*-gray sub-isotropic substance. The only brightly polarizing mineral is *calcite.*

Two sections.

Age. Archean (Lower Keewatin). N. H. W.

No. 359. Tuff (?) (*"Greenstone."*)

From the hill range running on the north side of Fall and Long lakes, taken on the portage from Burntside river to Burntside lake; S. E. ¼ sec. 23, T. 63–13 W.

Ref. Annual Report, ix, pages 93, 94.

Meg. Firm, tough, dark gray or greenish, fine-grained, appearing gray and granite-like at a distance when weathered.

Mic. The rock is fragmental, either because of crushing or by reason of original derivation. It consists, so far as can be determined, of triclinic *feldspar*, (probably *albite*), in fine pieces which have very irregular twin striations, and *chlorite* in fine shreds and strings. How much of the colorless ingredient may be of quartz cannot be determined certainly, because of its resemblance to the clear and limpid feldspar, but a considerable part of it appears to be *quartz*. A little *pyrite* is scattered through the rock.

Two sections.

Age. Archean (Lower Keewatin). N. H. W.

No. 360. Hornblende Schist.

Burntside lake, near the north end of the portage from the river which flows into Long lake; S. E. ¼ sec. 23, T. 63-13 W.
Ref. Annual Report, ix, pages 93, 94.

Meg. A dark green rock of medium grain, composed almost entirely of hornblende. A little feldspar is present, and many small veins of epidote.

Mic. The section is composed of matted, green *hornblende* fibres and a fine-grained aggregate of *quartz*, and considerably altered *feldspar;* also *epidote* and a little *pyrite.*

One section.

Age. Archean (Coutchiching).

Remarks. " Near the west end of the portage trail, on Burntside lake, within an area of thirty feet square, the following numbers, from 360 to 367, both inclusive, were obtained, Nos. 360 and 361 comprising the bulk of the rock."

" The rocks of these numbers are all arranged in a crooked lamination or coarse schistose structure, parallel with the same seen in the slates about here. The hornblende schist (No. 363) and the hornblende and feldspar rock (No. 364) gradually interchange, or pass onward to Nos. 365 and 366. Large masses in knolls and hills lie in the immediate neighborhood, made up of the same rocks." U. S. G.

No. 361. Hornblende Schist.

Same locality as No. 360.
Ref. Annual Report, ix, pages 93, 94.

Meg. A dark-green rock composed of hornblende and a little feldspar. It is quite similar to No. 360, but is coarser grained and does not contain as much epidote.

No section.

Age. Archean (Coutchiching). U. S. G.

No. 362. Hornblende Schist.

Same locality as No. 360.
Ref. Annual Report, ix, pages 93, 94.

Meg. A green rock, somewhat similar to the last two, but decidedly more schistose. It seems to contain chlorite and sericite as well as hornblende.

No section.

Age. Archean (Coutchiching). U. S. G.

No. 363. Hornblende Schist.

Same locality as No. 360.
Ref. Annual Report, ix, pages 93, 94.

Meg. A dark-green rock, finer grained than Nos. 360 and 361; composed of hornblende and some grayish feldspar, rather evenly distributed.

No section.

Age. Archean (Coutchiching). U. S. G.

No. 364. Syenyte.

Same locality as No. 360.
Ref. Annual Report, ix, pages 93, 94; Bulletin ii, page 87.

Meg. A rather coarse-grained, granitic rock, composed of hornblende and gray to pinkish feldspar.

Mic. The section is too thick for careful study. It shows green *hornblende* and much decayed *feldspar*, which is probably largely *orthoclase.*

One section.

Age. Archean (Coutchiching). U. S. G.

No. 365. Granite. *(Chloritic.)*

Same locality as No. 360.
Ref. Annual Report, ix, pages 93, 94.

Meg. A pinkish medium-grained granitic rock, composed of gray to pinkish feldspar, quartz and chlorite.

Mic. The section shows a large quantity of feldspar, with less quartz and a little chlorite. The *feldspar* is highly kaolinized; it does not usually show twinning striæ; some of the grains, however, show minute twin lamellæ which fade out in more altered parts of the same grain, thus suggesting that possibly all the feldspar was originally twinned. Its species cannot be certainly determined, but it is probably *orthoclase* and *anorthoclase* or *oligoclase.* The quartz shows very pronounced undulatory extinction. The *chlorite* is in small amount and is intimately associated with a brownish mineral, perhaps *bowlingite.* A few very minute grains of *epidote* are present. One section.

Age. Archean (Coutchiching near transition to Laurentian). U. S. G.

No. 366. Hornblende Granite.

Same locality as No. 360.
Ref. Annual Report, ix, pages 93, 94.

Meg. A medium-grained, granitic rock, composed of pink feldspar, hornblende, and a little quartz.

No section.

Age. Archean (Coutchiching near transition to Laurentian). U. S. G.

No. 367. Quartz *(from a vein)*.

Same locality as No. 360.
Ref. Annual Report, ix, pages 93, 94.

Meg. White, glassy, also stained by hematite; an accidental, thin fissure, or lamella, still retaining a little pyrite.

No section.

Age. Vein in the Archean (near Coutchiching). N. H. W.

No. 368. Granite.

North side of Burntside lake.
Ref. Annual Report, ix, page 94.

Meg. Light-colored, medium-grained granite.

Mic. Feldspar, sometimes plainly a *plagioclase*, and sometimes so kaolinized as to be undistinguishable from *orthoclase*, composes the greater part of this rock; but mingled with the feldspar is a little *quartz* in grains of some considerable, though mainly microscopic, size, and still less of *muscovite*, *calcite*, *epidote* and *pennine*.

Two sections.

Age. Archean (igneous).

Remark. This is not a freshly crystalline rock, like those which are plainly eruptive and later than some of the schists, but appears to have suffered dynamic and other forces, and may date from before the general eruption of the granites. For the present, however, both the older granites and gneisses, and the later eruptives are included under one category. N. H. W.

No. 369. Granite.

North side of Burntside lake, a vein or layer in No. 370.
Ref. Annual Report, ix, pages 94, 95.

Meg. Flesh colored, gneissic, rather fine grained.

Mic. Consists of *microcline*, a *plagioclase*, resembling *oligoclase* in its regular and fine striations and apparently of *orthoclase* with some *quartz*.

One section.

Age. Archean (igneous). N. H. W.

No. 370. Hornblende Schist. *(Siliceous.)*

North side of Burntside lake.
Ref. Annual Report, ix, pages 94, 95.

Meg. Gray, firm, apparently siliceous, like a quartzyte, with an angular, sharp fracture.

Mic. The rock consists very largely of *quartz*, but holds also *plagioclase* and *hornblende*. There are three feldspars. One is closely striated and rather fresh. One is clear and glassy, and the third is non-striated, but not glassy. The first has an extinction angle that sometimes reaches 18°. The second appears to be the same that has sometimes been identified in the sheared Archean as *andesine-oligoclase*, a secondary feldspar generated by the dynamic deformation to which the rock has been subjected, and the third appears to be of *orthoclase*. The *quartz* is broken and largely of secondary generation also, but probably pre-existed in the rock in large percentage in a free state. The *hornblende* constitutes a loose frame-work surrounding, in a lenticular manner, the quartz and feldspar, and producing by its prevailing direction a structure produced probably by pressure accompanied by some shearing. *Muscovite* is seen in the older feldspar, and some *apatite* is embraced in the secondary feldspar. There is also a little *epidote*.

One section.

Age. Archean (Coutchiching).

Remark. This rock was probably at first a graywacke, but has been recrystallized by the heat and pressure that accompanied the granitic intrusions. N. H. W.

No. 371. Graywacke. *(Metamorphic.)*

At the mouth of the river entering Burntside lake at the portage to Mud lake; N. E. ¼ sec. 36, T. 63-14 W.
Ref. Annual Report, ix, page 95.

Meg. Similar to No. 370, but somewhat more gneissic.

Mic. In place of hornblende this rock has an isotropic *chlorite*, varying to a *mica*, and more *epidote*. Otherwise the thin section does not differ from No. 370 in any noteworthy manner.

One section.

Age. Archean (Lower Keewatin).

Remark. The foregoing (Nos. 359-370) are all conformable when they show any stratification at all, which is always the case except where there is a full transition from No. 363 or No. 364, or even from No. 360 to No. 368. In that case, when No. 368 is fairly set in, the parallel structure, always dipping at a high angle to the south (or a little east) becomes more and more indistinct, or is lost, and in its place a jointage running in different directions, hardly ever parallel with the schists, is substituted. Yet even then, in some weathered situations, a natural parting of the rock brings out a rude schistose structure parallel with that in the slates. It is impossible to state whether these alternations of rock indicate a coming on of igneous rock, interstratified with the Coutchiching, or that the strata all belong to the Coutchiching, but all the appearances, both in the field and under the microscope, point to the gradual transition from the non-crystalline to the crystalline.

A similar alteration is seen again at the western end of the lake (Nos. 371 and 372), near the river, where the route leaves the lake westward. The bedding is here quite marked, running more south, and dipping at a high angle toward the northwest.

Besides this gradual transition, there is to be noted a sudden transition, which occurs when eruptive granite of a date later than the schists has invaded the schists, in the manner described by A. C. Lawson. Such rocks are strictly not of the same age, although they have commonly been together called Laurentian. (Compare Part I, page 27, *et seq.*) N. H. W.

No. 372. Granite. (*Chloritic.*)

Same locality as No. 371.
Ref. Annual Report, ix, page 95.

Meg. A rather fine-grained, pink granite composed of quartz, a pinkish feldspar and a little chlorite.

Mic. The section shows a granite composed largely of *quartz* and *feldspar*, with a little *chlorite* and *epidote.* The feldspar is quite extensively kaolinized and much of it shows no twinning lamellæ. There are, however, a number of grains with fine twinning lamellæ and very low extinction angles. While no distinctive characters were determined, it seems that the feldspar is *orthoclase* and *anorthoclase* or *oligoclase.* One grain, cut perpendicular to the positive bisectrix, gave an extinction of about 7°. The quartz and the less altered feldspars show pronounced undulatory extinction, and there is one vein-like band, crossing the rock, which is made up of fine grains of quartz and feldspar evidently formed by a crushing and shearing of the rock along this line.

One section.

Age. Archean (near Coutchiching). U. S. G.

No. 373. Clay Slate.

Northeast end of Mud lake; N. W.¼ sec. 2, T. 62–14 W.
Ref. Annual Report, ix, page 95.

Meg. A dark aphanitic rock, appearing like a hardened clay slate; rather soft; crossed by minute white veins probably composed of quartz and calcite.

No section.

Age. Archean (Keewatin). U. S. G.

No. 374. Clay Slate.

Same locality as No. 373.
Ref. Annual Report, ix, page 95.

Meg. Resembles No. 373, but is greener and more siliceous, almost cherty.

No section.

Age. Archean (Keewatin).

Remark. Later, a section of this rock was made by Marchand. It shows a composition essentially like those already described, viz.: Nos. 170 and 171, but much finer. N. H. W.

No. 375. Sericite Schist. *(Sheared quartz-porphyry?)*

South side of Mud lake; S. W. ¼ N. E. ¼ sec. 3, T. 62-14 W.
Ref. Annual Report, ix, pages 95, 102.

Meg. A light greenish-gray, roughly schistose, aphanitic rock, with large quartz grains and highly altered feldspars,—a sheared quartz-porphyry(?)

Mic. The section shows a groundmass of fine grain holding large crystals of *feldspar* and *quartz*. This groundmass is composed of *calcite, sericite* and an indistinct very fine-grained mass, apparently of *actinolite quartz* and *feldspar*. A little *pyrite* is present. A noticeable part of the section is a fissured quartz grain, the fissures being filled with *calcite*. The feldspar phenocrysts are very highly altered, so much so that their species cannot be determined. They are in places hardly distinguishable from the groundmass and are apparently decaying into an aggregate closely similar to this groundmass.

One section.

Age. Keewatin.

Remark. The section was evidently cut about parallel to the schistose structure. This rock perhaps represents a quartz-porphyry which has not only been sheared, but is also highly decayed. U. S. G.

No. 376. Quartz-Porphyry (?) *(Sheared.)*

West end of Mud lake, at an old mining location; S. W. ¼ N. W. ¼ sec. 3, T. 62-14 W.
Ref. Annual Report, ix, page 95.

Meg. Similar to No. 375, but perhaps more compact. A gray rock coarsely schistose, with quartz, and mottlings of green, the greenish parts being apparently amorphous, with hardness about 4.

Mic. Very fine-grained matrix, embraces large *quartzes*, evidently the latter the form of quartz that characterizes a quartz-porphyry. In the matrix are *mica-pennine, calcite* and *feldspar;* the last in much decayed large crystals, with some conspicuous deposits of *pyrite*. The chlorite polarizes in blue, like pennine.

One section.

Age. Archean (Keewatin). N. H. W.

NO. 377. QUARTZ, CALCITE, ETC. *(Vein matter.)*

Same locality as No. 376.
Ref. Annual Report, ix, page 95.

Meg. Coarsely crystallized quartz, with calcite, pyrite, green carbonate of copper, evidently from the decay of some copper mineral and limonite.

Mic. The section shows much fractured grains of quartz, which make up most of the section, around and between which is a finely crystallized mass of *sericite*, *calcite*, and evidently *quartz* and *feldspar*; in fact, this material is quite similar to the groundmass of No. 375. Green, brown and red staining material has been deposited in the cracks of the quartz in places.

One section.

Age. Vein in Archean (Keewatin) rocks. U. S. G.

NO. 378. QUARTZ SCHIST. *(Sericitic.)*

Mud creek; N. W. ¼ S. E. ¼ sec. 4, T. 62–14 W.
Ref. Annual Report, ix, page 96.

Meg. Slaty, quartzose, fine-grained, rusty with the oxidation evidently of carbonate of iron.

Mic. The matrix of this rock appears much like that of No. 376, but the quartz is more fragmental, and the matrix contains more *calcite*, while the *pyrite* of No. 376 is here replaced by *siderite*, whose conspicuous, partly oxidized idiomorphic rhombs are everywhere present.

One section.

Age. Keewatin.

Remark. This seems to be a condition of the rock Nos. 375 and 376, but more sheared. The carbonate of iron was generated instead of the pyrite, and since there is no evidence to show that one was derived from the other, it is reasonable to assign them both to the date of the shearing. N. H. W.

NO. 379. CHLORITE SCHIST.

Vermilion lake, at the mouth of Mud creek; near the centre of the south side of the S. W. ¼ sec. 6, T. 62–14 W. "This rock is like that in a range of hills which continues all the way to Mud lake, along the north side of this stream, apparently confining the stream on that side, the slates running west-southwest at Vermilion lake."
Ref. Annual Report, ix, page 96.

Meg. A soft, greenish-gray, very fine-grained schist.

Mic. The section shows a very fine-grained rock composed of numerous minute flakes of *chlorite*, *calcite* and *feldspar*. There are also gray areas, which, under a high power, are seen to be, in part at least, composed of very minute grains which are probably *epidote*. The section is more or less confused, the different minerals, especially the feldspar, having indistinct outlines, probably due to overlapping of the grains. In places the feldspar is in larger irregularly and indistinctly outlined areas, and contains the other materials of the rock poikilitically. These areas have undulatory extinction quite frequently. It is not improbable that *quartz* is also present, although none was determined certainly.

Age. Archean (Keewatin).

Remarks. This rock differs from others just described in that the feldspar areas are not so evidently the result of a fracturing of a larger grain. Here it does not seem improbable that the larger feldspar areas are the result of recrystallization *in situ.* U. S. G.

No. 380. Dioryte *(with quartz).*

Vermilion lake; one mile southwest from the mouth of the stream from Mud lake; S. E. ¼ N. W. ¼ sec. 12, T. 62–15 W.

Ref. Annual Report, ix, page 96; Annual Report, xv, page 306. This is the same rock as No. 875. Compare No. 403.

Meg. Massive, greenish-gray, medium-grained rock with some hornblende and a triclinic feldspar.

Mic. The section shows much dichroic, green *hornblende, calcite,* old feldspars which are plainly a *plagioclase* and *chlorite,* with a little *epidote* and *apatite.* Some of the feldspars are nearly lost in the products of their own decay, being charged with micaceous scales and sometimes holding micropegmatitic quartz. *Quartz* also exists as large isolated grains, and in one case an angular quartz is surrounded by a gray mass that has distinct crystalline orientation and which is probably a feldspar. This supposed feldspar, which is non-striated, also embraces two small *hornblendes,* and some *calcite,* and may be of secondary origin. The hornblende is generally idiomorphic toward the feldspar, as well as toward the calcite and the chlorite.

One section.

Age. Archean (Keewatin).

Remark. This is a peculiar rock in that the hornblende, as well as some quartz, antedated the feldspar and appear now as idiomorphic crystals surrounded by the feldspar. It seems to be a changed basic eruptive of the dioryte family. In the slide made from No. 875, the same features are visible, and further, it is apparent that the feldspars had two periods of growth, since they are zoned. It is the earlier feldspar generation that embraces the hornblende crystal mentioned above. Still another interesting feature is apparent in the section of rock No. 875, viz.: a quartz crystal, also embraced in a feldspar grain, has governed the orientation of pegmatitic quartz which has entered the surrounding feldspar. N. H. W.

No. 381. Porodyte.

Vermilion lake; probably near the north line of sec. 13, T. 62–15 W.

Ref. Annual Report, ix, page 96; Bulletin ii, page 123.

Meg. A grayish-green, fine-grained, rather soft rock, with quartz veins.

Mic. Dr. Wadsworth's description is as follows:

"The section is composed largely of debris that appears to be altered melaphyr, with a few argillyte fragments, *quartz*, a little *augite*, and much secondary *pyrite*. The groundmass of the section has sprinkled through it numerous gray and yellowish granular masses resembling *titanite* in the process of formation, but none are in sufficiently advanced a stage to be determined crystallographically. The melaphyr material is altered as in the preceding porodytes. Both sections of this rock show portions of a vein made up of irregular quartz grains containing liquid inclusions with moving bubbles. Portions of the rock material are arranged in wavy parallel bands, along the vein in one section, but these bands have no relation to the quartz grains themselves but pass through them indiscriminately, without regard to the boundaries of the grains."

Two sections.

Age. Archean (Keewatin). U. S. G.

NO. 382. QUARTZ. *(Vein.)*

Same place as No. 381.
Ref. Annual Report, ix, page 96.

Meg. Vein quartz, with feldspar, pyrite, chalcopyrite and rock material.

Mic. The section shows much clouded *quartz* in grains closely interlocking. The cloudiness is due to minute grayish inclusions and to cavities filled with liquid.

One section.

Age. Vein in Archean (Keewatin) rocks. U. S. G.

NO. 383. GRAYWACKE. *(Debris of quartz-porphyry.)*

Vermilion lake; N. W. ¼ S. W. ¼ sec. 13, T. 62–15 W. North bluff at the entrance to Armstrong bay.
Ref. Annual Report, ix, page 96.

Meg. The rock is very siliceous, and contains rounded, free quartzes. It is of a light color, and apparently destitute of structure such as schistosity. Yet, in the field, where a close jointage crosses the rock dividing it into sheets diagonal to the usual structure, when a specimen is taken from between two planes, so as to have one of these joints on each side, the specimen will persistently remain triangular, although it be broken till reduced to too small a size for preservation.

Mic. The *quartzes* are evident, but have not regularity of shape. They are evidently fragments of the quartzes of a quartz-porphyry. They are embraced in a matrix which has a confused appearance, but throughout which are the forms of large *feldspars*, much changed by saussuritic growths. Some of these feldspars are so filled with minute grains that have resulted from alteration that they are almost lost as feldspars and seem to be parts of the matrix, and can only be detected as actual feldspar forms by a darkening which spreads over them four times in each revolution between crossed nicols. They are not perfect, *i. e.*, idiomorphic, but are fragments of feldspars, and they appear to be mingled with many small fragments of the same kind. The groundmass, made up of more minute particles of feldspar and of quartz, is mainly homogeneous, as a groundmass, but sometimes it shows variations in the sizes and relative proportions of the feldspathic and quartzose elements, so that darker areas appear in the midst of the general mass. Such darker or coarser areas are themselves apparently of fragmental origin, *i. e.*, it appears that fragments of rock, though mainly like the average, yet varying somewhat from it in special characters, were included in this rock. What may be the cause of these variations it is not possible as yet to state. They are frequently considered the result of crushing and shearing of a homogeneous quartz-porphyry, or of a siliceous tuff, or porodyte, whose fragmental elements originally differed slightly in composition, as well as in structure, but that explanation seems insufficient.

Two sections.

Age. Archean (Keewatin).

Remark. The determination of the true nature of this rock has an important bearing on the Stuntz island conglomerate, since it is apparently in the line of extension from that place. So far as the samples now at hand in thin section will show this nature, it is impossible to say positively whether this rock was originally an acid igneous one, *i. e.*, a quartz-porphyry, or an acid tuff, *i. e.*, porodyte, but the question will remain open till other sections can be examined.

Later examination has shown that Stuntz island is composed of two sorts of rock, one a quartz-porphyry, a massive crystalline rock, occupying the northern part of the island, and the other a coarse fragmental largely derived from the other, making the well-known Stuntz conglomerate. Rock No. 383 may be considered a finer and more siliceous phase of the conglomerate. In the field this was called porodyte, with the idea that it may have been an acid tuff. N. H. W.

No. 384. Quartz-Porphyry. *(Altered.)*

Vermilion lake; probably in N. W. ¼ S. W. ¼ sec. 13, T. 62–15 W.
Ref. Annual Report, ix, page 97.

Meg. A roughly schistose, soft, greenish-gray, very fine-grained rock. Contains a few large quartz grains, altered feldspars, and pyrite.

Mic. The section shows a much sheared and decayed quartz-porphyry. The feldspars are broken, much decayed and are in places hardly distinguishable from the groundmass. The rock as a whole is very similar to No. 375. One large *quartz*, which is partially idiomorphic, shows embayments of the groundmass similar to those seen in unaltered quartz-porphyries. On one side of a large *pyrite* crystal is a greenish very slightly pleochroic mineral, which gives as an interference color greenish gray of the fourth (or higher) order as indicated by the color bands on the thin side of the section. The extinction is wavy. It gives an interference figure which is apparently uniaxial, although the optic axis is a little out of the field of the microscope. This interference figure is positive. The species of this mineral is not known.

One section.

Age. Archean (Keewatin). U. S. G.

Remark. Later investigation has shown that a debris from a quartz-porphyry will, when compacted and sheared, take the characters of this rock. A quartz grain showing embayments of the matrix may have carried that character with it from the original magma into the debris of the clastic, or, if the embayments have open wide mouths, as in this case, the fine debris of a clastic derived from quartz-porphyry, entering such re-entrant angles, could hardly be distinguished from the original matrix. N. H. W.

No. 385. Jaspilyte.* *(Dark, slaty.)*

N. E. ¼ N. E. ¼ sec. 22, T. 62–15 W.; Southeasterly shore of Vermilion lake. (Compare Nos. 1958 and 1959, Annual Report, xxii, page 16.)

Ref. Annual Report, ix, page 97.

Meg. Dark siliceous slate, in thin, rigid laminatious. Mainly in regular, thin sheets, but in some places confused, the slates running west to southwest, and nearly perpendicular, but sloping toward the south. This jaspilyte streak rises on to the hill, and can be traced for a quarter of a mile.

Mic. The section is apparently composed of silica only, in fine grains, yet with a few scattering rhombs of *siderite.* It is evidently from one of the white laminæ of the rock.

Another section, made so as to traverse the structure, shows alternations of layers of *quartz* in fine grains and of *magnetite.* Siderite rhombs are frequent, as shown by their rusty coloration, but *calcite* is also distributed with the siderite. The latter is apparently converted, in some instances, to *hematite* which is sparsely distributed amongst the magnetite. Piercing the quartzes, and interlocked amongst them, are numerous needle-shaped, highly polarizing fibres whose elongation is positive (*i. e.* they have the axis n_g practically parallel to their greater dimension), but on careful measurement their extinction is found to depart from parallelism about 15°. Their pleochroism is hardly apparent. They are supposed therefore to be some form of non-aluminous amphibole, probably *actinolite* or *grünerite.* Two sections.

Age. Archean (Lower Keewatin). N. H. W.

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*This term was proposed by M. E. Wadsworth in 1880 in a discussion of the iron ores of the Marquette region. *Bulletin Museum Comparative Zoölogy*, Cambridge, Geological series, vol. i, p. 75. It is current in the Minnesota reports and has a definite significance and application in the discussion of the Archean iron ores of the Vermilion range. Wadsworth's idea that this rock had an eruptive origin, an idea which he included in his definition of the term, is the only objection we can see to the use of the designation as a petrographical term. The term jasper is also applicable, but has not the definiteness which *jaspilyte* implies.

No. 386. Quartz-Porphyry. *(Altered.)*

"On a small island near the southeast shore; rock like No. 384. Here the schistose structure, sloping southeast, runs S. 50° W. by compass, and is sometimes a little wavy." Vermilion lake; perhaps in the centre of the W. ½ sec. 22, T. 62–15 W.
Ref. Annual Report, ix, page 97.

Meg. A greenish gray, roughly schistose rock quite similar to No. 384, but having almost no visible quartz.

Mic. The section is similar to No. 384. The *feldspar* fragments are numerous and very much decayed. Only a few quartz grains are present. One section.

Age. Archean (Keewatin). U. S. G.

No. 387. Quartz-Porphyry (?) *(Sheared.)*

"About a mile southwest of the last the rock varies to a schistose, chloritic syenyte, of a light-gray color. This is apparently only a variation in the ingredients of No. 386. It is a firm rock, and at a distance appears like massive granite or syenyte; yet, along the lake shore, it parts in a gneissoid manner. It rises higher than the adjacent hills, and is coarsely jointed, so that its rhomboidal parts rise like whitened sheep's backs. It extends perhaps twenty rods." Vermilion lake; near the centre of S. ½ sec. 21, T. 62–15 W.
Ref. Annual Report, ix, page 97.

Meg. A gray rock, somewhat sheared and thickly studded with porphyritic crystals of white feldspar. There are also less numerous and smaller, though abundant, porphyritic crystals of quartz. The groundmass in which these crystals are embedded, is sparse, aphanitic and dark gray. (See Nos. 874, 874 [A] and 1957.)

Mic. The section shows a rock which has been stretched or sheared, and this structure is shown both by the crushed and fissured larger grain and by yellowish lines which run roughly parallel in the section. The rock is composed of crystals and fragments of *feldspar* and *quartz* in a finer groundmass. The feldspar seems to be in part *orthoclase* and in part a plagioclase, probably *anorthoclase*. It is altering to *sericite*, and also in places contains minute crystals and grains of a colorless, strongly refractive mineral with low double refraction which is thought to be *zoisite*. The groundmass is of very fine grain, and is composed of *quartz*, *feldspar*, *sericite*, *calcite* and *actinolite (?)*. Pyrite and also probably granular *epidote* are also present. The mineral referred to questionably as actinolite is in fibres, is usually yellowish, although sometimes colorless, and makes up most of the yellowish lines mentioned above. It is usually not pleochroic, but sometimes shows slight pleochroism, varying from colorless to straw yellow, the latter being the color of the ray which vibrates parallel to the length of the fibres. It may be that this mineral is muscovite, slightly colored, rather than actinolite, as the rough measurements made showed practically parallel extinction. (Compare No. 431.) Two sections.

Age. Keewatin.

Remarks. This rock would be usually taken for a stretched quartz-porphyry, and this is probably its nature. But the fact that in this immediate vicinity is the

Stuntz conglomerate, sections of the matrix of which have been called "sheared quartz" porphyry, causes us to hesitate about stating positively the nature of the rock (No. 387). See under No. 874, and under the description of the Stuntz conglomerate in vol. iv, pages 526-538. U. S. G.

No. 388. Jaspilyte. *(Gray.)*

Vermilion lake; perhaps near the centre of the E. ½ sec. 20, T. 62-15 W.*
Ref. Annual Report, ix, page 97.

Meg. Fine-grained, gray, cherty rock.

Mic. The section shows fine, angular grains of *quartz*, with a few rhombs of carbonate of iron. The latter are idiomorphic and perfect as crystals (or nearly perfect), but the former are crowded upon each other. In one section the *siderites* are somewhat clouded by included magnetite, and quite frequently they embrace at their centres a powder of *magnetite*, which is also distributed in clusters elsewhere, giving the section a spotted appearance. It is probable that this magnetite antedates the siderite, only serving as nuclei on which the carbonate grew, while the limonite is seen to be a result, so far as it exists, of alteration from the carbonate, the crystals of which are stained by it. Two sections.

Age. Archean (Lower Keewatin).

Remark. The distribution of this magnetite powder in the individual quartzes causes the rock to resemble taconyte. N. H. W.

No. 389. Arkose.

Vermilion lake; S. W. ¼ S. W. ¼ sec. 20, T. 62-15 W.
Ref. Annual Report, ix, pages 97, 98.

Meg. Gray, compact, coarsely schistose, none of the minerals being well characterized. No quartz is distinguishable under the hand glass, but fine glittering surfaces are visible which are apparently of some mica. The rock has a vague and indefinable aspect, the coarsest grains, which are apparently feldspar and have a diameter of about one millimeter, fading out into the surrouuding matrix. The rock is evidently of fragmental origin, as indicated by the perfect stratification described by the field notes.

Mic. The section consists essentially of feldspar *(plagioclase)*, a little *quartz*, much isotropic chloritic substance, some *epidote*, *muscovite*, and a reddish-yellow stain which probably is iron oxide, and *calcite*.

The feldspar is sometimes distinctly twinned, and other crystals are destitute of striations. The grains are all much altered, and are specked with flakes of muscovite, which also is scattered irregularly through the finer grains. Two sections.

Age. Upper Keewatin.

*When these specimens were collected (1878), the United States land survey had not yet been extended over these localities. In making assignments of these localities in the terms of the "towns" and "ranges" of that survey a little allowance must be made for possible error as to the exact locations of the points at which the specimens were obtained.

Remark. This locality, and the rocks associated with this rock, are thus described in the Ninth Annual Report:

"A mile further west, and near the entrance to the bay that leads to the portage going south from Vermilion lake to Squagemaw lakes, the rock of this number, which is a gray, chloritic schist, is seen to have a nearly east and west slaty structure, varying to a little south of west. This slaty structure is intersected diagonally by alternations in the rock due to sedimentation, running nearly northwest and southeast. The kinds of rock exhibited by this alternation are as follows, from Nos. 389 to 394, both inclusive, the former being on the northeast side and the latter on the southwest side." Other rocks from this immediate vicinity are Nos. 1 to 7 (W.), Annual Report, xv, pages 19, 20.

Another section bears the No. 389, but as it differs considerably from the foregoing it is supposed to have been misnumbered. It is probably from the Lower Keewatin of the region. The following description is given, since the section shows well some important characters:

Mic. The section consists essentially of feldspar *(plagioclase)* and *muscovite,* with *siderite.* The feldspar is of the clear variety which in small fragments is difficult to distinguish from quartz. It is not crowded with kaolinic scales, but has dust-like particles which cross it in lines, but hardly impair its translucency. Some of the larger grains interlock in such a manner as to indicate secondary growth, and in one case a large grain has partially enveloped another by forming about its projecting corner. It is distinctly twinned on the albite plan. A section cut perpendicular to n_p gives an extinction angle of 73°, which agrees well with Fouqué's extinction for *andesine-oligoclase.* Although this translucent feldspar prevails, or exists almost alone, in one section, there is still another which is quite different in its inclusion of what appear to be *mica* scales set in every conceivable angle with reference to the structure of the grain, and of the scales themselves. These are also of some plagioclase, but as the single grain in this slide has no cleavage nor crystalline character on which to measure extinction the species cannot be determined. The *siderite* is distributed irregularly, both as single rhombs and as shapeless aggregates of many grains. It has a uniaxial interference figure, slight absorption and rather strong refraction index approaching that of epidote. Its double refraction is similar to that of calcite. It has a clear glassy color, when unaltered and in simple crystals, but much of it in compressed masses appears of an ashen-gray color. When it is altered it becomes brown or reddish with the resulting oxide of iron. Its cleavages are conspicuous. Except for the rustiness that sometimes permeates it, and its ashen color, it can hardly be distinguished from calcite in ordinary light, but its high refractive index, in convergent light, is also a good diagnostic.

Age. Archean (Keewatin). N. H. W.

Remarks. We are forced to conclude that by some means a secondary feldspar and siderite have been developed to the almost total exclusion of the original feldspar. The dynamic stress through which the rock, in common with all the rocks of the region, has passed, is probably responsible for these new minerals. N. H. W.

No. 390. Clay Slate.

Same locality as No. 389.
Ref. Annual Report, ix, page 97. (See remarks under No. 389.)

Meg. A rather soft, gray or greenish-gray, aphanitic clay slate.

Mic. The section is very fine grained. It is composed essentially of *calcite*, minute flakes of *sericite* (or muscovite) and *chlorite*, and a very minutely granular, rather indistinct aggregate which probably contains both quartz and feldspar.

One section.

Age. Archean (Keewatin). U. S. G.

No. 391. Graywacke.

Same locality as No. 389.
Ref. Annual Report, ix, page 97. (See remarks under No. 389.)

Meg. A light gray, or greenish gray, fine-grained rock. A few grains of quartz and occasionally a feldspar are all the minerals that can be seen macroscopically. The rest is a flaky, indistinct, talc-like (but harder than talc) base.

Mic. The section shows scattered grains, rounded and subangular (sometimes quite angular), of *quartz* and *feldspar* in a much finer grained background. The quartz grains are not sharply outlined, but their peripheries are closely cemented to and interlocked with the small grains of the groundmass. The feldspar is clouded and kaolinized and is not always very distinct from the groundmass. The species of the feldspar could not be determined, although it seems likely to be largely *orthoclase*. No polysynthetic twinning lamellæ were seen, but there were indications of a few simple twins, apparently by the Carlsbad law. The groundmass is composed of a fine-grained aggregate, similar (but a little coarser grained) to No. 390. *Calcite*, *sericite*, *chlorite*, *quartz*, and probably also feldspar, form the chief constituents of this groundmass. There are collections of very minute grains, which cannot be determined, but which are perhaps *epidote*.

One section.

Age. Archean (Keewatin).

Remarks. The similarity of the groundmass of this rock to others from Vermilion lake, the slates and schists, is quite decided. Without the larger grains of quartz and feldspar the rock could be termed a clay slate, or perhaps a sericite schist. It is also to be noted that in many respects this groundmass resembles the groundmass of the highly sheared and altered "quartz-porphyries," U. S. G.

No. 392. Clay Slate.

Same locality as No. 389.
Ref. Annual Report, ix, page 97. (See remarks under No. 389.)

Meg. A very fine-grained, dark gray, clay slate.

Mic. The section is similar to No. 390, but is much finer grained and contains little or no calcite. It is composed essentially of very minute flakes of *chlorite* and *sericite*, and minute grains, probably of *quartz*, with also probably *feldspar*.

One section.

Age. Archean (Keewatin). U. S. G.

No. 393. Porphyry (?) (*Sheared.*)

Same locality as No. 389.
Ref. Annual Report, ix, page 97. (See remarks under No. 389.)

Meg. A gray rock, consisting of small (about one twenty-fifth of an inch across), white, crowded feldspar crystals in a sparse, very fine-grained, darker groundmass.

Mic. In section the crowded *feldspar* crystals are not as distinct as in the hand specimen, for they are much altered and clouded and are composed largely of almost the same materials as found in the groundmass. The species of the feldspar cannot be determined. Nearly all the grains show no twinning, but a few show traces of twinning striæ, and one is a simple twin, apparently according to the Carlsbad law. In shape, these feldspars are rounded or subangular, and others are partly idiomorphic. In reflected light they appear gray and semi-opaque, and this character is also found irregularly in the groundmass. The groundmass is composed of flakes of *sericite* and *chlorite*, and small grains of quartz with probably feldspar also. The sericite is developed especially often in cracks of the feldspars and between the different grains, and the flakes sometimes have their long axes perpendicular to the surfaces of the feldspar grains. Crossing the section is a small vein-like form composed mainly of small grains of quartz, and similar quartz occurs elsewhere in the slide.

One small section.

Age. Archean (Keewatin).

Remarks. The exact nature of this rock is not evident. The feldspars may have been crystals in an acid eruptive, now much altered, or it is quite possible that they are clastic in their origin, being either true waterworn grains or else of a tuffaceous origin. That these feldspars have developed *in situ*, seems rather improbable when we consider their highly altered characters; at least, if they did develop *in situ*, they have been much decayed since. U. S. G.

No. 394. Sericite Schist.

Same locality as No. 389.
Ref. Annual Report, ix, page 97. (See remarks under No. 389.)

Meg. A siliceous, very fine-grained sericite schist, greenish gray in color.

Mic. The section is very fine grained. It consists of scales of *sericite*, and a little *chlorite*, and grains apparently of both *quartz* and *feldspar*. These grains make up a large portion of the section, but their exact nature cannot be determined. The section contains specks, gray and semi-opaque in reflected light, which under a high power are seen to be made of aggregates of very fine, rather highly refractive grains. The nature of these cannot be made out. They have elsewhere been referred to *epidote*, but may be siderite.

One section.

Age. Archean (Keewatin). U. S. G.

No. 395. Clay Slate.

Vermilion lake; New York Mining Company's location; S. W. ¼ S. W. ¼ sec. 26, T. 62–16 W.
Ref. Annual Report, ix, page 98; Annual Report, xviii, page 20; Annual Report, xix, pages 125, 127. This locality is also described in the Fifteenth Annual Report, pages 280, 281.

Meg. A gray, very fine-grained clay slate.

Mic. The section is composed very largely of minute grains of *quartz* (with probably feldspar also); chlorite and a little sericite are also present. There are two particularly interesting features in this section. The first is the presence of much *siderite* in rough rhombs and irregular areas. Frequently a yellowish stain *(limonite)* accompanies the siderite. The second feature is the presence of numerous minute *rutile* crystals. These give bright polarization colors, and many heart-shaped twins are seen. One section.

Chemical analysis. Nos. 395, 396, 397, 398, 400, 423 and 428 represent some of the gold ores of the Vermilion lake gold excitement of 1866. These specimens were assayed together, as one sample, by Prof. C. F. Sidener and no gold nor silver was found.

Age. Archean (Keewatin). U. S. G.

No. 396. Quartz. *(Vein.)*

"'Gold' quartz, from the above mining location. This is white. It is scattered in the joints and irregular veinings in No. 395, similar to what may be seen in many places about Vermilion lake. (See report for 1878, page 23.)"
Ref. Annual Report, ix, page 98; Annual Report, xviii, page 20; Annual Report, xix, pages 125, 127.

Meg. Specimen missing.

No section.

Age. Vein in Archean (Keewatin) rocks.

Remark. See chemical analysis under No. 395. U. S. G.

No. 297. Slate. *(Chloritic.)*

Vermilion lake. Locality uncertain. Minnesota Company's mining location. Perhaps on Birch point. *Ref.* Annual Report, ix, page 98; Annual Report, xviii, pages 20, 21; Annual Report, xix, pages 125, 127.

Meg. Specimen missing (used for assay).

Mic. The section shows a distinct parallel structure, evinced by the prevailing direction of the *chlorite* shreds. It embraces much decayed feldspars, with minute *mica* scales, a little *quartz* in the form of independent, yet sub-rounded, sizable grains, and a noticeable amount of *siderite*, which is easily diagnosed by its high refractive power. It is usually clear and unoxidized, yet occasionally some dark accumulations are enclosed in it. It has an evident, fine and regular cleavage in two directions. This structure again distinguishes it from calcite, which generally shows only a coarse and rather distant cleavage in rigid heavy lines, or is destitute of evident cleavage.

Remark. This existence of siderite in the rocks of the region, sheared "quartz-porphyries," graywackes, clay slates and chlorite slates, as well as in the jaspilytes, is worthy of special note, as it is the source, as supposed by some geologists, of the iron ore lodes of the Vermilion range. (See chemical analysis under No. 395).

One section.

Age. Archean (Keewatin). N. H. W.

No. 398. Quartz. *(Vein.)*

"The quartz from this mining location occurs in the joints of the rock, in irregular deposits, but generally coincident with the slatiness. It carries considerable pyrite, which is also scattered through the slates." Same locality as No. 397.

Ref. Annual Report, ix, page 98; Annual Report, xviii, pages 20, 21; Annual Report, xix, pages 125, 127.

Meg. Specimen missing (used for assay).

Age. Vein in Archean (Keewatin) rocks.

Remark. See chemical analysis under No. 395. U. S. G.

No. 399. Chlorite Schist.

"Talcose (?) slate, from Simonds' location. This is farthest northwest (or west), and about four miles from the outlet of the lake; and between this and the Minnesota Company's location was that of Nobles, numerous islands occurring all along. This number represents the country rock. It is siliceous, and contains scattered nests or broken layers of white quartz, both coincident with the slates and in the diagonal jointage. Pyrite is scattered through the quartz, and through the slates, and particularly in a line of contact where they unite, the quartz becoming gray." Vermilion lake. The exact location is uncertain, but it may be on Silver (Shonea) island (southwest corner of sec. 31, T. 63-16 W.), where mining for gold was carried on. (See map in vol. iv, page 523.)

Ref. Annual Report, ix, page 98; Annual Report, xviii, pages 20, 21.

Meg. Specimen missing (used for assay).

Mic. The section is composed of *calcite*, *chlorite*, minute scales of *sericite*, and very fine grains of *quartz* and probably also *feldspar*. Considerable opaque material which is almost black in transmitted light and gray in reflected light, is present in small patches and also in minute specks. The characteristic feature of the rock is the presence of large amounts of calcite, or more probably both calcite and *siderite*, as some of this material shows a very slight absorption.

One section.

Age. Archean (Keewatin). U. S. G.

NO. 400. QUARTZ. (*Vein.*)

Same locality as No. 399.
Ref. Annual Report, ix, page 98; Annual Report, xviii, pages 20, 21; Annual Report, xix, pages 125, 127.

Meg. Specimen missing (used in assay).

Mic. The section shows coarsely crystallized *quartz* which has been fissured and in places evidently crushed into a mass of finer grains. The quartz shows very pronounced undulatory extinction and is cloudy, the cloudiness being due to the presence of numerous minute dust-like particles and cavities containing liquid; occasionally a cavity with a bubble is seen. Besides the quartz there are present small amounts of a gray opaque substance, reddish and yellowish stains, *chlorite*, *pyrite* and a metallic glistening mineral, perhaps *chalcocite.*

One section.

Age. Vein in Archean (Keewatin) rocks.

Remark. See chemical analysis under No. 395. U. S. G.

NO. 401. HORNBLENDE SCHIST.

Vermilion lake; probably from Menan island, or a little island just to the east of it; S. E. ¼ sec. 36, T. 63-17 W.
Ref. Annual Report, ix, pages 98, 99.

Meg. A gray, compact, fine-grained schist, with a distinct fibrous elongation. The rock is arranged in laminations that run S. 55° W., sloping south and embraces laminations and wide belts, also conformable with the rest (except where large areas come in) of No. 402.

Mic. The colored, shining mineral which gives the rock a micaceous aspect, proves not to be of mica, but of *hornblende* with a little *chlorite*, probably of the species *pennine*. The rock also contains *feldspar*, but much decayed, and much *quartz*, the latter probably of secondary date. Some *biotite*, and also *epidote*, the latter in large grains, appear in the slide, with some altered *garnet*, the alteration product being *chlorite*. There is also a little *sphene*, and of *ilmenite*, having a border of *leucoxene*. There are a few crystals of *apatite* and others of *zoisite*.

Two sections.

Age. Archean (near Coutchiching). N. H. W.

NO. 402. GRANITE.

Same place as No. 401.
Ref. Annual Report, ix, pages 98, 99.

Meg. Light colored, slightly chloritic granite.

Mic. The section shows quartz abundant, and a feldspar which is in part *microcline*, and in part perhaps *orthoclase* or *oligoclase*, but which is rather too much kaolinized to warrant an attempt at specific determination. One section.

Age. Archean (near transition to Coutchiching).

Remark. Where No. 402 occurs in large masses its boundary is not always parallel with the schists, but jogs across a foot or two of them and then runs again parallel, sometimes also crowding them confusedly. This is on the island nearest the point at the narrow passage for canoes bound west. The extremity of the point is of the same character of rock, but the change from the finer grained chloritic to mica slate or schist, is very gradual and imperceptible, the colors and characters blending and mixing apparently in the same rock. N. H. W.

No. 403. Dioryte.

Vermilion lake; same place as No. 401.
Ref. Annual Report, ix, pages 99, 101; Bulletin ii, pages 120, 121.

Meg. A dark-gray, rather fine-grained, apparently micaceous and hornblendic rock.

Mic. The most conspicuous mineral, and perhaps the most abundant, is a pleochroic *hornblende*, which has elongated sections, but rarely shows good cleavages. Next to this is *epidote*, scattered irregularly throughout. Feldspar is both original and secondary, the former filled with micaceous microliths and having ill-defined boundaries, and the latter being clear and quartz-like in extinctions, frequently without cleavages or twinning. This feldspar is not common in this slide. When albite twinning appears it has the aspect of the species *albite*, as described in the rock No. 872. *Chlorite* is hardly distinguishable from some of the hornblende. When fortunately a grain is destitute of cleavage, remains dark or nearly dark on rotation, and has a rounded or perhaps a somewhat angular-hexagonal outline, it may be tested in convergent light. If it give a dark cross, or a very low angle 2 E, it is plainly chlorite. *Apatite* is present in a few stout, highly refractive crystals, evidently from the original crystallization from a molten magma. *Sphene* is scarce, and *biotite* common. *Pyrite* shows a few cubic sections. Two sections.

Age. Archean.

Remark. As remarked by Wadsworth this rock is probably an old eruptive. The glassy feldspar has much the appearance of quartz, which latter we do not find in the slide. It may be compared with rock Nos. 380, 875 and 872. N. H. W.

No. 404. Granite *(with biotite)*.

Vermilion lake, on the north shore; perhaps in sec. 26, T. 63-17 W.
Ref. Annual Report, ix, pages 99, 100.

Meg. A fine-grained gray granite, composed of gray to pinkish feldspar, quartz and biotite.

Mic. The sections are too thick for careful study. They however show that the rock is a granite composed of *feldspar, quartz, biotite* and *chlorite.* The feldspar is frequently much clouded. It seems to be *orthoclase, microcline* and a plagioclase near *anorthoclase.* The biotite and chlorite are quite dark and filled with inclusions and are frequently opaque.

Two sections.

Age. Archean (igneous). U. S. G.

No. 405. Biotite Schist.

"A few rods further a ridge of this rock appears. This is a firm mica schist, with reticulations and interlaminations of gray quartzyte and quartz, and also cross layers and interlaminations of syenyte. In the main the syenyte is coincident with the schistose structure." Near the same locality as No. 404.

Ref. Annual Report, ix, pages 99, 100.

Meg. A fine-grained, dark-gray schistose rock composed of biotite, quartz and feldspar.

Mic. The section is composed of flakes of dirty brown *biotite, chlorite, feldspar* and *quartz.* The arrangement of the biotite and chlorite scales causes the schistosity of the rock. The chlorite is charged with minute black particles and appears to be an alteration product from the biotite. The feldspar is very largely altered to kaolin and chlorite; its species was not determined.

One section.

Age. Archean (Coutchiching). U. S. G.

No. 406. Biotite Schist and Gneiss.

Near the same locality as No. 405.

Ref. Annual Report, ix, page 99; Annual Report, x, page 95.

Meg. A fine-grained, gray biotite schist, with laminations of a light-gray granitic rock which is composed of white feldspar, quartz and a little biotite.

No section.

Age. Archean (Coutchiching). U. S. G.

No. 407. Hornblende Schist.

Near the same locality as No. 406.

Ref. Annual Report, ix, page 99.

Meg. A fine-grained, gray, somewhat schistose rock, composed of hornblende and quartz and feldspar.

Mic. The section is composed essentially of a granular aggregate of green *hornblende, quartz* and *feldspar.* A little *epidote, pyrite, magnetite* and *apatite* are also present. The feldspar is quite largely altered to kaolin and a gray opaque substance, although much of this feldspar is rather fresh. Most of it shows no twinning lamellæ. One grain, which gave a positive bisectrix perpendicular, showed an extinction angle of about 3°, and another grain, which was twinned, gave a negative bisectrix and an extinction of 74°. . These results correspond closely with *andesine-oligoclase.*

One section.

Age. Archean (Coutchiching) U. S. G.

No. 408. Dioryte.

Near the same place as No. 404.
Ref. Annual Report, ix, page 100; Annual Report, x, page 95.

Meg. A bold and rocky shore, running northeast, with the general character and structure seen at the last locality, is fairly represented by this rock, which is confused and granitoid, but largely of a dioritic aspect.

Mic. The section shows a semi-regenerated rock, in which a kaolinized feldspar is associated with a fresh and glass-clear feldspar. The latter is twinned on the albite plan, but the former has lost its structure and it cannot be determined whether it was ever striated. With these feldspars is *quartz* of secondary origin, and a *chlorite* which frequently polarizes with the peculiar bluish tint characteristic of *pennine.* A few grains with high refractive index are probably *sphene.*

One section.

Age. Archean (Coutchiching). N. H. W.

No. 409. Granite *(with biotite).*

Vermilion lake, near the outlet. Perhaps S. E. ¼ sec. 23, T. 63–17 W.
Ref. Annual Report, ix, page 100.

Meg. Light colored and granitic.

Mic. With much feldspar and quartz is a little biotite.

One (poor) section.

Age. Archean (igneous). N. H. W.

No. 410. Granite.

Same place as No. 409.
Ref. Annual Report, ix, page 100.

Meg. A coarsely granular aggregate of quartz and flesh-colored feldspar which embraces apparently two species, an orthoclase and a finely striated plagioclase, and a very little mica.

Mic. The small slide shows *microcline*, an unstriated feldspar and *quartz.* It happens not to cut the feldspar which shows evident albite striations under the hand-glass, which probably is *oligoclase.* It shows no mica.

One section.

Age. Archean (igneous). N. H. W.

No. 411. Granite.

Same locality as No. 409.
Ref. Annual Report, ix, page 100.

Meg. Medium-grained, pinkish granite, composed of a flesh-colored feldspar and quartz. There are also a few darker areas now mostly occupied by iron oxide from the decay of some dark mineral.

Mic. The section shows a granitic aggregate of quartz and feldspar. The feldspar is much clouded. A considerable part of it shows *microcline* grating, while much is finely twinned by the albite law. The twinning lamellæ are often discontinuous and bent, and there is a fine-grained aggregate between some of the grains, the whole suggesting that the rock has been subjected to pressure. These effects, however, cannot be carefully studied owing to the extreme thickness of the section. There are brownish stains throughout the section, and a few small, opaque, black areas, on the borders of which can sometimes be seen a very little *chlorite.* One of these areas is made up partly of *biotite.*

One section.

Age. Archean (igneous). U. S. G.

No. 412. Biotite Schist.

Same locality as No. 409.
Ref. Annual Report, ix, page 100.

Meg. A roughly schistose, gray rock, rather fine grained. It is composed of biotite, sometimes in scales of considerable size, and a granular aggregate of apparently quartz and feldspar.

Mic. The section is quite thick. It shows much feldspar, a considerable part of which is much clouded, usually not twinned. Two grains, each of which gave a positive bisectrix, had extinction angles of 4° and 6°. This result would place the the feldspar near *oligoclase* or *orthoclase. Biotite* and *chlorite* are both present in considerable amount, and *quartz* is not uncommon, although not nearly as abundant as the feldspar.

One section.

Age. Archean (Coutchiching). U. S. G.

Remark. At the place where were obtained Nos. 409–412 there is an exposure of gneiss which passes confusedly to granite and to mica schist, but has no general schistose structure. There are small patches of mica schist surrounded by granite and bands of coarse granite running through the whole, varying to a fine granite.

N. H. W.

No. 413. Biotite Schist.

From the Vermilion rapids, at the outlet of Vermilion lake northward; N. E. ¼ N. W. ¼ sec. 11, T. 63–17 W.
Ref. Annual Report, ix, page 100.

Meg. Rock similar to No. 912.

Mic. The section shows *biotite*, *hornblende*, *quartz* and *andesine*, with a little *garnet*, *magnetite*, *sphene* and *pennine*.

Two sections.

Age. Archean (Coutchiching). N. H. W.

No. 414. Granite.

Near the outlet of Vermilion lake, eastward from Outlet bay.
Ref. Annual Report, ix, page 100; Annual Report, x, page 95.

Meg. Light-colored, or flesh-red, coarse, biotitic.

Mic. *Microcline*, *quartz* and *orthoclase (?)*, the last being entirely kaolinized. The microcline is fresh and bright, presenting a perfect exemplification of the characteristic structure. It affords a suggestive contrast with the much decayed other feldspar, and may be of secondary date. There is a little *biotite*.

One section.

Age. Archean (igneous). N. H. W.

No. 415. Biotite Schist.

Embraced in No. 414. This rock is entirely like Nos. 412 and 413.

One section.

Age. Archean (Coutchiching). N. H. W.

No. 416. Biotite Schist.

Location uncertain; in the vicinity of Outlet bay and Avis island.
Ref. Annual Report, ix, page 100.

Meg. Glistening mica schist.

Mic. The *mica* is less abundant in the slide than would be supposed from the color and general aspect of the rock, but a fresh feldspar is abundant. The mica has been partly changed, apparently to *chlorite*. The feldspar is, in part, at least, striated, but in the absence of crystallographic characters in those sections giving bisectrices, it is not possible to determine the species by the microscope alone.

One section.

Age. Archean (Coutchiching). N. H. W.

No. 417. Biotite Schist. *(Garnetiferous.)*

Location uncertain, but at some point on the east side of Outlet bay of Vermilion lake.
Ref. Annual Report, ix, page 100; Annual Report, x, page 95.

Meg. Dark, fine-grained, firm mica schist.

Mic. Much resembles rock No. 412, in having much-clouded feldspar, but in that respect differs from No. 416. It also contains considerable quartz. *Garnet*, with many microscopic crystals, appears in conspicuous grains. It has coarse irregular cleavages, and a faint rose tint.

One section.

Age. Archean (Coutchiching). N. H. W.

No. 418. Granite.

Location not exactly known, but somewhere on Outlet bay, east side, on Vermilion lake.
Ref. Annual Report, ix, page 101; Annual Report, x, page 17.

Meg. Gray or flesh-red, medium-grained.

Mic. *Orthoclase* (kaolinized), *microcline*, *quartz*, *biotite*, compose this rock.

One thick section.

Age. Archean (igneous). N. H. W.

No. 419. Biotite Schist.

Exact location unknown. At some point in the schist area of Outlet bay of Vermilion lake.
Ref. Annual Report, ix, page 101.

Meg. Compact, fine-grained, gray schistose.

Mic. The thick section only warrants the statement that this rock consists of a dense, markedly schistose aggregate of clouded *feldspar*, *biotite*, *quartz* and *chlorite*.

One section.

Age. Archean (Coutchiching). N. H. W.

No. 420. Biotite Schist.

Location not exactly known, but near the southern limits of Outlet bay.
Ref. Annual Report, ix, page 101.

Meg. Softer mica schist, fine and glistening.

Mic. With much fresh and quartz-like *feldspar* appears *biotite*. After considerable search amongst these translucent grains, not one could be found that could be said unqualifiedly to be quartz, but the greater part of them gave, in convergent lig' t, characteristic figures showing a biaxial mineral. These feldspars, differing remarkably from those in some of these schists, are believed to be of secondary origin, dating probably from the pressure and shearing of the original material. The much-clouded feldspars, which sometimes prevail, but are often seen in the same slide with the glassy forms, are therefore to be classed with the original elements of the rock. A striated, original grain, cut perpendicular to n_p, shows an angle of 10° between the optic plane and the albite macles, indicating *oligoclase*, the grain being in the reverse position from that required by Fouqué's tables.

One section.

Age. Archean (Coutchiching). N. H. W.

No. 421. Quartz Ore.

Vermilion lake; perhaps N. W. ¼ sec. 6, T. 62–16 W. This rock is missing, having been used in making assay of the Vermilion Lake gold ores. (See Annual Report, xviii, page 19.)

Ref. Annual Report, ix, page 101.

N. H. W.

No. 422. Mica Schist.

Same place as No. 421.

Ref. Annual Report, ix, page 101.

Meg. A very fine-grained, micaceous, schistose rock, of a glistening, somewhat silky lustre, but which, notwithstanding its fineness, is probably of the same nature as the biotite schists of the region.

Mic. Consists of *quartz, biotite, muscovite, calcite;* the biotite is frequently occupied by a web of *sagenite* needles which form the characteristic angles of 60° with each other.

One section.

Age. Archean (Coutchiching). N. H. W.

No. 423. Gold Ore.

Nobles' mining location, Vermilion lake; apparently on the south shore of Black Duck point; N. W. ¼ sec. 9, T. 62–16 W.

Ref. Annual Report, ix, page 101; Annual Report, xv, page 282; Annual Report, xviii, page 20; Annual Report, xix, pages 125, 127.

Meg. The samples consist of two rocks, evidently the country rock and some vein material. The former is green, fine, calcareous, pyritiferous, apparently sericitic. The latter is largely of calcite, with quartz and a little pyrite.

Mic. The slide was made evidently from the green portion of the rock, and while *chlorite* gives it color, it consists, still, largely of *calcite.* There is also a notable amount of a fresh secondary *feldspar,* and of some *mica,* less refractive than calcite, apparently *muscovite.* The calcite is not in large crystalline individuals, but in aggregates of many small crystals that interlock.

One section.

Age. Archean (Keewatin).

Remark. See chemical analysis under No. 395. N. H. W.

No. 424. Dioryte.

Vermilion lake; perhaps on Birch point, a little west of the Minnesota Company's mining location; represents a local variation, apparently, in the slates of the region.

Ref. Annual Report, ix, page 102.

Meg. A hornblendic, barely schistose, green rock of rather fine grain.

Mic. The *hornblende* is the most conspicuous mineral, making the rock resemble the rocks already described from the east side of Vermilion lake (No. 380). Some of it is nearly colorless, and most of it is light green. It does not show any idiomorphic relation to the feldspar, indeed feldspar is not an abundant ingredient. Yet there is a small amount of glassy secondary *feldspar*. *Calcite* is an important constituent.

One section..

Age. Archean (probably dike in the Keewatin). N. H. W.

No. 425. Granite.

Vermilion lake; probably from the island just south of Birch point and crossed by the west line of sec. 15, T. 62–16 W. Forms a low island in a large bay west of the government's station near the head of the bay.

Ref. Annual Report, ix, page 102.

Meg. The rock is jointed and somewhat schistose coarsely, in about the same direction as the slates. It is light-colored, consisting of quartz and a clouded, or slightly flesh-red crushed feldspar resembling orthoclase. There is also a nearly white feldspar abundant in this rock, which is twinned on the albite plan, and which is probably of later origin. Its form is more evidently that of definite crystals and these lie in a matrix, of the other feldspar and quartz.

Mic. The feldspars are all much kaolinized. One prism of apatite is visible.

One section.

Age. Archean (Keewatin). N. H. W.

No. 426. Quartz-Porphyry. *(Macerated debris, sheared.)*

The rock of Ely island.

Ref. Annual Report, ix, page 102; Annual Report, x, page 94.

Meg. Resembles the rocks Nos. 311 and 375. It is of a light-gray color, often with a light-green tint, having free quartz in an amorphous siliceous matrix, with sparse pyrite crystals.

Mic. The section is very fine grained, but there are forms of much frayed and altered feldspars, of the *plagioclase* type, which are conspicuous although they are so permeated by the fine scales and other crystalliths resulting from their alteration that they can only be seen in polarized light, otherwise they are lost in the fine matrix in which they lie, and which is composed of the same materials. Sometimes rounded, or sub-rounded *quartzes* of considerable size are visible, sprinkled sparingly through the hand sample. Crystalline cleavages appearing like those of calcite can occasionally be seen on a broken surface, but this mineral under the microscope in part proves to have the characters of *siderite* rather than calcite.

One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 427. Jaspilyte. *(Fragment in No. 426.)*

"Rock of Ely island, containing jaspery pieces."

"In traveling over the island, where much of the rock is bare, occasionally may be noticed bright red pieces of jasper superficially embraced in the formation, some of them three or four inches across. The position and structure of these pieces is at variance with the schistose structure of the rock in which they are embraced.

* * * These jaspery pieces, generally smaller than a butternut, but sometimes as large as one's fist, are nearly always angular, or but little rounded, and are in some portions thickly sprinkled over the surface of the schists."

Ref. Annual Report, ix, pages 102, 103. (The section described as No. 427, in Bulletin ii, page 113, is not of this rock.)

Meg. The hand samples show two red-banded jaspilyte pieces in a rock which is somewhat similar to No. 426, but is more decayed and roughly schistose. A few small feldspars and quartzes are present in this rock.

No section.

Age. Archean (Keewatin). U. S. G.

NO. 428. QUARTZ-PORPHYRY. *(Altered.)*

Rison's place, Ely island, Vermilion lake.

Ref. Annual Report, ix, page 103; Annual Report, xviii, page 20; Annual Report, xix, pages 125, 127.

Meg. Specimen missing.

Mic. The section is too thick for careful study. It shows numerous highly altered *feldspar* crystals and a few small *quartz* grains in a groundmass which is composed largely of *sericite* with also probably *quartz* and *feldspar*. *Pyrite* and considerable *siderite* are present; also some specks of an opaque gray substance, and one piece of *muscovite* which contains some of this opaque substance. Other similar areas are also seen, but they are much decayed. One section.

Age. Archean (Keewatin).

Remark. See chemical analysis under No. 395. U. S. G.

NO. 429. HEMATITE.

North ridge, near Tower; probably in N. ½ sec. 27, T. 62-15 W.

Ref. Annual Report, ix, pages 103, 104. Compare No. 871, which is hematite from the Lee mine on the South ridge.

Meg. The specimens show the usual, hard, glistening, crystallized hematite of the Vermilion iron range at Tower. A little quartz is present, and there are small cavities into which project minute plates of hematite. In some of these cavities is a little limonite.

Mic. The section shows *hematite* and coarsely crystallized *quartz*. The hematite sends small fibres into the quartz where the two minerals are in contact; and in places there is a narrow band of these fibres a little removed from, but parallel to, the outline of the hematite. The quartz is much clouded, this feature being in part due to minute dark specks, most probably of hematite, and cavities filled with *liquid*, frequently also containing bubbles.

One section.

Age. Archean (Keewatin). U. S. G.

NO. 430. JASPILYTE.

Same locality as No. 429.

Ref. Annual Report, ix, pages 103, 104. Compare No. 866, which is jaspilyte from the South ridge.

Meg. The usual jaspilyte of the Vermilion iron range. One of the specimens is gray, another brownish and another red. The last is finely banded with darker bands which contain small magnetite crystals.

No section.

Age. Archean (Keewatin). U. S. G.

No. 431. Mica Schist.

"Rock that forms the first rapids of Pike river; three feet of gray, firm, fine-grained, heavy, crystalline rock, similar to some of the beds of the jaspilyte and slate formation." S. W. ¼ N. W. ¼ sec. 3, T. 61-16 W.

Ref. Annual Report, ix, page 105; Annual Report, xv, page 277.

Meg. A hard, fine-grained rock, apparently containing much quartz. Numerous glistening, small cleavage faces of mica are seen throughout the rock.

Mic. The section shows a rock composed largely of *feldspar.* This is in grains of considerable size, which have irregular outlines and which are surrounded by a fine-grained mass of similar feldspar with perhaps some quartz. The large grains of feldspar are not very sharply marked off from the smaller ones, but many of intermediate sizes occur. The feldspar rarely shows cleavage or twinning and the species was not determined. Scattered through the rock, and lying with their long axes in all directions, are small flakes of *muscovite.* These cut through the feldspar. There are also a few minute brownish *biotite* scales *chlorite* scales and a little *epidote.* A peculiar feature of the rock is the presence of large amounts of black dust-like material.

One section.

Age. Archean (Keewatin). U. S. G.

No. 432. Biotite Schist.

"In general a gray quartzyte, but varying to a syenitic rock, and to a siliceous slate, and to white quartz, as well as to a tremolitic (?) mica schist, which is dark gray. It exhibits small faults, in which the otherwise parallel and regular strata, or laminations, are jagged or twisted, the west end moving southward about five inches or less. This rock, except in its perpendicular arrangement, and the absence of trap, resembles the gray quartzyte formation of Pigeon point. It is more highly tilted, and generally metamorphic. The beds are nearly perpendicular, but dip to the south." Falls of Pike river; N. W. ¼ S. W. ¼ sec. 3, T. 61-16 W.

Ref. Annual Report, ix, page 105.

Meg. The hand specimen shows alternations of layers of a hard, dark-gray, siliceous, almost slaty rock and of lighter colored, coarser grained rock, which contains small white feldspars. There are gradations between these two extremes and also very fine laminæ, the whole showing a fine example of sedimentary banding.

Mic. The section, which is small, shows a biotite schist. It is composed essentially of a fine-grained aggregate of *biotite, quartz* and *feldspar.* Most of the biotite is cut parallel to the cleavage. There is more quartz present than feldspar, but the two are not easily distinguished, the feldspar being clear and fresh and untwinned. The feldspar shows no cleavage and its species cannot be determined. The most striking feature of the section is the presence of long needle-like crystals of *hornblende*. The terminal planes are not developed, but cross sections show in good development the prism and brachypinacoid. These hornblendes are quite pleochroic, $\mathfrak{a}$ being light brownish or straw colored, $\mathfrak{b}$ greenish brown, and $\mathfrak{c}$ bottle green. They run at random through the section and at times enclose grains of the other minerals.

One section.

Age. Archean (Keewatin). U. S. G.

No. 433. Gneiss.

Pike river, above the crossing of the old Vermilion road; perhaps in sec. 26, T. 61-16 W.
Ref. Annual Report, ix, page 106.

Meg. Reddish, fine-grained, apparently an alteration from quartzyte or graywacke.

Mic. Presents an aggregate of much altered *feldspar* and *quartz*. The feldspar is crowded with brightly polarizing scales, apparently of *muscovite*, and cannot be specifically determined. Some *hornblende* and a little *zircon (?)* also appear in the slide. A fine sprinkling of dark substances, perhaps of *hematite*, gives some color to the section in high powers. One section.

Age. Archean (Coutchiching). N. H. W.

No. 434. Granite *(with hornblende)*.

Portage between Pike and Embarras rivers, about a mile from the north end of the portage; perhaps in sec. 31, T. 60-15 W.
Ref. Annual Report, ix, page 106.

Meg. A medium-grained, gray granite, composed of white to pinkish feldspar, quartz and hornblende.

Mic. The section is composed mostly of *feldspar* and *quartz*. The feldspar is often much clouded by alteration and sometimes indications of a zonal structure are seen. Some of it shows no twinning, but much has very minute twinning lamellæ, and a few grains show the *microcline* grating. No satisfactory determinations were made, but it seems that the feldspar is *orthoclase*, microcline and *anorthoclase* or *oligoclase*. A few areas of *chlorite*, *biotite* and *epidote* are seen; these evidently are the product of alteration of some dark mineral (the hand specimen seems to indicate hornblende). A little *apatite* and iron ore are also present.

One section.

Age. Archean. U. S. G.

No. 435. Granite *(with hornblende)*.

Embarras river: perhaps S. W. ¼ sec. 7, T. 59-15 W.
Ref. Annual Report, ix, page 107.

Meg. Dark, hornblendic, with reddish feldspar.

Mic. The slide shows *microcline*, a cloudy feldspar which shows neither cleavage nor twinning and is presumed to be *orthoclase*, *quartz*, *hornblende*, *magnetite* and a single compound grain, not twinned, of a biaxial, light yellow, rather highly polarizing and refractive mineral which has the characters of *augite*, except that the light yellow color is more like that of epidote. Its extinction is at a position which bisects the angle between the principal cleavages, and when the cleavages are vertical to each other its extinction is parallel to the cleavages. This occurs when the section is cut perpendicular to the plane of symmetry (compare No. 133). This mineral is always in association with some of the hornblendes, and is sometimes seen in remnants in the centres of the larger hornblendes, indicating that it has been altered largely to hornblende. In some instances there is a light-colored periphery separating it from the hornblende which extinguishes with the hornblende, but has a low bi-refraction; indeed, as low as the white of the first order. The hornblende is light green and distinctly pleochroic; it often embraces *sphene*, which is also quite common elsewhere in the form of small isolated sub-angular yellowish grains.

Two sections.

Age. Archean.

Remark. This granite resembles the granite of Kekequabic lake in several respects. The clouded feldspars above mentioned are the central areas of feldspars which, about their borders and often running all through them, have fresh growths. This might be called a zoning, when casually examined, but it is not due to zonal accretions about a feldspar floating in a magma. It is due rather to the regeneration which has penetrated a granitic debris. This rock, therefore, is to be considered a recomposed and recrystallized granite. N. H. W.

No. 436. Magnetite.

Near east line of sec. 15, T. 59-14 W.
Ref. Annual Report, ix, page 108.

Meg. Fine-grained, glistening *magnetite*, probably containing some quartz or other siliceous mineral. No section.

Age. Animikie. U. S. G.

No. 437. Grünerite-Magnetite Rock.

Same locality as No. 436. The rock associated with the ore.
Ref. Annual Report, ix, page 108; Annual Report, xvi, page 72; Bulletin vi, pages 119, 123, 129, 420.

Meg. A fine-grained brownish-gray rock which becomes lighter or almost white on weathering. It is made up of a mass of small, short, rather fibrous grains and magnetite and effervesces with hydrochloric acid.

Mic. The section is composed of a light yellowish mineral, *magnetite* and *calcite*. The light yellowish mineral is a monolinic *amphibole*. It is light yellowish to almost colorless, and is sometimes slightly pleochroic, $\mathfrak{a}$ being almost colorless, $\mathfrak{b}$ light yellowish and $\mathfrak{c}$ nearly like $\mathfrak{b}$ but sometimes showing a tinge of greenish. It has a strong double refraction and is repeatedly twinned, and is referred to *grünerite.* It is massed in small grains, hardly fibrous, which show the prismatic cleavage well developed. Cross sections sometimes show one or two prism faces partly developed, but the mineral is usually completely allotriomorphic. The magnetite is in small grains and in large, granular, porous masses. The *calcite* is quite common, although not nearly as abundant as the other minerals. It is in small grains, quite frequently in connection with the magnetite, being between it and the grünerite or enclosed in the magnetite. This seems to be calcite rather than siderite, which mineral might be expected in this rock. It does not show the high index of refraction, rough black cleavage lines and the pleochroism which are common to the siderite of the iron-bearing rocks of Minnesota. Moreover the hand sample effervesces very readily in acid. Three sections.

Age. Animikie.

Remarks. This rock is part of the iron-bearing series of the Animikie. It is supposed to owe its crystalline character to the influence of the great gabbro mass just to the south. U. S. G.

No. 438. Magnetite.

Sec. 15, T. 59-14 W.
Ref. Annual Report, viii, pages 150, 151; Annual Report, ix, page 108.

Meg. Magnetite similar to No. 436.

No section.

Age. Animikie. U. S. G.

No. 439. Taconyte.

Same locality as No. 438. Rock associated with the ore.
Ref. Annual Report, ix, page 108.

Meg. A fine-grained, hard, siliceous rock, gray in color, but becoming brownish and porous on weathering. It is seen to contain rather indistinct crowded granules in an aphanitic groundmass.

Mic. The section is too thick for careful study. It, however, shows a taconyte with numerous rounded granules in an almost colorless groundmass. These granules are quite distinct in ordinary light, being stained yellowish. In polarized light the granules are hardly distinguishable, the whole section breaking up into a fine-grained aggregate of *quartz.* Usually the grains in the granules are a little larger than those of the groundmass. *Magnetite* and *siderite* are also present, and there are some tufts composed of very minute radiating fibres. These fibres are colorless alone, but when massed together are yellowish brown. They are perhaps of *actinolite.* One section.

Age. Animikie.

Remarks. For a full description and discussion of the taconyte and its granules see Bulletin x. U. S. G.

No. 440. Iron Ore.

Perhaps in sec. 11, T. 59-14 W.
Ref. Annual Report, ix, page 108; Annual Report, xi, pages 156-159.

Meg. A dark reddish-brown, massive iron ore. Some is black and magnetic, other parts are apparently hematite, and much of it gives off water in heating, thus indicating limonite.

No section.

Age. Animikie. U. S. G.

No. 441. Iron Ore and Taconyte.

Same place as No. 440. Near the top of the shaft.
Ref. Annual Report, viii, pages 150, 151; Annual Report, ix, page 109.

Meg. The ore is banded and irregularly spotted with gray, the latter being siliceous and somewhat globular, characteristic of taconyte.

Mic. The section shows the characteristic round silica grains stained with *magnetite*, and in other parts is wholly occupied by iron ore.

The following sketch shows the manner of distribution of the ore in a section of this rock which is more siliceous than the average. There are several characters to be noted:

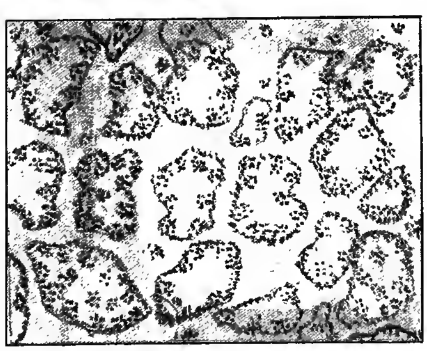

FIG. 20. DISTRIBUTION OF CLUSTERS OF MAGNETITE GRAINS IN THE PERIPHERIES OF SILICEOUS BALLS.

FIG. 21. SHAPES OF THE MAGNETITE CLUSTERS SEEN IN FIGURE 20.

These are chosen from a great number that generally show no grouping into cellular arrangement.

1. The ore consists of a very fine powder or dust, which is black in the section examined as if it were magnetite, and, except for the manner of grouping, which seems to have depended on some earlier or perhaps cotemporary cause, this fine powder is the idiomorphic or first element that shows independent or original characters. These dust-like particles are prevailingly in clusters, somewhat as roughly shown in the figure (figure 20), except that each little cluster comprises many times as many of the particles as are shown in the figure.

2. These clusters are again grouped, in a larger way, into balls or siliceous grains, and in these larger grains they are most numerous at the peripheries. There is, besides, a thread of dust-like opaque particles at the very periphery of each of these balls, making thus a dark thread which quite distinctly outlines each section of a ball.

3. The only other observable element is silica, of a form that is so fine grained that it is comparable to the so-called chalcedonic silica of the jaspilyte of the Vermilion Iron range. It might be supposed that each of these balls consists of a single mass of silica, having one orientation; but each ball is composed of many fine grains, and similar fine grains also fill the interstices between the balls.

4. In a high power, and the nicole crossed, these fine silica grains show their separate boundaries, and it is observable that in many cases they have the clusters of dark particles as nuclei. Each silica grain embraces one, rarely two, of these clusters where the clusters are numerous, but where they are wanting the silica grains have no central dark cluster. Occasionally a dark cluster is separated from the rest and occupies the centre of a grain in the midst of silica grains that have no nuclei. There is occasionally some confusion, and a cluster seems to be divided between two silica grains. But in the main it is plain that the silica grains grew up in some way under the influence of the dark clusters whenever the material of the clusters was present.

The dust particles are so fine that in the thickness of the slide, cut less than .03 millimeters in thickness, many particles overlap and interfere with each other so as to produce, in the otherwise clear quartz, a grayish obscurity. By lowering the objective, after the first particles come into view (in natural light), others are seen, but, owing to the effect of those that lie above the focal point, as well as to others that still lie below, they cannot be clearly differentiated from the obscurity; yet it is possible in many cases to discern the shapes of the dust clusters; hence, as seen in figure 21,

5. These clusters are rarely or never angular, though frequently they have one part sharper than the general rotundity. They are so constructed, sometimes, as to show that the particles are arranged in a manner of a cylinder or tube. This is evident by a proper manipulation of the fine adjustment screw, viz.: After the objective is lowered so as to focus on the upper side of the section, the particles that are distinctly in focus form perhaps a circular enclosure, or an oblong figure. By lowering the objective by a very small turn, the ring disappears, but its form reappears at the lower focal point, with greater or less distinctness. If the cylinder be crooked so that one side or end protrudes to the right or left from the focal point, the lowering of the objective brings into view distinctly the whole length of the tube on one side as different parts come into focus, until it is cut off by the lower surface of the section.

In other cases, indeed, in most of the clusters, there is no semblance of any structure, but frequently the clusters themselves are grouped, separated by transparent boundaries of siliceous matter in a manner that simulates the cells of foraminifers cut at hazard by the section. Indeed, they suggest strongly the cellular structures represented by Messrs. Woodward and Thomas on plates C and D of volume i of this report. It seems as if the clusters may have been the cells in which gathered the greensand element, and that on conversion from the protoxide to the sesquioxide the iron particles were forced to take such distribution as the walls of the apartments allowed, the walls themselves being replaced by silica. The general aspect of the magnetite, in its distribution in the thin section, suggests the debris of foraminiferal cells, with only occasionally a form preserved that exhibits a probable organic arrangement.

The illustrations that are given by Clark (Geol. Survey of New Jersey, 1892) showing the manner of accumulation of glauconite in the cells of foraminifers, might be supposed to show the original forms of the glauconite grains from which these clusters of magnetite powder were derived, but these are much finer than those.

The first suggestion of the glauconitic origin of the iron ores of the Mesabi range was made by Mr. J. E. Spurr, in Bulletin x, of the Minnesota Survey, and he likewise first conjecturally referred the greensand to the agency of foraminiferal organisms. His material was from the western end of the range where the ore is hematite, and where much of the glauconite is yet in the amorphous protoxide state. He found no structural evidence of organic agency in the microscopic slides which he examined. A re-examination of the same slides, while revealing much amorphous, though globular, greensand, yet does not give any suggestion of composite cellular arrangement. It seems that all the slides examined by him were made from rock in which the glauconite grains are isolated, each from the other, or are so broken and recompacted into a formless mass that no organic order is preserved. In the eastern end of the range the strata have been affected by the nearness of the gabbro range, and at the same time, fortunately, the separate cells are not so completely isolated from their fellows. The result seems to be a partial preservation of the original cellular arrangement, as well as a more perfect crystallization of the iron into magnetite. The calcareous surroundings have been entirely replaced by silica, the exact outlines of each cell are more or less revealed by the positions of the opaque magnetite-dust clusters, and by the transparent lines that surround and separate them. When the greensand was broken and disseminated loosely, it seems to have been gathered, under the same dynamic force, into larger magnetite crystals and spicules, some of which appear in the same slide from which the foregoing drawings are taken. A photograph of this slide is represented by figure 8 of plate I.*

Two sections.

Age. Animikie. N. H. W.

No. 442. Jaspilyte.

From the shallow pit dug for silver by the Chester expedition of 1875. About half a mile south from the from the last; S. E. ¼ sec. 11, T. 59-14

Ref. Annual Report, ix, page 109; Annual Report, xi, page 159. This is the same rock as No. 1642, Bulletin vi, page 203.

Meg. A fine-grained, somewhat gray or greenish quartzyte which in the field is somewhat banded with iron ore, and is associated with greenish graywackes and schist similar to the schists at Tower.

Mic. The section shows a characteristically fine siliceous rock which consists wholly of *quartz.*

One section.

Age. Archean (Keewatin).

Remark. This locality is discussed and illustrated by a diagram in Bulletin vi, pages 203, 204. The nature of this jaspilyte is greatly in contrast with that of No. 441. The two are found here in close proximity, yet they maintain their own characters. This rock is also illustrated by No. 1642. N. H. W.

No. 443. Sandrock.

Near Fond du Lac, near the centre of sec. 2, T. 48-15 W.

Ref. Annual Report, x, pages 9, 30; Final Report, vol. i, pages 200-203.

Meg. Light-colored, coarse, approaching a conglomerate, with lenticular thin, interpositions of green shale which are sometimes an inch in greatest extension.

Mic. Along with many angular *quartzes* and *microcline* fragments is a large ingredient of aporhyolyte, or devitrified glass, the glass being more evident in the gray portion and the aporhyolyte in the red. *Hematite* is the coloring element, but is more abundant in connection with the aporhyolyte. Occasional grains of *biotite, chlorite* and amorphous *leucoxene (?)* are also present.

*Compare W. D. Matthew. On phosphate nodules from the Cambrian of Southern New Brunswick. *Transactions of the New York Academy of Science*, vol. xii, April 10, 1893.

This rock was analyzed chemically by Prof. J. A. Dodge, with the following result (Final Report, vol. i, page 202):

SiO_2	78.24
Al_2O_3	10.88
Fe_2O_3 / FeO	3.83
CaO	.95
MgO	1.60
K_2O	1.67
Na_2O	.06
Total	97.23

Two sections.

Age. Cambrian (*i. e.*, "Upper" Cambrian).

Remark. This light-colored rock is only a phase in the red sandrock of the region, and constitutes only a subordinate part of it. Other samples collected are red, but spotted with gray, these gray spots much resembling the rock of the above description. N. H. W.

No. 443A. Quartz. (*Pebble in sandstone.*)

Same locality as No. 443.
Ref. Annual Report, x, pages 9, 30.

Meg. A roughly egg-shaped, well-rounded quartz pebble, nearly three inches long, is contained in red sandstone similar to the red portion of No. 443. There are also pebbles of a soft red shale and one pebble of a fine-grained, brownish, soft rock whose nature is not evident.

No section.

Age. Cambrian (*i. e.*, "Upper" Cambrian). U. S. G.

No. 444. Red Shale.

About the centre of S. W. ¼ sec. 6, T. 48–15 W., near Fond du Lac. Here a bed of dark-red shale strikes across the bluff. This is about eighteen feet thick, and has thin beds of sandstone occasionally. This shale has spots that are greenish.
Ref. Annual Report, x, pages 9, 30.

Meg. A fine-grained, soft, red shale. Two small circular spots, less than one-tenth of an inch in diameter, occur. These are greenish gray in color, and except for the color seem to be the same as the rest of the rock. The rock contains many minute glistening flakes of a micaceous mineral.

No section.

Age. Cambrian (*i. e.*, "Upper" Cambrian). U. S. G.

No. 445. Conglomerate. (*Fine, red.*)

Near the centre of sec. 1, T. 48–16 W., valley of the St. Louis, above Fond du Lac.
Ref. Annual Report, x, page 10 (No. 2 of the section); Annual Report, xxiii, page 239. (Compare No. 1976, which is a collection of pebbles from this conglomerate.)

Meg. A rather fragile conglomerate consisting of Keweenawan and Keewatin debris and of quartz sand.

Mic. The principal ingredient is quartz, in rounded grains which have iron rust about their borders. But *microcline, orthoclase, muscovite* and micro-granulitic quartzyte are common. Some of the pebbles are cloudy, being an imperfectly devitrified *glass*. The quartzes are to some extent enlarged by secondary quartz, and in some of the interspaces is a fresh interlocking fine-grained quartz of secondary origin.

Age. Cambrian (in other places associated with the Manitou trap sheets).

N. H. W.

No. 446. Slate. *(Black.)*

Near the centre of the south side of S. E. ¼ sec. 30, T. 49–15 W. The exposure is in the bottom of a branch of Mission creek. Slaty cleavage strikes east and west.

Ref. Annual Report, x, pages 11, 30.

Meg. A very dark gray or black slate. It cleaves rather roughly and apparently is not so fine grained as most slates, but its constituent grains cannot be distinguished. Crossing the slaty cleavage, at an angle of about 20°, is a rough, schistose structure.

No section.

Age. Archean (Keewatin). U. S. G.

No. 447. Shale. *(Gray.)*

Near centre of south side of S. E. ¼ S. E. ¼ sec. 31, T. 49–15 W. In Mission creek. Slaty cleavage strikes in the same direction as in No. 446.

Ref. Annual Report, x, pages 11, 30.

Meg. A very fine-grained, light greenish-gray, soft slate or perhaps more probably a shale.

No section.

Age. Archean (Keewatin). U. S. G.

No. 448. Conglomerate. *(Red.)*

Near same place as No. 445.

Ref. Annual Report, x, page 11.

Meg. Specimen missing.

No section.

Age. Cambrian (*i. e.,* " Upper " Cambrian.) U. S. G.

No. 449. Conglomerate. *(Pyritiferous.)*

S. W. ¼ N. E. ¼ sec. 1, T. 48–16 W.; St. Louis valley.

Ref. Annual Report, x, pages 11, 12, 17, 30. (Compare No. 1975.)

Meg. Hard, pebbly with vein quartz, with much pyrite, and having in general a light-gray color. Dips with the red beds about 10° E. of S. Some of the pebbles are two or three inches across. In some places nearly one-half of the pebbles are of the underlying slate formation. Nothing of a Keweenawan origin can be found in this conglomerate. The finest part of the cement is apparently a consolidated kaolinic mud. The entire thickness is probably about 100 feet.

No section.

Age. Basal conglomerate of the fragmental Keweenawan (Puckwunge).

Remark. This conglomerate was struck in the deep well at Short Line Park, where it lies below a considerable thickness of "gabbro," and is interbedded with eruptive rock, some of which is apparently amygdaloidal. The age of this conglomerate is considered in vol. iv, page 567, also in this volume at page 54. N. H. W.

No. 450. Shale. *(Greenish.)*

S. E. ¼ S. E. ¼ sec. 2, T. 48–16 W. North bank of St. Louis river. Underlies conformably No. 449.
Ref. Annual Report, x, page 12. Same as No. 1974.

Meg. A soft, very fine-grained greenish gray shale, quite similar to No. 447. When scratched with a knife blade a buff-color streak is left. There are a few brownish rusty areas, probably from the decay of pyrite, as a small pyrite grain is seen in the center of one of these areas.

No section.

Age. Archean (Keewatin). U. S. G.

No. 451. Shale.

Same place as No. 450. The bedding dips southwest about 4°.
Ref. Annual Report, x, page 12.

Meg. A soft, purplish-gray shale or slate having a rough, imperfect slaty cleavage which crosses the bedding of the rock at an angle of about 70°. The bedding of the rock is well exhibited by bands and laminæ of different color. This rock is in general the same as Nos. 447 and 450. It has some greenish-gray blotches and streaks.

No section.

Age. Archean (Keewatin). U. S. G.

No. 452. Slate. *("Pencils.")*

Same place as No. 450.
Ref. Annual Report, x, page 12.

Meg. Rock essentially the same as Nos. 447, 450 and 451. It breaks into long, rough prisms having a rhomboïdal cross section. The two specimens preserved are about five inches long and usually less than a half inch in width.

No section.

Age. Archean (Keewatin). U. S. G.

No. 453. Slate. *(Black.)*

Lower falls of the St. Louis river; S. E. ¼ sec. 10, T. 48–16 W.
Ref. Annual Report, x, page 12.

Meg. A dark-gray, almost black, rock, having a rough cleavage. It is considerably coarser grained than most slates, but the constituent minerals are not to be determined macroscopically. It has a much rougher texture than the usual black slates of the region.

Mic. The section is composed essentially of dolomite and a black finely disseminated material which may be carbonaceous. There are also a few minute grains of *quartz*, and possibly some *feldspar*, and some flakes of *chlorite*. The *dolomite* is the main constituent of the rock. It appears like calcite, but is called dolomite, because the rock effervesces very slowly in cold acid, but rapidly when warm. In seams in the hand specimen the same mineral is developed.

One section.

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

No. 454. QUARTZ. *(Vein.)*

Same locality as No. 453.
Ref. Annual Report, x, pages 12, 21.

Meg. A måss of coarsely crystallized milk-white quartz. There are also pieces of what might be the wall rock of the vein. These are quite soft, and green or greenish gray in color. A little dolomite is also scattered through the specimen.

No section.

Age. Vein in Animikie(?) rocks. U. S. G.

No. 455. ARGILLYTE.

Lower falls of the St. Louis river. Embraced between and contiguous to white quartz veins and laminæ.
Ref. Annual Report, x, page 12.

Meg. This is a fine, nearly black clay state, with numerous joints and plications formed by pressure and slight shearing, apparently sparsely garnetiferous.

No section.

Age. Animikie(?) N. H. W.

No. 456. GRAYWACKE.

Embraced in the slate at the lower falls of the St. Louis river.
Ref. Annual Report, x, page 12.

Meg. This is a typical graywacke. The grains of quartz are abundant, their larger diameters sometimes reaching one half a millimeter. The feldspars are somewhat kaolinized and rarely of a flesh-red color, and would average perhaps a little larger than the quartzes. These are embraced in a fine matrix of greenish, perhaps chloritic and siliceous matter, which gives color to the rock, which is dense, fresh and firm. It has a coarse, oblique structure, hardly susceptible of being called schistosity, which is coincident with the slatiness of the contiguous argillyte and which was produced probably at the same time and by the same pressure that gave the argillyte its slaty cleavage.

Mic. The *quartzes* are sub-rounded and angular, and have a conspicuous undulatory extinction, indicative of incipient crushing. The *feldspars* are usually crowded with microliths and clouds of impurities which render them unidentifiable. These are probably of *orthoclase*, since others, which are plainly striated, and which must have undergone the same general history, are well preserved, though not of secondary origin. The fine matrix is composed of a gray or greenish-gray chloritic, ill-defined substance which probably represents simply the finer debris from the same source as the coarser grains. There is in it more or less of opaque dust.

One section.

Age. Animikie(?) N. H. W.

No. 457. SLATE. (*Graywackenitic.*)

"Slate; average sample for the rock of the lower falls." Same locality as No. 453.
Ref. Annual Report, x, pages 12, 21.

Meg. A black, rough, slaty rock. The mass of the rock is dark, apparently siliceous and very fine grained. In it can be seen small scattered grains of quartz and some of feldspar.

Mic. The section shows grains of *quartz* and *feldspar* embedded in a dirty greenish groundmass. These grains vary from those which are rounded to those which are sharply angular. The feldspar is usually somewhat kaolinized. Many of the grains show no twinning, while a few show fine twin lamellæ. As a rule cleavage is not noticed, and the species of none of the feldspar grains was determined. The groundmass, under a high power, is seen to be made up of minute flakes of *chlorite* and *sericite*, among which are fine grains of probably both quartz and feldspar. There are also many opaque black to grayish specks throughout the groundmass. One small fragment thought to be *rutile* was seen, also apparently a fragment of brown *hornblende*. A few small *epidote* grains were seen also.

One section.

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

No. 458. GRAYWACKE.

From the clastic beds adjoining a dike at the lower falls of the St. Louis river, S. E. ¼ sec. 10, T. 48-16 W. The clastic rocks here have a coarsely basaltic structure along the east side of the dike, which is at least twenty feet wide (No. 459). The columns run east-southeast and dip about 30° from the horizon, while the dike runs north-northeast.
Ref. Annual Report, x, pages 12, 13; Annual Report, xxiii, page 239.

Mac. There are two hand specimens. One is a gray, hard, compact rock with an almost aphanitic background in which are numerous small quartz grains and gray and pink feldspar grains. This specimen is perhaps a fair representative of what

Kloos terms *horn-slate* (Annual Report, xix, pages 109–113). The other specimen is a fine-grained reddish-brown rock which much resembles the metamorphosed quartzytes occuring at Wauswaugoning bay and Pigeon point. It is composed of quartz and red feldspar mainly. It contains three blotches of bright red feldspar, two of which blotches have centres of calcite.

Mic. A slide from the gray specimen shows one of the usual graywackes of the region. Numerous angular and subangular, with few rounded, *quartz* and *feldspar* grains are embedded in a background which is of quite fine grain. The quartzes and feldspars are of all sizes up to those half a millimeter or more in diameter. The fewness of rounded grains may perhaps be accounted for by secondary enlargements but no grains which showed such enlargements distinctly were seen. The feldspar is apparently *orthoclase*, *anorthoclase* and *oligoclase*, although no grains were definitely determined, and the rock seems to represent granitic debris. The feldspar is in places altering to *sericite* and some of the grains are reddened. The background of the section is a very fine-grained aggregate of quartz and feldspar with numerous *chlorite* flakes, a few *sericite* (or *muscovite*) flakes and some opaque gray material. The chlorite flakes have their long axes usually parallel and they often bend around the larger quartz and feldspar grains. Much of the quartz shows distinct undulatory extinction and sometimes fracturing.

The section cut from the brown hand specimen shows a different rock. This slide is composed of quartz, feldspar and chlorite. It is very similar to sections of metamorphosed quartzyte from the Pigeon point region. The feldspar is abundant and presents the characteristic reddened appearance so common in the Pigeon point rocks; it is probably both orthoclase and anorthoclase. No quartz grains showing distinct enlargements were noticed. The quartz shows undulatory extinction, but the chlorite scales are not in parallel arrangement as in the other slide. This rock is part of the graywacke of the region altered by a dike of basic rock, but at present the rock is holocrystalline and shows no distinctly clastic structures.

Two sections.

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

NO. 459. DIABASE (*with quartz and hornblende*).

Lower falls of the St. Louis river; a dike cutting the slates of the Animikie(?) in a direction north-northeast at least twenty feet wide. This has so hardened the slates that they are more durable under the action of the river than the dike itself.

Ref. Annual Report, x, page 13; Bulletin ii, pages 108, 109; Final Report, vol. iv, plate A.

Meg. A heavy, coarse, nearly black, or gray-black diabase, with hematitic spots.

Mic. The *feldspar* is *labradorite*, as shown by an extinction angle of 61° in a section nearly perpendicular to the bisectrix n_p. It is fresh and twinned on the albite, pericline and apparently on the Baveno plans. No other feldspar is present.

Olivine is not abundant, but preceded the feldspar. It is much darkened by *magnetite*, and somewhat by *chlorite* and also by *bowlingite*.

Augite preceded the feldspars in large part—indeed, but little or no augite can be seen that followed the feldspars—but it is much altered, some of it having given place to a cloudy, brown and confused mass which cannot be differentiated, but apparently consisting of chlorite and bematite principally. This alteration of the old augite seems to have been cotemporary with the formation of several other minerals, viz.:

Quartz, *hornblende* and *biotite*, which appear as secondary minerals, but not in sufficient amount to seriously interfere with the classification of the rock.

Apatite is abundant, cutting the feldspar and the quartz.

There is a small amount also of what may be considered a devitrified *glassy residuum* from the magma, although these areas are so similar to the decomposition products from the augite that they can hardly be distinguished. One section.

Age. (Cabotian?) dike in the Animikie(?)

Remark. It is the most reasonable to refer this rock to the age of the great eruptive which forms the hills adjacent, which has been called a part of the gabbro. It has also certain petrographic alliances with the great dikes of the Grand Portage region, especially in the fact that the augite preceded the feldspars, a character which has not, as yet, been known to be prominent except in the Grand Portage region.

As to the date of the alteration of the augite, and its cause, see special discussion of petrographic peculiarities in Part III. N. H. W.

No. 460. Diabase *(with olivine)*.

Diabase from dike above the lower falls of the St. Louis river, nearly opposite Island No. 6; N. E. ¼ S. W. ¼ sec. 10, T. 48-16 W. From a smaller dike—probably a dike ten feet in width.

Ref. Annual Report, x, page 13; Final Report, vol. iv, plate A, and pages 17, 571.

Meg. A rather fine-grained, heavy, black diabase with a resinous luster.

Mic. The section shows a diabase composed essentially of lath-shaped *plagioclases*, *augite* and *magnetite*. The plagioclase shows equal extinction angles on either side of the twinning plane running up as high as 30°; a grain which gave a positive bisectrix had an extinction angle of 23°; both of these determinations indicate labradorite. The augite is mostly later than the labradorite, though some grains seem to be as early or earlier than some of the labradorite. The rock, especially the augite, has been altered considerably in places, and as secondary minerals there are *hornblende*, *chlorite*, *biotite*, *magnetite* and *quartz*. There are also some yellow areas *(bowlingite ?)* which perhaps represent original olivine, and a few grains of *olivine* altering to a green product are present. One section.

Age. (Cabotian ?) dike in Animikie(?) rocks. U. S. G.

No. 461. Diabase.

Same locality as No. 460. From a dike eight feet wide.
Ref. Annual Report, x, page 13.

Meg. A fine-grained, dark-gray, diabasic rock with a few small porphyritic crystals of plagioclase.

Mic. The section, which is rather thick, shows small *plagioclases*, mostly lath-shaped, in a confused, dirty, greenish groundmass of alteration products. The *plagiociase* and part of the *magnetite* are the only original minerals present. What the original nature of the groundmass was is uncertain, but it seems probable that it was largely *augite* and the rock a diabase.

One section.

Age. (Cabotian?) dike in Animikie(?) rocks. U. S. G.

No. 462. Diabase.

From a dike crossing the river at the mouth of the creek coming from the north on S. W. ¼ sec. 10, T. 48–16. It is about 30 feet wide, and is less durable than the hardened slate.
Ref. Annual Report, x, pages 14, 19.

Meg. Dense, black and fine grained, but sparsely porphyritic, with feldspars of the earlier consolidation.

Mic. The thick section only shows that the rock is composed essentially of *plagioclase*, *augite*, *magnetite*, and that the augite was earlier than the feldspar.

One section.

Age. (Cabotian?) dike in the Animikie(?) N. H. W.

No. 463. Diabase.

From a dike eight feet wide running north about 15° E. on the N. E. ¼ S. E. ¼ sec. 9, T. 48–16, crossing the river.
Ref. Annual Report, x, page 14.

Meg. The rock is medium grained, dark (nearly black), and has small, metalloidal reflections, appearing like pyrite.

Mic. The much decayed section shows the augites were principally earlier than the feldspars, and that long magnetite rods have been generated.

One section.

Age. (Cabotian?) dike in the Animikie(?) N. H. W.

No. 464. Diabase *(with olivine)*.

"From a dike crossing the river a short distance above the last [No. 463], in the same direction, but thirty feet wide."
Ref. Annual Report, x, page 14.

Meg. A rather fine-grained, dark-gray diabase.

Mic. The section is very similar to that of No. 460, and has the same secondary minerals, except the yellow bowlingite (?). The rock contains considerable *olivine*, and *apatite*, both in short stout prisms and in long needle-like forms, is common.

One section.

Age. (Cabotian?) dike in Animikie(?) rocks. U. S. G.

No. 465. Graywacke. *(Fine.)*

From the railroad cut, N. W. ¼ S. W. ¼ sec. 9, T. 48–16, St. Louis valley.
Ref. Annual Report, x, page 15.

Meg. Tough, gray, firm rock, hardly showing any tendency to slaty cleavage, finely arenaceous.

Mic. The section appears much like that of rock No. 456. The only variation from that description necessary to apply it to this rock is to reduce the size of the quartz and feldspar grains about two-thirds, or even nine-tenths; the former seems to be the correct statement in examining the slide, and the latter in megascopic aspect.

One section.

Age. Animikie(?) N. H. W.

No. 466. Clay Slate. *(Siliceous.)*

St. Louis river; from the falls; centre of sec. 8, T. 48–16.
Ref. Annual Report, x, page 15; Annual Report, xviii, page 47.

Meg. The beds here dip 33½° toward the south-southwest, swinging round to the south-southeast, and being then in a dip of 39° to 43°. At these falls the rock is less slaty, and more siliceous. Yet it breaks in the direction of the prevailing cleavage easier than against it.

Mic. The rock might be called a fine siliceous graywacke.

One section.

Age. Animikie(?) N. H. W.

No. 467. Diabase *(with olivine.)*

Rock of the dike at Thomson bridge. The river at the bridge is running in the course of this dike, which is about twenty-five feet wide. It is not so durable as the hardened slates on either side. Its direction is north-northeast.
Ref. Annual Report, x, page 16.

Meg. This rock resembles the rock of the great dikes at Grand Portage and Pigeon point, which there cut the slates, forming the principal hill ranges. (Nos. 293, 297, 298, etc.; compare, also, dike rocks Nos. 459, 460, etc.)

Mic. It has the composition and structure of a beautifully ophitic diabase, with older olivines.

In the feldspar extinction on 010 is 25½°, showing the usual result for these dikes, viz., *labradorite-bytownite.* It is pierced by long and large microscopic needles of *apatite.*

Chlorite, *biotite* and *bowlingite*, as alteration products, are dispersed scantily in the section, while *magnetite* plays its customary rôle.

Two sections.

Age. (Cabotian?) dike in the Animikie(?) N. H. W.

No. 468. Argillyte (?) *(Metamorphic.)*

Rock adjoining the dike at the Thomson bridge; a part of the argillyte hardened.
Ref. Annual Report, x, page 16; Annual Report, xxiii, page 239.

Meg. Dense, black, apparently a fine-grained basalt.

Mic. The thick section shows between the nicols that an incipient crystallization has been started. This is evinced by the existence of roundish and oblong areas which thickly stud the slide, which are much lighter than the rest. These areas occupy more than one-half of the whole space. They are specked with scales of *muscovite (?)*, which lie in all positions, and which cause the areas to remain light continually on rotation, although separately each scale has its extinctions.

One section.

Age. Animikie(?)

Remark. This may be from the selvedge of the dike itself. N. H. W.

No. 469. Graywacke.

Near Miller's mill, a quarter of a mile north of Thomson; probably in N. E. ¼ S. W. ¼ sec. 5, T. 48–16 W. This bed is eleven feet thick, and in places it is conglomeratic; it has slaty layers on each side of it.
Ref. Annual Report, ix, page 82; Annual Report, x, pages 16–18, 20, 21, 23, 29; Annual Report, xxiii, page 239.

Meg. A light-gray rock, hard and siliceous. Small quartz and feldspar grains occur in a fine-grained matrix.

Mic. The section shows numerous rounded to angular *quartz* and *feldspar* grains in a dirty greenish groundmass. The section is too thick to enable this groundmass to be carefully studied, but it is evidently composed essentially of *chlorite*, iron ore, and a fine-grained aggregate of *quartz* and *feldspar*.

One section.

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

No. 470. Slate. *(Black.)*

Near the same locality as No. 469. Quarried for roofing slate.
Ref. Annual Report, x, page 17.

Mic. A very fine-grained, black, clay slate, with a rather rough cleavage.

No section.

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

NO. 471. SLATE. *(Black.)*

Near the same place as No. 469. From another quarry.
Ref. Annual Report, x, page 17.

Meg. Almost exactly the same as No. 470, except that it is not quite so black and cleaves a little better.

No section.

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

NO. 472. QUARTZ. *(Vein.)*

Forty rods above the railroad (St. Paul & Duluth) bridge; S. W. ¼ S. W. ¼ sec. 5, T. 48–16 W. The vein coincides with the slaty cleavage of the enclosing slates, but it is irregular and soon pinches out.
Ref. Annual Report, x, pages 17, 18; Annual Report, xviii, page 47; Final Report, vol. iv, page 9 and plate A.

Meg. A mass of coarsely crystallized, milk-white quartz.

No section.

Age. Vein in Keewatin(?) rocks. U. S. G.

NO. 473. GRAYWACKE. *(Pyritiferous.)*

From the ridge in which No. 472 occurs. Some of the pyrite cubes are three-fourths of an inch across, and occasionally an inch.
Ref. Annual Report, x, page 18.

Meg. A fine-grained, hard, siliceous, grayish rock, containing cubes of pyrite which are usually about a quarter of an inch across. The rock is so fine grained that its constituents cannot be determined macroscopically, but it appears like a fine quartzyte. The weathered surface is almost white, but on a fracture just below this surface the rock is brownish, evidently due to the decay of some iron-bearing mineral.

Mic. The section shows *quartz, feldspar, siderite* (and also *calcite*), *chlorite, sericite* and opaque earthy specks. The quartz and feldspar are in grains of various sizes. In places larger grains of these minerals are embedded in a finer grained groundmass which is composed of all the minerals of the rock. There are, however, gradations in size from these larger grains to the smaller ones of the groundmass. In shape these larger grains are roughly rounded to angular, but even the rounded ones do not have sharp boundaries, but interlock with the surrounding grains. These grains appear to be fragmental, but a careful search failed to show any of them which show distinct outlines which had been added to by secondary growths, although there seems to be no doubt but what this process has occurred widely in this slide. The feldspar is often clouded; no careful determinations were made, but it appears to be orthoclase and oligoclase. The siderite is quite common and is frequently accompanied by a brownish stain. Two small prismatic crystals were seen which show a decided absorption of the ray vibrating parallel to the short axis of the crystal and also parallel extinction. These crystals are probably *tourmaline*. Two sections.

Age. Keewatin(?)

Remark. In general the rock has the same composition as other graywackes from this region. It seems to represent debris from a granitic rock mixed with some finer material most of which has crystallized as chlorite and sericite. U. S. G.

NO. 474. DIABASE *(with olivine).*

Dike rock near Carlton. There are several similar dikes in the near vicinity. This one is thirty feet wide. The slates dip 57° to the S. 5° E. (compass). The dikes all run about N. 5° E., with a slight variation either to the east or west of that, which is about the direction of the main gabbro mass northward from Rice's point.

Ref. Annual Report, x, page 18.

Meg. The rock is not distinguishable from that of the dike, already mentioned, running north and south under the railroad bridge near Thomson.

Mic. The *feldspar* shows extinction on 010 at 24°, indicating *labradorite-bytownite.* The *olivine* is sometimes changed to *bowlingite. Biotite* is shown by its pleochroism and *chlorite* by its green color. These with *augite* and *magnetite* constitute the rock.

Two sections.

Age. (Cabotian?) dike in the Animikie(?) N. H. W.

NO. 475. DIABASE *(with olivine).*

From the most westerly of several dikes at Carlton. This dike passes west of Paine's sawmill.

Ref. Annual Report, x, pages 18, 27, 29.

Meg. This dike differs from the foregoing in having conspicuous porphyritic feldspars. One of these cut perpendicular to n_g has extinction at 23°, which is indicative of *labradorite.* Another parallel to 010 has extinction at 19°.

There are small *augites* which preceded the feldspars, but in the main the augite is later than the feldspar and embraces it ophitically. *Apatite* and *magnetite* are common, but *olivine* is not evident, as it is obscured by accumulations of magnetite.

One section.

Age. Cabotian dike in Animikie(?) N. H. W.

NO. 476. GRAYWACKE.

From the south bank of St. Louis river, about a mile above Knife falls.

Ref. Annual Report, x, pages 20, 21.

Meg. Rather fine and granular, gray, coarsely schistose.

Mic. This rock appears like Nos. 469 and 465.

One section.

Age. Keewatin(?) N. H. W.

NO. 477. GRAYWACKE.

Same locality as No. 20.

Ref. Annual Report, x, pages 20, 21.

Meg. A gray rock composed of small quartz and feldspar grains in a finer grained background.

Mic. The section shows *quartz* and *feldspar* grains in the usual dirty greenish groundmass. Both macroscopically and microscopically this rock is very similar to No. 469. (Compare also description of No. 473.)

One section.

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

NO. 478. GRAYWACKE.

"Represents the last rock on the right [south] bank of the St. Louis above Knife falls."
Ref. Annual Report, x, pages 21, 23, 29.

Meg. Rock of the same general character as No. 477. Running through it is a band of decidedly coarser grain, but of the same composition.

Mic. The section was evidently made from the coarser band. It shows the usual *quartz* and *feldspar* grains in a greenish groundmass. The rock is very similar to No. 477. Compare also the description of No. 469, which is a similar, but finer-grained, rock. Nos. 477 and 478 differ from No. 469 in only one essential particular, *i. e.*, in lacking, or almost lacking, siderite and pyrite.

One section.

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

NO. 479. GRAYWACKE.

From the brink of Knife falls, St. Louis river.
Ref. Annual Report, x, pages 21, 22.

Meg. Similar to No. 477, a gray, hard, arenaceous fragmental rock.

Mic. The section shows no essential variation from the characters already mentioned for several graywackes.

One section.

Age. Keewatin(?) N. H. W.

NO. 480. GRAYWACKE.

"From the brink of Knife falls."
Ref. Annual Report, x, page 21.

Meg. A greenish-gray rock, much finer grained than most of the graywackes already described. A few small quartz and feldspar grains can be seen in a greenish background.

Mic. The section shows a few scattered *quartz* and *feldspar* grains, much smaller and fewer in number than usual in these rocks, in a greenish groundmass. The section is too thick for a careful study, but it is evident that this groundmass is composed, as usual, of *chlorite* (and probably *sericite*), and fine grains of *quartz* and *feldspar*. The rock is thus like the other graywackes of this vicinity except that it is mostly composed of the material which makes only the groundmass of the other specimens.

One section.

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

No. 481. Argillyte. *(Siliceous.)*

From the brink of Knife falls, St. Louis river.

Meg. The piece has lines of shearing structure intersected by the slaty cleavage. No section.

Age. Keewatin(?)

Remark. The structure lines in this rock might easily be mistaken for sedimentary banding. They seem to indicate planes of movement under a shearing stress. On the parting surfaces they are characterized by straight, parallel ridges and depressions, which by the natural shadows give the surface a fine banding of light and dark, but there is no apparent variation in the composition of the rock. Across the edges of the slates produced by the prevalent slaty cleavage, are other bands and ridges which do not have a close correspondence with those which mark the flat surfaces of the slates. Compare a similar structure seen in the rock of the railroad cut southeast from Carlton (Nos. 1978, 1979). N. H. W.

No. 482. Graywacke.

At Knife falls, in the channel on the north side of the island.
Ref. Annual Report, x, pages 22, 23.

Meg. Slaty graywacke, alternating with graywacke.

Mic. This slide, which is too thick for microscopic use, only shows the usual composition of these fine graywackes, as already mentioned. It is crossed by alternating fine and coarser bands due to sedimentation.

One section.

Age. Keewatin(?) N. H. W.

No. 483. Graywacke.

Knife falls, in the channel on the north side of the island.
Ref. Annual Report, x, pages 22, 23.

Meg. Coarse and arenaceous graywacke.

Mic. This rock is like No. 482, except in being coarser.

One section.

Age. Keewatin(?) N. H. W.

No. 484. Graywacke.

Knife falls, in the channel on the north of the island.
Ref. Annual Report, x, pages 22, 23.

Meg. This sample is intermediate in coarseness between Nos. 482 and 483 and presents no new features.

One section.

Age. Keewatin(?) N. H. W.

No. 485. Graywacke. *(Fine.)*

Knife falls, in the St. Louis river. This rock is jointed, hard, and dike-like in appearance.
Ref. Annual Report, x, page 23.

Meg. A fine-grained rock very similar to No. 480.

Mic. The section shows a fine-grained graywacke of the same general characters as others from this vicinity. It is similar to, but finer grained, than No. 480, which see.

One section.

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

No. 486. Graywacke.

From the quartzyte spit below Knife falls, St. Louis river.
Ref. Annual Report, x, page 23.

Meg. A greenish-gray, medium-grained graywacke, similar to No. 479.

Mic. The section shows the same general characters as already described,—quartz and feldspar grains in a dirty greenish groundmass.

One section.

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

No. 487. Argillyte. *(Slaty.)*

Knife falls, from slaty alternations in the spit below the falls.
Ref. Annual Report, x, page 23.

Meg. The specimen is a fine-grained argillyte, showing the curious banding described in the remark under No. 481, which might be mistaken for a sedimentary structure. There is simply a zigzag grain or fibosity which by its oblique intersection on the face of the cleavage planes produces a series of straight minute elevations, in the form of ridges, alternating with depressions. When the light strikes these favorably they cannot be seen at all, but when the ridges cast shadows over the little troughs the banding is conspicuous. There is no variation in the size of the grain, nor in its composition. The structure must be attributed to successive slippings, accompanied by crushing pressure, the resulting motion being minute and permeating the whole rock, so as to displace the original structure, and affecting the rock in a sort of undulatory fracture along parallel planes.

Mic. It is only when the section is very thin that the ultimate composition of this rock can be seen. It is then found to embrace only the usual minerals of the graywackes, but in a finer condition.

One section.

Age. Keewatin(?) N. H. W.

No. 488. Graywacke. *(Coarser.)*

Near the lower end of a small island north of Homestead island, St. Louis river, above Knife falls.
Ref. Annual Report, x, pages 23, 24, 29.

Meg. A coarser graywacke similar to Nos. 469, 477, 478.

Mic. The section shows the usual grains of *quartz* and *feldspar* in a rather sparse groundmass of *chlorite*, *calcite*, *sericite* and finer *quartz* and *feldspar*. A few small grains of a yellowish mineral with a high index of refraction and strong double refraction are present; this seems to be *epidote*. There is also a rock fragment similar to the finest-grained of these graywackes. This rock shows more rounded and sub-angular grains than, and not so many sharply angular ones as, most of the rocks from this vicinity. Moreover, the outlines of the rounded grains are distinct and they do not interlock with the adjacent grains as in No. 473.

Two sections.

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

No. 489. Graywacke.

From a large boulder near the same locality as No. 488.
Ref. Annual Report, x, page 24.

Meg. Finer grained than the last, and intermediate between it and the more slaty portions. Similar to No. 486.

Mic. One of the usual graywackes of medium grain.

One section.

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

No. 490. Graywacke.

From the rapids in the middle channel, north of Island No. 5, near Knife falls.
Ref. Annual Report, x, pages 24, 29.

Meg. The hand specimen and the section are closely similar to No. 489.

One section.

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

No. 491. Graywacke.

From the same place as No. 490.
Ref. Annual Report, x, page 24.

Meg. An arenaceous, somewhat slaty, hard gray rock.

Mic. The section shows the same composition.

One section.

Age. Keewatin(?) N. H. W.

No. 492. Diabase *(with olivine)*.

From large boulders at the rapids at the head of Island No. 4, apparently from a large dike in place near, but which cannot be seen.
Ref. Annual Report, x, pages 24, 29; Bulletin ii, page 108.

Meg. Gray, rather coarse-grained and fresh, heavy rock.

Mic. The *feldspar* is ophitically embraced by the *augite*. *Olivine* is not abundant. *Magnetite* and a small quantity of alteration products, these constitute the rock, which is similar to many other dike rocks already noted, in the same region.

One section.

Age. Cabotian dike in the Keewatin(?) N. H. W.

NO. 493. GRAYWACKE.

At the rapids at the head of Island No. 4. From boulders, but evidently from the formation in place at this point.
Ref. Annual Report, x, pages 24, 26.

Meg. A coarse, gray, harsh, graywacke.

Mic. The description of No. 473 or of No. 488, will apply to this rock, but it is rather more coarse than they.

One section.

Age. Keewatin(?) N. H. W.

NO. 494. GRAYWACKE.

About half a mile below Knife falls at the river bank. From one of the firmer beds of the formation.
Ref. Annual Report, x, pages 24, 26.

Meg. Schistose, gray, ordinary graywacke.

Mic. The section shows the usual ingredients, also some large areas of *calcite* or of *siderite.*

One section.

Age. Keewatin(?) N. H. W.

NO. 495. DIABASE.

From a dike 200 feet wide. Fall in the St. Louis river near southwest corner of sec. 18, T. 49-16 W.
Ref. Annual Report, x, pages 25, 26.

Meg. A medium-grained, gray, heavy diabase.

Mic. The section is quite thick. It shows an ordinary diabase with considerable of a green alteration product.

One section.

Age. Cabotian dike in Keewatin(?) rocks. U. S. G.

NO. 496. GRAYWACKE.

At the head of the uppermost of the Chain islands above Knife falls. Same as No. 493.
Ref. Annual Report, x, page 26.

Meg. Gray, medium grained.

Mic. The *quartz* and *feldspar* grains show the same sub-angular shapes. They lie in a gray matrix of chloritic substance in which are finer grains of the same minerals, with some *calcite.*

One section.

Age. Keewatin(?) N. H. W.

No. 497. Graywacke.

"From near the middle of the central channel a short distance above the head of the uppermost Chain island."

Ref. Annual Report, x, pages 26, 29.

Meg. A rather light gray graywacke of medium grain. It is quite similar to Nos. 496 and 493, but finer grained than the latter.

Mic. The section shows, as usual, quartz and feldspar grains in a greenish groundmass.

One section.

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

No. 498. Argillyte.

The rock of the country 150 yards above the fall where No. 495 was obtained.

Ref. Annual Report, x, page 26.

Meg. Gray, fine-grained, firm, cleaved argillyte.

Mic. This rock has no representing section. It is of a lighter gray color on the edges of the laminæ than on the sides. It is plainly too siliceous to make a roofing slate.

Age. Keewatin(?) N. H. W.

No. 499. Graywacke.

"Rock immediately overlying No. 498."

Ref. Annual Report, x, page 26.

Meg. A rather fine-grained graywacke. A few small pieces of a black argillyte are seen in the hand sample.

Mic. The section shows the usual graywacke described more fully under Nos. 473 and 488.

One section.

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

No. 500. Graywacke. *(Slaty.)*

From near the southwest corner sec. 18, T. 49-16. From just below the falls which here occur in the St. Louis river.

Ref. Annual Report, x, page 26.

Meg. Fine grained, gray.

Mic. Besides the usual minerals this section shows a few grains that are much oxidized and stained with *limonite,* which were probably *siderite.* There is also one large oblong area which is filled with finely granular *quartz* grains, and appears to be of the well-known jaspilyte, or at least like that rock.

One section.

Age. Archean (Keewatin).

Remark. This grain of jaspilyte shows that as a rock it must have pre-existed. It could not, therefore, have been as late as those granites which are supposed to have been eruptive since the Keewatin, *i. e.* unless those granites be themselves derived from fusion of Keewatin rocks, and such a material escaped fusion. (Compare H. V. Winchell, Geological Age of the Saganaga Syenyte, American Journal of Science [3], xli, 386.) N. H. W.

NO. 501. DIABASE.

Right bank of the St. Louis river; centre of sec. 19, T. 49-16 W.
Ref. Annual Report, x, pages 26, 28, 29.

Meg. A black, heavy, rather fine-grained diabase.

Mic. The section shows *feldspar* laths, *augite*, *magnetite* and alteration products. The feldspar is abundantly twinned according to the albite law, and a few grains are seen which show this twinning and also that according to the pericline law. Equal extinction angles on either side of the composition faces of the albite twins run up as high as 29°, and a grain which grave a negative bisectrix very nearly perpendicular had an extinction of 63°; both of these results indicate *labradorite.* The labradorite is altering in places to a cloudy brownish material. The augite, instead of being in small plates, as would seem to be the case when viewed in ordinary light, in polarized light is seen to be in grains, which, however, are usually later than the labradorite. Some of the augite appears to be earlier than, or about the same date as, the feldspar. The augite is altering to a greenish material,—mostly chlorite. Much magnetite is present in small grains and crystals, probably original, and in rough rods, probably secondary.

One section.

Age. Cabotian; dike in Keewatin(?) rocks. U. S. G.

NO. 502. DIABASE *(with olivine).*

Near Knife falls, at a cut by the railroad; width and direction not easily seen.
Ref. Annual Report, x, page 28; Bulletin ii, page 112.

Meg. Rather coarse-grained and dark-gray rock.

Mic. The *feldspar* is embraced ophitically by the larger *augites*, but there are many augites, of smaller size, that preceded the feldspar. A little *hornblende* has been formed by alteration of tbe augite, also a little *epidote* from the same source. The *olivine* is considerably altered also, becoming a brownish or yellowish brown *bowlingite. Magnetite* is common as rods and shapeless aggregations.

Two sections.

Age. Cabotian; dike in Keewatin(?) N. H. W.

NO. 503. DIABASE *(with olivine).*

From another dike near the same place as No. 502.
Ref. Annual Report, x, page 28; Bulletin ii, pages 105, 106.

Meg. Rather coarse-grained and dark-gray rock.

Mic. All the characters mentioned under No. 502 appear in this rock except hornblende and epidote, and in addition one good sized and two smaller microscopic crystals of *rutile* are present. In the larger crystal the plane of the larger section happens to be so nearly perpendicular to the optic axis as to show unmistakably the uniaxial interference figure in convergent light; the grain also exhibits the four intersecting cleavages in two systems standing at 45° with each other, each system having its own intersection at 90°. *Biotite* is also scantily generated in this rock and abundance of *apatite*. *Chlorite* stains some of the feldspars.

One section.

Age. Cabotian dike in the Keewatin(?).

Remark. The above rutile grains are undoubtedly original. They are not in association with any possible alteration products from ilmenite. The largest grains are themselves somewhat altered about their margins, and while they are idiomorphic their outlines still are blunted. N. H. W.

No. 504. Graywacke.

At two miles and a half north of Carlton, on the railroad.
Ref. Annual Report, x, pages 28, 29; Annual Report, xviii, page 47.

Meg. Contains black pebbly masses of what appears to be argillyte. These are somewhat rounded, often half an inch in larger dimension, and occasionally two inches long. They are covered with a black, shining and slippery coating, apparently slickensided.

Mic. *Quartz*, feldspar *(microcline, orthoclase, plagioclase) muscovite, chlorite, calcite, ziron(?)*, with more or less coloring matter in the form of *hematite*; these constitute this clastic rock, which is not much, if any, metamorphosed beyond compact consolidation.

Two sections.

Age. Upper Keewatin(?) N. H. W.

No. 505. Graywacke.

Two miles north of Carlton, on the railroad grade, at a long rock cut.
Ref. Annual Report, x, pages 17, 19, 29.

Meg. Hard, gritty graywacke.

Mic. Angular, frequent grains of *quartz*, *feldspar* of several kinds, and a few of jaspilyte, are embraced in the usual more or less clouded matrix, which consists of *chlorite*, *calcite* and fine *quartz* and feldspar debris.

One section.

Age. Keewatin(?) N. H. W.

No. 506. Argillyte. *(Slaty.)*

One mile north of Carlton, on the Knife Falls railroad.
Ref. Annual Report, x, page 29.

Meg. Large sample of slate, showing the slaty cleavage crossing the sedimentary structure.

No section. N. H. W.

No. 507. Graywacke.

Knife falls, just across the north channel, at the head of the second rapids, on Homestead island.
Ref. Annual Report, x, page 30.

Meg. Rather fine grained, with numerous seams and patches of vein quartz.

Mic. The comparative fineness of the grain, combined with the thickness of the section, renders it impossible to individualize the finer elements, though there is no reason to suppose this rock differs from others of the region. There are sparsely disseminated angular grains of quartz and of triclinic feldspar which are embraced in the much finer, gray, sub-opaque matrix.

One section.

Age. Keewatin(?) N. H. W.

No. 508. Graywacke.

"At the extreme upper end of Homestead island, at the very point, higher up than any rock along there before mentioned." St. Louis river above Knife falls.
Ref. Annual Report, x, page 30.

Meg. A rather light, greenish-gray graywacke of medium grain, very similar to others from this vicinity.

Mic. The section is quite thick, but shows that the rock is composed of grains of quartz and feldspar in the usual greenish groundmass.

One section.

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

No. 509. Graywacke.

"Some rods east of the head of Homestead island, on the north side [of the St. Louis river], about one hundred rods west of the head of the rapids that there run across to the other islands."
Ref. Annual Report, x, page 30.

Meg. Closely similar to No. 508.

Mic. A graywacke of the usual type, but the greenish groundmass is not as abundant as is common. Besides the usual minerals, *calcite* and small grains of *epidote* are seen, and there are a few small highly refractive, strongly double refractive grains which are probably *sphene.*

One section.

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

No. 510. Slate. *(Graywackenitic.)*

"Slate from the very foot of Homestead island, below the rapids last mentioned [under No. 509]."
Ref. Annual Report, x, pages 12, 30, 38.

Meg. A very fine-grained, greenish-gray, slaty rock.

Mic. The section shows none of the large grains of *quartz* and *feldspar* common in the associated graywackes. It is composed of a greenish mass which under a high power is seen to be made up essentially of minute flakes of *chlorite* and a micaceous mineral (probably *sericite*), and minute grains of *quartz* and *feldspar.* A few grains of *epidote* are also seen, and there are specks which appear yellow in reflected light which are perhaps composed of very minutely granular *epidote.*

One section.

Age. Keewatin(?)

Remark. In composition this rock is essentially the same as the greenish "groundmass" of the graywackes of this locality. It simply represents the finer material of these rocks and it lacks the coarser grains of quartz and feldspar which are so characteristic a feature of the associated graywacke beds.

This rock is the last of the graywackes from the St. Louis river, and in this connection it is necessary to refer to the description of Dr. J. H. Kloos of rocks from the vicinity of Thomson (Annual Report, xix, pages 109–113). He described in detail two rocks, which he termed *horn-slate* and *roofing-slate.* The former evidently was a medium or fine-grained graywacke (compare Nos. 473, 508, 509, and others), while the latter seems to have been one of the black argillaceous slates which vary to graywacke slates like No. 510. U. S. G.

The doubtful assignment of the rocks from Thomson northward to Cloquet to the Keewatin, is designed to express a slight preference for that rather than for Animikie. The more probably Animikie part of this series lies further south, appearing at the lower falls of the St. Louis, and at the cuts made by the Northern Pacific railroad. The question of the age of the Thomson rocks is considered in vol. iv, page 551. N. H. W.

No. 511. Gabbro and Granite. *(Contact.)*

Duluth. At a point in the bed of Miller's creek, near the quarter section line of sec. 32, T. 50–14, 424 feet above lake Superior. This rock extends indefinitely up stream.

Ref. Annual Report, x, pages 34, 35; Bulletin ii, page 94.

Meg. The specimen consists of two rocks, a reddish granite and a gray gabbro.

Mic. The red rock has much *quartz*, both in isolated grains and in finer pegmatitic growths in the feldspars. The *feldspar* is stained with *hematite*, a fact which causes the general redness of the rock. It cannot be specifically determined, but is probably largely of *orthoclase*, yet occasionally along with some evident *plagioclase* a trace of very fine albite twinning can be seen, indicating, in this situation, that some of the feldspar is *anorthoclase.* No other mineral is abundant. There is some *hornblende*, a little *biotite* and *chlorite*, and an occasional *pyrite.*

The gray portion consists essentially of *augites* and *plagioclase*. The former are small, much altered and earlier than the latter. A little *magnetite* and a few grains of *biotite*, with a few isolated small areas of *quartz*, due to the proximity of the acid rock and much *apatite*, make up the category of minerals of this portion of the slide. The quartz does not appear in this portion in the form of micropegmatyte, but as isolated sizable grains. Rods and spicules, as well as irregular accumulations of magnetite seem to constitute the chief impurity in the augites. Still they are frequently simply clouded with alteration products in such a manner that their nature cannot be determined. One section.

Age. Cabotian. N. H. W.

No. 512. Gabbro.

N. E. ¼ sec. 25, T. 50-15, on the "Herman Town road," northwest from Duluth. Land of Peter Benson. Occasional exposures of this rock rise above the rolling surface of gravelly red till. Elevation here is 500 feet, more or less, above lake Superior.

Ref. Annual Report, x, page 35; Bulletin ii, page 91.

Meg. Heavy, gray, trappean rock with so much magnetite that it sometimes disturbs the needle, rather coarse grained.

Mic. The *feldspar* is not wrapped about by the pyroxene, but was generated about cotemporary with it, presenting the structure of gabbro. It has an extinction angle on 010 of 21° which is about that of *labradorite;* another has extinction at 26°, at *labrador-bytownite*. Extinction on a section nearly perpendicular to n_g is 15½° to 17½°, which is rather low for labradorite, but not conclusive, since the obliquity of the section may cause this deviation.

The *pyroxene* has a fine, clear, lamellar cleavage, like the cleavage seen in No. 133, but in the whole slide but two or three augite grains can be found whose extinction, like that of the augite of No. 133, is parallel to this cleavage. It occasionally shows twinning bands similar to those of albite in the plagioclase. Pyroxene forms rims about the olivine.

Olivine in subordinate amount occasionally surrounds the magnetite grains. In date it preceded the pyroxene. In some cases it has been replaced by ferruginous products of decay (bowlingite). A hematitic stain is a common feature in the vicinity of the olivines. The section studied is so thick (about .055 millimeters) that the olivine shows the light tints of the fourth order, whereas the augite is highly colored and about its edges all of the lower orders can be counted. In another section, made thin, the same fact in respect to the relative ages of the olivine and the feldspar is seen as in No. 258, viz.: it is in some cases later than the feldspars and than the augite. (Compare No. 703.)

Apatite is visible in sizable grains of the first consolidation. They are rounded at the extremities, and elongated, and present a marked shagreen on lowering the polarizer and condenser. They are distinguishable from the olivine by reason of their clear white color in parallel light, their marked, single cleavage, which is parallel with one nicol at the instant of extinction, and by their very low double refraction, even in very thick section.

In order to be satisfied that this mineral is really olivine, further examination was made, viz.:

1. Another thin section was prepared, and about one-half of it was not covered by the glass lamella,

2. This uncovered portion was immersed in nitric acid for eighteen hours. There not being sufficient evidence of solution,

3. This uncovered portion was kept for five hours in a strong hydrochloric acid at 40° centigrade. In order to detect any gelatinous silica,

4. A part of the slide thus exposed to acids was covered with an aniline color, and then after thorough washing and even long soaking in clean water,

5. On examination there was a characteristic stain of the aniline in some of the border areas about the magnetite. But as there is very little of olivine in the portion thus treated, but little permanent coloration was produced. The other minerals were not visibly affected by these acids.

It seems plain, hence, that there is an olivine later than the feldspars. There is also an earlier olivine, which is now so changed that it takes the form of an isotrope, and must be considered to date from the first consolidation. The later olivine probably dates from the epoch of cooling, as already suggested for the rock No. 1.

Remark. Considering its exposed position this rock is little weathered. The relation of the olivine to the feldspar, as seen in No. 258, is illustrated by figure 18.

N. H. W.

No. 513. Forellenstein.

From an outcrop near Duluth; N. W. ¼ N. E. ¼ sec. 27, T. 50–15; at about the same altitude as No. 512, and not far distant.

Ref. Annual Report, x, page 35; Bulletin ii, page 95.

This rock consists, as remarked by Wadsworth, essentially of *plagioclase* and *olivine*, making a forellenstein. The sections are too thick to be of use in making any further determinations. The rock is well preserved. It is probable that the lateness of the last glacial period has not allowed sufficient time for much decay on these summits, since the removal of the pre-glacial decay.

In another section of this rock appears a little *diallage*, surrounding, or at least embracing, the early *olivines*, accompanied by a little *magnetite* and still less of *biotite*.

Three sections.

Age. Cabotian.

Remark. This rock might be styled anorthosyte. By far its largest constituent is feldspar. It is similar to the "feldspar rock" of Carlton's peak, and to that of Little Saganaga lake. N. H. W.

No. 514. FORELLENSTEIN. *(Gabbroid.)*

Near the centre of the S. W. ¼ sec. 22, T. 50-15 W., near Duluth.
Ref. Annual Report, x, page 35; Annual Report, xxiii, page 230; Bulletin ii, page 95, plate V, figures 1 and 2.

Meg. A dark gray rock of medium grain. Gray feldspar grains and crystals are seen enclosed in an almost black crystalline mass.

Mic. The section is composed of a granular mass of *feldspar*, *olivine* and *diallage; magnetite* and alteration products are also present, although the rock is comparatively fresh. The diallage is in small amount, the feldspar and olivine being the essential minerals. These two minerals mutually interfere in their outlines, having crystallized at about the same time. However, much of the olivine is earlier than the feldspar, though not idiomorphic, while occasionally a feldspar grain is seen which conditions the outline of the adjoining olivine. The diallage is in part later than the feldspars and in part of about the same date. It is seen enclosing olivine grains and in the interstices between the feldspars.

The *feldspar* is abundantly twinned according to the albite law and rarely a grain shows the pericline twinning. Equal extinction angles on either side of the twinning plane run up as high as 31°, and a grain which shows a positive bisectrix closely perpendicular gave an extinction of 20°, both of which results indicate *labradorite.*

The *olivine* is in roughly rounded grains and more commonly in aggregates in which the grains have polygonal outlines. It is altering to a yellowish and also to a green serpentine.

The *diallage* is only in small grains. It is much clouded by minute black (magnetite) inclusions which are usually arranged in lines parallel with the parting. In places the *pyroxene* extends in a narrow band between the olivine and the feldspar, and occasionally surrounds an olivine grain.

Magnetite is not very common and nearly all which is present is secondary, occuring in the altered olivines. Three sections.

Age. Cabotian.

Remark. The diallage is in such small quantities that it can be regarded as non-essential and the name forellenstein can be applied to the rock, which is essentially a granular aggregate of labradorite and olivine. It seems, however, that this forellenstein is only a facies of the usual gabbro very rich in olivine and very poor in diallage. Such a facies of the gabbro is not uncommon. It occurs in considerable amount about fifty miles northeast of this locality.* U. S. G.

* A. H. ELFTMAN. *Annual Report*, xxiii, pp. 224-230.

NO. 515. DIABASE *(or fine-grained gabbro).*

At Sucker river; crosses the mouth of the river; runs northeast. Compare No. 89.
Ref. Annual Report, ix, page 24; Annual Report, x, page 36.

Meg. Brownish green, fine grained.

Mic. The great multitude of little *augites* antedated the microlitic *feldspars,* but occasionally a large augite is seen to be cut ophitically by the feldspars and also to include augite grains having different orientation, apparently of the older generation. *Magnetite* now largely replaces the olivines. There is a confusion of indeterminable secondary products, such as chloritic substance, bowlingite (?), biotite (?), hematite (?)

One section.

Age. Cabotian.

Remark. The date of the augites, with respect to the feldspars, in this fine-grained rock, is like that in some of the coarse-grained gabbros. N. H. W.

NO. 516. DIABASE.

Forms the bed of the stream at the mouth of Sucker river, and appears like a bed of lava. This disintegrates into globules and rots to a great depth before falling away.
Ref. Annual Report, ix, page 24; Annual Report, x, page 36.

Meg. Heavy, dark green and almost black when wet.

Mic. The section shows an ordinary diabase with ophitic structure.

One (poor) section.

Age. Cabotian. N. H. W.

NO. 517. DIABASE. *(Gabbroid.)*

From the foot of the bluff, on the north side, at the mouth of Gooseberry river. Compare No. 108.
Ref. Annual Report, ix, page 28; Annual Report, x, pages 37, 38.

Meg. A fine-grained diabase, with some red mottling.

Mic. The section shows that in general the *augite* preceded the *feldspars.* The crystals of augite are small, but are independent of the feldspars, yet occasionally there is a larger augite which was of later date, as it is cut by the feldspars in an ophitic manner. Whether there is any chemical difference between the augites of different dates would be an interesting point to determine, but optically they appear much alike. The crystalline form in neither is perfect.

One section.

Age. Cabotian. N. H. W.

NO. 518. DIABASE.

From the top of the low bluff at the south end of the beach at the mouth of Gooseberry river, containing amygdules of chalcedony. Furnishes some of the pebbles and all of the agates of Gooseberry beach. This rock slopes into the water, and, where it is constantly under the action of the waves, it is reddish, like the pebbles, but the pebbles mostly come from another bluff farther east, and are more acid. Compare No. 108.
Ref. Annual Report, ix, page 28; Annual Report, x, pages 37, 38.

Meg. The rock is sparsely porphyritic with a striated feldspar. It is in general medium grained and brown.

Mic. The section shows an ophitic structure and a spottedness caused by the *augites.* The larger augites are less decayed and are less clouded by magnetite than the surrounding rock. The porphyritic *feldspar* has an extinction angle on the brachypinacoid of 28°, indicating *labrador-bytownite.* In a thinner section made by Marchand, of Paris, may be seen a brilliant orange red mineral in fine grains whose date seems to be earlier than the microlitic feldspars, whose extinction is parallel to a cleavage. It is taken to be *bowlingite,* an alteration from olivine. There is also a notable amount of a minutely crystalline mineral, so confusedly compact that it gives only an aggregate, yet granulated, polarization or simple darkening. This is probably what was called *saponite* by Owen, but which probably merits a specific designation of its own. (See No. 91B.)

Two sections.

Age. Cabotian. N. H. W.

No. 519. Agates.

"Agates, taken from the rock at Gooseberry river."
Ref. Annual Report, x, page 37; Annual Report, xviii, pages 27, 61.

Meg. Agates, somewhat banded and usually white in color. In the interior of these the quartz is sometimes distinctly crystalline. A little calcite is also present.

No section.

Age. Cabotian. U. S. G.

No. 520. Aporhyolyte.

At one mile west of Splitrock river. Rises from the water in a small bay, and continues eastwardly. This bluff is the source of the red pebbles which constitute the most of the beach at Gooseberry river. The rock does not crumble, but goes to pieces in a multitude of small fragments, which strew the beach and work westward under the action of storms. It belongs stratigraphically above the agatiferous trap at Gooseberry river, and is probably the same as the red granite at the west point of Beaver bay. Compare No. 110.
Ref. Annual Report, ix, pages 29, 30; Annual Report, x, pages 38, 39, 40.

Meg. The rock is finely porphyritic with a red feldspar and with quartz, but in the main it appears to be almost amorphous.

Mic. The great endurance of the pebbles derived from this rock is explained at once by an examination of the thin section, for it is permeated by poikilitic *quartz.*

In the section is seen an instance of a rather unusual unison of orientation of several small, clear *feldspars.* The individual crystals are sometimes idiomorphically formed, and show crystal faces and edges. They lie adjacent in the matrix of amorphous red substance, though are not in contact, but they all extinguish at the same instant. The drawing below was made by the use of the camera lucida in order to show this curious combination. In another place in the same section a much larger number of similar grains are grouped. These are, however, not perfect in any instance in outward boundaries. The appearance is as if a rounded fragment, made up of many small fragments of feldspar, had been involved in the rock. That, however, is not a possible explanation, since they are oriented in common, and they must have originated in the rock. They seem to be an instance of *feldspar "globulaire,"* to use a term which has been applied by Fouqué to incipient quartz. The photographic reproduction of this structure is seen in figure 9, of plate I.

Two sections.

Age. Cabotian.

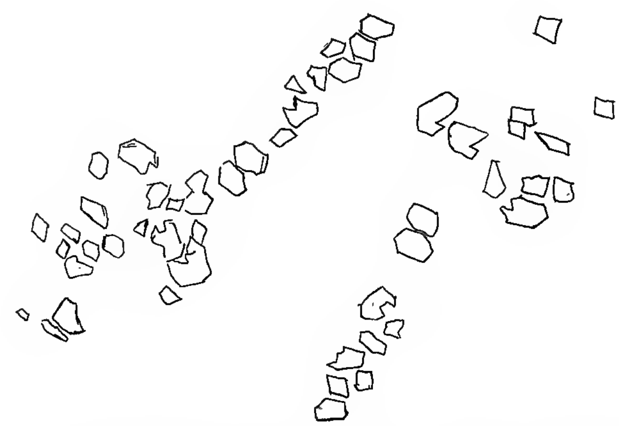

FIG. 22. FELDSPAR GRAINS HAVING SIMULTANEOUS EXTINCTION.

Remark. The identity of orientation in these small feldspar grains points to their being remnants of feldspar crystals which have suffered corrosion by the encroaching siliceous matrix. The poikilitic quartz of the rock appears to be a secondary element and the whole rock may be the result of an extreme alteration of a once more basic one; in which transformation the slow entrance of silica has been the chief feature. The general appearance of the rock itself is not noticeably different from the aporhyolytes of the region. These features, and other facts which are brought together in Part III, raise the question of the origin of all the poikilitic quartz of the aporhyolytes, as well as of the aporhyolytes themselves. (Compare No. 526.) N. H. W.

No. 520A. Laumontite, Calcite, etc. *(Vein matter.)*

From a vein in No. 520.
Ref. Annual Report, x, page 38.

Meg. A mass of red laumontite and coarsely crystallized calcite. The specimen seems to represent the width of a vein—about three inches. The sides are of calcite and the interior of calcite and laumontite.

No section.

Age. Vein in Cabotian rock. U. S. G.

NO. 521. APOTRACHYTE. *(Breccia.)*

"Is an irregular thrust-up rock, appearing in the beach near the west end of No. 520. Its bedding is distorted. It almost appears conglomeritic."
Ref. Annual Report, x, pages 38, 114.

Meg. The hand sample shows a breccia composed of rock which is somewhat similar to No. 520, but is more decayed and darker colored. Occasionally small spots, apparently amygdules, can be seen in the rock. It is seamed through and through by fine pinkish and gray veinlets, and the cementing material of the whole rock is a white, very finely crystallized silica, with some calcite.

Mic. The section was evidently made from one of the larger fragments of the hand specimen. It shows small porphyritic *feldspars*, considerably altered and clouded and frequently holding *chlorite* in irregular areas in a groundmass composed of small poikilitic areas of *quartz* holding minute, cloudy, feldspathic grains, and in all respects resembling the groundmass of many of the devitrified rocks already described. The species of the porphyritic feldspars was not determined. *Pyrite* and *calcite* also occur. The rock can be referred to an apotrachyte.

One section.

Age. Cabotian.

Remark. From the field description it seems possible, though not certain, that we have here a deposit of tuffaceous material. The hand specimen, however, would not warrant us in certainly referring this rock to a volcanic fragmental. U. S. G.

NO. 522. BASALT. *(Amygdaloidal.)*

Near the top of the bluff in the bay first north of Splitrock point.
Ref. Annual Report, ix, page 30; Annual Report, x, page 40.

Meg. A very fine-grained, dark brown rock, with amygdules of laumontite and calcite. The rock appears considerably decayed and contains many indistinct small areas of chlorite.

Mic. The section is made up of minute lath-shaped *feldspars* in a mass of alteration products, *hematite*, *magnetite* and *chlorite*. The feldspars are somewhat altered. A considerable number show albite twinning and equal extinction angles on either side of the composition face running up as high as 23°, indicating *labradorite*. What the original nature of the rock, aside from the feldspars, was, is uncertain, but it seems most probable that it was largely glassy.

Two sections.

Age. Cabotian. U. S. G.

NO. 523. BASALT (?)

From the base of the bluff from which No. 522 was taken.
Ref. Annual Report, ix, page 30; Annual Report, x, page 40.

Meg. A very fine-grained, reddish-brown rock, holds a very few small porphyritic feldspars. Some small dark dots, probably magnetite, are visible.

Mic. The sections are much charged with *magnetite* and are highly stained by hematite, thus considerably obscuring the other minerals, which are *quartz* and *feldspar*. The feldspar is in small lath-shaped crystals and in larger grains, but the main mass of the rock, aside from the iron ores, seems to be composed of secondary quartz, often in small poikilitic areas. The exact nature of the rock is not clear, but as it seems to be similar to No. 522, it is thought to be a rather basic rock, largely glassy originally, but now much charged with secondary quartz. It is nòt, however, improbable that the rock was originally more of a trachyte than a basalt.

Two poor sections.

Age. Cabotian. U. S. G.

No. 524. Diabase *(with olivine)*.

Splitrock point. The great sheet of dark, basic rock that embraces the anorthosyte pieces. This piece was obtained near the large anorthosyte block that forms Splitrock point. This rock can be seen, at places along here, to be underlain by Nos. 522, 523, and the Two Harbor rock (No. 117) in the order named. At Splitrock point this sheet is seventy-five feet thick (see No. 112).

Ref. Annual Report, ix, pages 29, 30; Annual Report, x, page 40.

Meg. A massive, homogeneous, dark-green rock.

Mic. The *augite* has the ophitic relation to the *feldspars*. The *olivines* are small. One section.

Age. Cabotian. N. H. W.

No. 525. Sandstone.

Associated with some of the amygdaloidal parts of Nos. 522 and 523.

Ref. Annual Report, x, pages 40, 114.

Meg. Apparently a grit composed of grains of devitrified glass similar to rocks Nos. 8A or 17, but mingled with masses of considerable size of amygdaloid. In the sand rock which also varies to a shale, and is light-colored as well as red, are flat, water-laid surfaces with an undulatory parting which has impressions resembling fucoids.

No section.

Age. Cabotian(?)

Remark. This rock is less firm and less siliceous than most of the grit rocks derived from apobsidian (as Nos. 17 and 30). Its shaly structure also is different from anything seen as yet in the Cabotian, and it might therefore be placed higher in the series. It is referred to the Cabotian rather than to the Manitou because of its association with the eruptives Nos. 522 and 523, which are immediately connected stratigraphically with No. 117 (the Two Harbor rock), and all of these have been referred to the Cabotian. Owing to the complexity of the structure, and the occurrence of faults, such as that at Baptism river, and eastward from there, it is obviously impossible to speak at present with certainty of the stratigraphic sequence of the strata of the coast. N. H. W.

No. 526. Granite. *(Granophyric.)*

From the knob of red rock at the west side of Beaver bay (see No. 124).
Ref. Annual Report, ix, page 32; Annual Report, x, pages 40, 41; Final Report, vol. i, page 196.

Meg. An even-grained rock of a purplish gray color, not coarse.

Mic. The section shows a semi-crystalline rock, *i. e.*, one that retains still a trace of its original magmatic condition. While it shows much *quartz*, this quartz is not in definite and separate crystalline grains. Some of it is poikilitic, embracing a multitude of minute impurities, many of them opaque, and some of it is pegmatitic. The poikilitic parts are not clearly and fully oriented into separate areas, as is frequently seen in some of the aporhyolytes, but they seem to be more interlocked and blurred, as if there were still some glassy residuum. Other quartzes are evidently from the original magma, having taken their form while still the fluid condition remained, since they have embayments in which an isotropic glassy(?) substance is seen. This *glassy substance* is somewhat reddened by *hematite*, when viewed in natural light, and cannot be distinguished from the bulk of the apobsidian which constitutes a prominent feature of this part of the coast. From these embayments the same substance can be traced, with greater or less distinctness, throughout the slide, sometimes less isotropic and frequently embracing polarizing microliths.

There is another feature that allies this rock with No. 520, viz.: the existence of clear *globular feldspars* which are grouped sometimes to the number of half a dozen, surrounded by the same amorphous reddened substance, all extinguishing at the same instant. In this case the feldspar grains are plainly of some *plagioclase*, since occasional striation is apparent.

All the minerals, except the porphyritic quartzes, are much clouded by fine microliths and reddened by *hematite*, and the quartzes themselves are not free from dark particles—even those which might perhaps be considered to date from the quartz-porphyry stage of the rock.

The specific determination of the feldspar is impossible. While the larger part of it is probably of *orthoclase*, some is still *plagioclase.*

Some *magnetite* and a trace of some ferro-magnesian mineral can also be observed. Two sections.

Age. Cabotian.

Remark. This interesting rock affords another petrographic link between the extremes of the red rock of the region; i. e., between the rhyolyte and the red granite. It has commonly been known as a granite, but it is more nearly a granophyre.

The close resemblance of the groundmass of this rock to the red, so-called felsitic, or feldspathic, substance which encloses the phenocrysts in the quartz-porphyries and rhyolytes of the region, induces us to assume that it has the same origin, and especially as other petrographic characters seem to conspire to unite this rock with those. Hence in the foregoing description it is referred to as a devitrified glass on the assumption that the rock resulted from completely fused material, but with the further supposition that some portion of the magma was interrupted in the process of consolidation, by such unfavorable conditions that the crystallization was not carried to completion. This incompleted differentiation, however, is not evinced (it is admitted) so much by the occurrence of actual glass in the rock at the present time, as by the crowded microlitic structure of much of the groundmass, and by the indefinite forms of the crystal grains which did take shape. (Compare No. 520.)

An analysis of this rock was made by Prof. J. A. Dodge, published in volume i of the Final Report, in the discussion of the building stones, as follows:

SiO_2	71.81
Al_2O_3	12.82
Fe_2O_3 and FeO	6.02
CaO	2.26
MgO	0.56
K_2O	1.92
Na_2O	2.51
Total	97.90

N. H. W.

No. 527. Anorthosyte and Diabase. *(Contact.)*

"Sample showing the union and welding of the feldspar mass at Beaver bay, with coarse trap enclosing it. It is not thus welded generally, so far as visible, but is loosened from the trap."

Ref. Annual Report, x, pages 40, 41.

Meg. The hand sample shows a contact between the anorthosyte and the inclosing diabase, which is a fine-grained, almost black rock. The two are closely welded together.

Mic. The diabase is an *olivine* diabase with large plates of *augite.* The anorthosyte shows that the different grains have been broken, especially along their peripheries, into fine particles, but the thickness of the sections will not permit a careful examination of this point. In the immediate vicinity of the contact the augite and olivine of the diabase are found in the anorthosyte.

Two sections.

Age. Cabotian.

U. S. G.

No. 528. Apobsidian.

Beaver bay, at the mouth of the creek, and also running back from the creek toward the west. It is in an abrupt and isolated outcrop, but runs below the rock of the promontory.

Ref. Annual Report, ix, pages 32, 33, 53; Annual Report, x, pages 41, 112, 113; same as No. 127, which see.

Meg. On a fresh fracture the rock is ashen gray in color. It is aphanitic, contains no porphyritic crystals and presents no variations in grain except a fine, indistinct mottling in lighter and darker shades of ashen gray. The specimen is crossed by several, narrow, distinct bands nearly parallel and about half an inch apart. These bands are from one to two millimeters wide and are of a gray to pinkish color. Frequently a narrow strip along the centre of a band is darker colored than the rest of the band and is seen to be composed largely of quartz. Sometimes these quartz bands are wavy. The material of these bands, except for the central strip of quartz, is as aphanitic and structureless as the rest of the rock.

Mic. The sections in ordinary light present a cloudy appearance, with small transparent areas and numerous black dots of *magnetite*, also some *hematite*, and a few larger irregular areas of magnetite. In a few places these grains of iron ore are surrounded by a narrow rim of a highly refracting substance, probably *sphene*, thus indicating that the iron ore is, in part at least, *ilmenite* rather than magnetite. Under crossed nicols and a high power the section breaks up into an irregular patchy aggregate of small poikilitic *quartz* areas. The quartz encloses the iron ore and minute, cloudy, semi-opaque, irregular grains which as a rule show no influence on polarized light, although occasionally one is seen which shows slight changes on rotating the stage. The nature of this material cannot be determined, but it is thought to be largely feldspathic, most probably *orthoclase*. The quartz frequently has a clouded appearance and thus resembles feldspar, but no cleavage is present and some of the grains which resembled feldspar the most gave uniaxial interference figures.

A section across one of the bands shows hardly anything different from the rest of the rock, as the band, except for the central strip of quartz, is hardly distinguishable under the microscope. If anything is to be noticed, it seems to be a greater abundance of the opaque feldspathic grains in the band. The central strip is more transparent and contains very little of the feldspathic material. Three sections.

Age. Cabotian.

Remarks. This rock is thought to have been originally a glassy rock like an obsidian, and its present condition is due to devitrification. No glass, as such, can be said to be present, although it cannot be said that part of the opaque so-called feldspathic substance is not still glassy. The bands which cross the rock do not furnish evidence as to their original nature, but it seems probable that they represent chains of spheruliths, although no trace of spheruliths is present. In the hand specimen these bands are quite similar to the spherulith layers in the rocks from South mountain.* U. S. G.

*F. BASCOM. *Journal of Geology*, vol. i, pp. 818, 819, 1893; *U. S. Geol. Survey, Bulletin cxxxvi*, plate X.

No. 529. Diabase (*or gabbro*).

Beaver bay. From the peninsula which forms the southern barrier to enclose Beaver Bay harbor.
Ref. Annual Report, x, page 41; Bulletin ii, page 117.

Meg. Dark, diabasic rock, apparently from the great sheet which carries the feldspar masses.

Mic. The *augite* was in part earlier than the *feldspar*, and is considerably altered, sometimes to a grayish mineral that resembles *leucoxene*, but more frequently to a greenish chloritic substance. When it is cut favorably and is sufficiently fresh it shows a diallagic lamination parallel with 100. There is considerable *quartz* in pegmatitic growth in the feldspars.

Two sections.

Age. Cabotian.

Remark. The samples collected represent a series of six numbers, designed to illustrate the progressive stages in the decay of this rock to a surface soil. It is evident that the freshest of the samples collected is yet considerably altered, though probably not by weathering, the chief change consisting in the entrance of quartz. This is more likely to have entered the mass while it was still hot. N. H W.

No. 530. Diabase.

From the shallow bay half a mile west of the west point of Beaver bay. This rock contains patches of red rock like No. 526, and within two rods, after a short interval not exposed, the rock No. 526 is seen in full force, forming a bush-covered bank. The patches are as fragments or boulders, generally, but some patches do not appear like transported masses, but like dikes and veins. Forms a narrow dike-like belt two and a half feet wide, running east and west.
Ref. Annual Report, x, page 41.

Meg. Dark, rather fine-grained diabase.

Mic. The section shows an ordinary ophitic diabase, with some of the *augite* earlier than the plagioclase, and with a little *quartz* and *biotite*. The augite is the gathering place of much magnetite in fine grains, and the gray *leucoxene* mentioned in Nos. 529 and 531 as a result of alteration indicates that it is titaniferous.

One section.

Age. Cabotian.

Remark. The irregular inclusions of the "red rock" in this diabase, although they appear, in some instances, like veins and dikes, are not to be taken as evidence of the later date of the red rock. They illustrate the easy dissemination of the acid elements of the red rock in the basic, a fact which is exemplified in many places, and which has been noted by Bayley on Pigeon point.* On the other hand the isolated, scattered pieces of the red rock in the diabase, which in some places are nearly as abundant, but never so large, as the pieces of anorthosyte, can be explained only by assuming the greater age of the red rock. N. H. W.

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

No. 531. DIABASE *(or gabbro, with quartz).*

From the narrow dike-like belt mentioned under No. 530.
Ref. Annual Report, x, page 41.

Meg. Rock of even grain and purplish-gray color, resembling rock No. 526, but of a darker tint.

Mic. The feldspar is (or was) a *plagioclase* in crystals of considerable size, but is now so penetrated by pegmatitic quartz and impurities that its optic properties are nearly destroyed.

There are grains of *diallage* which yet show the polarization and the characteristic lamination, but the most of the diallage is altered to other substances, or penetrated by other minerals so that it could not be recognized were it not for the visible steps of transition from one extreme to the other. In some cases it seems to form a gray semi-opaque substance resembling *leucoxene*; in others it is converted to a green mineral, and in others still it is brown with accumulated *hematite.* It is not ophitic, but is in small roundish grains which preceded the feldspars.

Apatite is not uncommon, and *biotite* is in some conspicuous grains. There was apparently no olivine in the rock, at least nothing can be seen of it in the slides.

Quartz is not abundant, but forms separate grains in angular spaces between the other grains; also frequently as pegmatitic growths in the plagioclases. Two sections.

Age. Cabotian.

Remark. The assignment of this rock to an alteration of a basic rock by contact with acid material is necessary not only by force of the field relations, but also of the petrographic characters. There is no independent space which seems to have been occupied originally and wholly by the acid elements, but these are simply insinuated amongst the basic elements after the practical formation of the basic minerals. The transformation must have taken place while the mass and the adjoining rocks were yet hot, and were easily penetrated by liquids and gases. The rock, therefore, is to be considered as a silicified selvedge of a basic intrusive or flow-sheet. This, of course, brings up the question: How much of this red-rock series can be attributed to the same origin? and may not rock No. 526 (the red "granite" of Beaver bay) be assigned to this origin, rather than to the consolidation of an acid magma? In this connection comparison may be made with the descriptions of rocks Nos. 263 and 265, Wauswaugoning bay, and with much of the so-called "intermediate rock" of Bayley. (Bulletin cix, U. S. Geol. Survey.) N. H. W.

No. 532. APORHYOLYTE. *(Breccia in diabase.)*

"Reddish, and sometimes greenish, trap-like rock, surrounding or embracing pieces of the feldspar at Beaver bay. This rock is similar to rock No. 526, at least in some of its parts. The feldspar masses have the appearance of having been carried in this rock, or to have been *in situ* when it was deposited as a sedimentary rock, and subsequently to have suffered the metamorphosing forces with it."

Ref. Annual Report, ix, page 33; Annual Report, x, page 41.

Meg. The rock is dark, brownish-gray in color, is aphanitic, and contains a few small porphyritic quartzes and feldspars. It appears macroscopically like a dark quartz-porphyry or aporhyolyte. The peculiar feature of this rock is that it contains many pieces of a nearly similar but more quartzose and flesh-colored or reddish rock. These pieces are firmly welded to the main rock and in some places no very sharp line can be drawn between the two rocks as they blend together. The included pieces are quartz-porphyry or aporhyolyte.

Mic. The section is a small one and is assumed to have been made from the main mass of the rock, although it may have been taken from one of the included masses. The section shows a groundmass composed of the usual devitrified material of the aporhyolytes—of semi-opaque, isotropic feldspathic grains and areas of poikilitic *quartz.* In a thinner section the feldspars are microlitic and frequently in spherulitic arrangement. The other half of the same slide has the feldspars in a diabasic or radiated arrangement, and lacks the quartzes. There are a few small quartz phenocrysts, not distinctly idiomorphic, and some confused areas composed of cloudy material, *quartz*, *chlorite* and iron ores, which seem to represent completely altered *feldspars.* Several of the quartz crystals are separated into several parts, similar to the corroded quartzes of many quartz-porphyries. The section shows small dark rod-like bodies which are composed of chlorite and granules of iron ore. *Hematite* and *magnetite* in small granules and crystals are abundant throughout the rock, and there are also flakes of *chlorite* and a few flakes of *biotite.*

One section.

Age. From the Beaver Bay diabase. U. S. G.

Remark. This rock has complicated and interesting relations. That it is more recent than the great amorthosyte and than the red rock pieces that it carries, goes without saying, but it is not to be inferred that they were separated by important geologic events. They were, as supposed, involved in the same grand eruptive epoch. The abundance of genuine quartz-porphyry pieces shows the near proximity of the great Cabotian quartz-porphyry formation, and it is perhaps most reasonable to refer this rock to the fusion and incorporation in a basic flow, of Cabotian acid eruptives. Thus its abnormal features may be due to almost cotemporary eruptions of differing degrees of basicity. A casual glance might lead an observer to take it for a brown diabase. It is a phase of the Beaver Bay diabase, due to the inclusion but not complete digestion of numerous fine pieces of the red rock series. The great diabase of the region thus seems to have played a multiple rôle, as it acted now on anorthosyte, now on Cabotian quartz-porphyry, now on Cabotian diabases and amygdaloids* and now on clastic strata, all of which seem to have pre-existed in the

*Mr. Elftman is authority for the statement that in the midst of the great diabase sheet of the Beaver Bay region are detached pieces of fine diabase and of amygdaloid. These are doubtless from the old Cabotian surface flows.

region. It certainly produced in a belt of varying width and volume an intermediate rock (No. 531) caused by the reaction of the acid element on the diabase itself. This diabase and its geognostic relations are more fully treated in Part I, of this volnme.

N. H. W.

No. 533. Aporhyolyte.

"Rock of the Great Palisades. (Compare No. 139.)"
Ref. Annual Report, x, page 41.

Meg. A reddish-brown rock, hard, compact and aphanitic. It is thickly strewn with small phenocrysts of quartz and a gray to pinkish feldspar.

Mic. The section contains two quartz phenocrysts and one small *feldspar* in a groundmass which shows poikilitic *quartz* areas of considerable size. The section furnishes an excellent example of these poikilitic quartzes in a devitrified rhyolite. (Compare No. 68.) *Magnetite* and much *hematite* are present in minute particles throughout the rock, and also in larger grains. A feature of the section is a small quartz vein which crosses it and which cuts directly through one of the quartz phenocrysts. In this crystal the vein is cloudy, but the quartz deposited in the vein has the same orientation as the phenocryst. Another section, made later, shows essentially the same features.

Two sections.

Age. Cabotian. U. S. G.

No. 534. Conglomerate. *(Red.)*

At one mile east of Manitou river. The same is seen at the mouth of Manitou river.
Ref. Annual Report, x, page 42.

Meg. Easily crumbling, the cement being principally of calcite. Some of the pebbles are about an inch in diameter, and from that size they grade downward to mere sand, yet the whole mass is composed of eruptive materials, of which the most of it was originally porous. It appears to have been produced entirely by waste from an amygdaloidal lava.

No section.

Age. Potsdam. N. H. W.

No. 535. Diabase. *(Mesolite, scolescite* and thomsonite amygdaloid.)*

Terrace point. (See Nos. 163A and 193.)
Ref. Annual Report, ix, page 51; Annual Report, x, page 42; American Geologist, vol. xxii, page 347, December, 1898.

Meg. Amygdaloidal diabase, containing many zeolites which have been widely distributed as thomsonite.

Mic. A fine large section made by Marchand shows the nature of this rock in a beautiful manner. As a whole the rock is ophitic and amygdaloidal, but the small

*If, according to Dana, this name is derived from σκωληξ, the proper spelling is neither scolecite, preferred by him, nor scolesite, used by Lacroix, but scolescite, the letter ξ being derived from a Doric composition of σκ.

feldspars are much changed by a kaolinic alteration and apparently sometimes this promoted the formation of thomsonite in the immediate vicinity. In such a case the fibres of thomsonite are vertical to the elongation of the feldspars. In the augites are embraced sometimes ten or twenty of such altered microliths.

The olivines which are small are also changed largely to *bowlingite*, which sometimes is faintly greenish, but is usually of a dark red or orange red.

The zeolites constitute the most interesting element in the rock. They are of two kinds which optically are quite distinct, inasmuch as one is almost dark constantly between crossed nicols, and the other is translucent. They are both radiately fibrous, but the former is more fine and more regular in its structure. These are for the most part in separate amygdaloidal masses or areas, but occasionally they are seen in the same mass, where they are contrasted in the same manner, though intimately intergrown. The coarsely fibrous zeolite is easily identified as thomsonite. It is elongated both negatively and positively, and extinguishes parallel to the elongation. The finer zeolite is that which has usually been distributed under the name of thomsonite. It has a parallel extinction which may be observed by a faint increase of its darkness when in agreement with either nicol. Its section, viewed macroscopically, is white, in the slide. It is probably a soda zeolite, *i. e.*, a form of the natrolite group of Dana. These zeolites are discriminated under Nos. 535A and 535B.

Besides the foregoing, *scolescite* forms rounded amygdules in the same rock. Outwardly they resemble *thomsonite* except that so far as noticed this mineral does not grow into such large masses as thomsonite, but forms small round balls. It is not iron-stained in pinkish bands, like mesolite, but is clear and glassy white. When mesolite is white it is porcellanous. Under the microscope the section of scolescite shows negative elongation and low double refraction, characters that distinguish it from thomsonite.

Lintonite is green outwardly, very fine and hard, and seems to grow in small rosettes in the mesolite and in larger independent masses.

Two sections.

Age. Manitou. N. H. W.

Nos. 535A and 535B. Mesolite and Thomsonite.

There were made nine thin sections of the zeolites from the amygdaloid No. 535, intended to bring to light the characters of the beautiful mineral which has been widely distributed under the name thomsonite, and several sections of the species lintonite, all bearing this number. These minerals are also enumerated under other numbers (Nos. 163A, 193 625A, 625B) and by reference to those numbers further facts may be found. These sections and others made of the same zeolite from other places on the north shore of lake Superior, from the same series of diabase sheets, show plainly the close intermixture of two zeolites, mesolite and thomsonite, the former being more abundant than the latter.

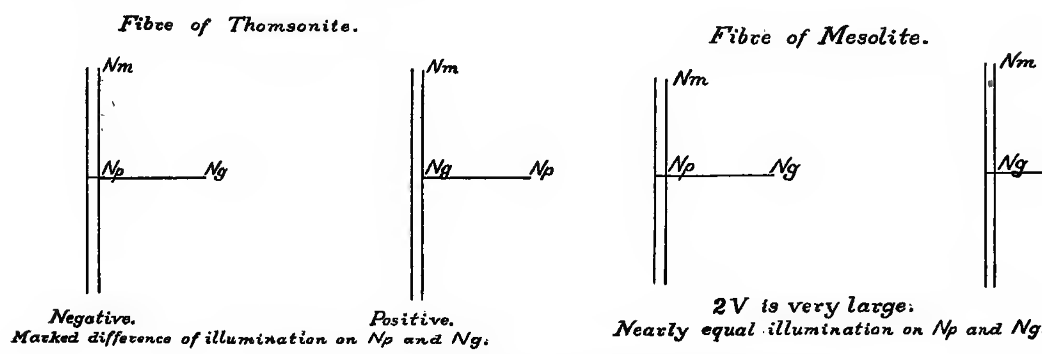

FIG. 23. DIAGNOSTIC OF THOMSONITE AND MESOLITE.

The concentric growth, shown by the eyelets seen on the exterior of the beach-worn pebbles, is evinced in the thin section by concentric bands of varying colors. These bands vary in composition as well as in fineness of fibre, sometimes fading gradually into each other, and sometimes changing rather abruptly.

Of the specimens chosen the following notes were taken prior to the making of the sections:

(a) No. 535. Amygdaloidal rock, containing small zeolitic spherules supposed to be thomsonite.
(b) No. 535A. Coarsely fibrous zeolite, possibly stilbite, from the rock.
(c) No. 535A. Supposed thomsonite, two sections, from the rock.
(d) No. 535A. Supposed thomsonite.
(e) No. 535B. Supposed thomsonite, from the beach, with some of the rock, two sections.
(f) No. 535B. Supposed lintonite, from the beach, with some of the rock.
(g) No. 535B. Supposed thomsonite, from the beach, pyramidal form, very common.

Of these the following results were reached after petrographic and micro-chemical investigation, viz.:

(a) The amygdaloidal rock (a) contains only thomsonite as zeolitic filling.
(b) Composed of thomsonite.
(c) Composed of mesolite banded with minute fibres of thomsonite; specimens are quite similar.
(d) Composed of mesolite banded with minute fibres of thomsonite.
(e) Mesolite, with spheruliths in the rock and in the mesolite surrounded by another undetermined mineral which seems to be gonnardite, as described by Lacroix (Minéralogie de France, vol. ii, page 279), and also to resemble lintonite.
(f) Is not homogeneous, but consists largely of some amphibole, hardly dichroic, of zoisite, sphene and of some other undetermined fine-grained substances.
(g) Proves to be mesolite.

Of these numbers c, d and g represent the variegated and banded pebbles which are credited, in recent publications, to Grand Marais, as thomsonite, particularly c and d; while the pebbles that are actually of thomsonite are usually not chosen for their beauty and are coarse-grained and non-banded.

Thomsonite and mesolite have not only similar chemical composition, but similar optical properties. Yet in two important particulars their characters are so different, under the microscope, that they are easily distinguished. In general also it can be said that the fibres of thomsonite are coarse and irregular compared to those of mesolite, which are fine, rigid and straight. The distinguishing difference, however, is in the low double refraction of mesolite (about 0.012) compared with the rather high double refraction of thomsonsite (about 0.028). Consequently in an ordinary section of the former the fibres are all uncolored in whatever position they are cut and in some very thin sections they are almost isotropic between the nicols, at least invisible. In thomsonite, however, the fibres show variations of color, and as they are cut more and more obliquely their colors rise until, in a section nearly or quite transverse to their length, the colors are red, blue or green. The color is green in such a section when it is 0.03 millimeter in thickness, and blue or red when slightly less than 0.03 millimeter.

The variations of light and darkness in a mesolite section or in a lot of fibres mounted in balsam by themselves, are quite small. This is owing to the fact that the optic angle being large and the optic plane perpendicular to the fibres (or sensibly perpendicular), the sides of the fibres always present n_p or n_g (or some intermediate pole) in the field of the microscope, and the amount of light capable of passing parallel to n_g is nearly the same as parallel to n_p. It is not so with thomsonite. The optic plane, situated transverse to the fibres as in mesolite, causes some of the fibres to show n_p and n_g in the same manner as in mesolite. But in thomsonite the optic angle is small, and the sections perpendicular to the acute bisectrix n_g are much darker than those perpendicular to the obtuse n_p. In a longitudinal section, in the midst of a lot of dark fibres (n_g) may run parallel a lot of brightly illuminated ones (n_p), the contrast being very striking. It is only necessary to apply the convergent lens when it is quickly seen that they only differ in being perpendicular to different axes of elasticity. Such light fibres are scattered, in some cases, amongst the dark ones, and, in finer and finer lines which also become shorter in the finer portions of the slide, they make a network of light and dark fibres, sometimes parallel the one to the other, and sometimes at right angles. These differences are visible in No. 535A(b) above enumerated.

It will be shown (No. 625B) that in the amygdaloids containing these two zeolites they are sometimes in the same vacuole, the thomsonite being pierced by the needles of mesolite, and somewhat later in date than the mesolite. It appears, by this series of sections that in many cases the two were generated simultaneously. This is shown by some of the bands of the handsome mesolite pebbles. In thin section some of these bands are wholly of white mesolite, and uniformly they are marked by the low tints of the gray of the first order, but, toward the exterior of the band, suddenly begin to appear bright spicules which pierce the darkness of the mesolite. These are thomsonsite fibres cut so as to present the obtuse bisectrix n_p perpendicular in the microscope. Those which are cut so as to present n_g are so nearly dark that they cannot be distinguished from the surrounding fibres of mesolite. Nor indeed can it be stated that the next succeeding band consists wholly or only partly of thomsonite. These very fine bright fibres are distributed through it. They are always negative in elongation. It has to be assumed that they are associated with about an equal number that are cut so as to present n_g perpendicular, but these cannot be distinguished. That the whole band is not of thomsonite is probable from the fact that, on tracing the fibres toward their converging point, while the bright fibres disappear, there are some fibres which are cut transverse to their elongation. Their sections are quadrilateral and their color of double refraction is low—even lower than that of the bright needles of thomsonite. They must be therefore of mesolite, for a similar section of thomsonite would show, as already stated, a color either red, blue or green.

It is hence allowable to infer that mesolite and thomsonite are closely intergrown throughout the band in which there are occasionally the bright needles which have always negative elongation.

In none of the sections is there a band made up wholly of thomsonite in the midst of mesolite bands.

That these bright needles are of thomsonite and not of mesolite is evinced by the fact that they occur sometimes in the midst of a coarser mesh of mesolite fibres which of themselves show slight difference of light, indicating that they lie sometimes in a position to show n_p and sometimes n_g perpendicular.

A green pebble having this number, collected as lintonite, proves to be not homogeneous, but consists largely of fragments or imperfect crystals of an *amphibole* mingled with *zoisite* and some *sphene*, with other indeterminate substances. N. H. W.

NO. 535B. LINTONITE, MESOLITE, OKENITE (?)

An unfavorably thick section shows the first two of these zeolites distinctly, but in the same mass as the mesolite the mesolite fibres which are negative in elongation are replaced in the direction toward the apex of the fibration by an entirely different mineral which, with much coarser fibres, parallel extinction and low double refraction, thus resembling scolescite, has a positive elongation, a combination of characters which would allow of its being *okenite*. Without chemical test, however, this is only a provisional determination.

One section. N. H. W.

NO. 536. DIABASE. *(Gabbroid.)*

From the basaltic columns at Grand Marais (see No. 199).
Ref. Annual Report, x, page 43.

Meg. A brownish rock of medium grain, standing in vertical columns, in a manner similar to the rock at Little Marais, forming the barrier that encloses the harbor of Grand Marais.

Mic. The *feldspar* shows its *plagioclastic* character in many striations of albite twinning. The *augite* is both earlier and later than the feldspars. The earlier crystals, which are the most abundant, are small, and interfere with the outlines of the feldspars, but the later are fresher and embrace several of the feldspars ophitically. But two or three augites of this later date can be seen in the two sections examined. They are much larger than the earlier augites. The *olivine* is for the most part altered to a yellowish brown mineral which represents *bowlingite*, although most of it is not perfectly developed as bowlingite. Olivine was generated before the feldspar, but later than the augite. *Magnetite* in small amount and a small quantity of the magmatic residuum may be seen in the slide.

Two sections.

Age. Cabotian. N. H. W.

No. 537. Diabase. *(Luster-mottled.)*

West side of Cow's Tongue point; S. W. ¼ sec. 10, T. 61–2 E.; same as No. 211.
Ref. Annual Report, x, page 43.

Meg. A fine-grained, brownish diabasic rock showing, especially on weathered surfaces, luster-mottling.

Mic. The section shows small feldspar laths embedded in augite plates and in a dark opaque mass which is almost entirely hematite and magnetite. The iron ores fill in the spaces between the augite plates.

One section.

Age. Cabotian. U. S. G.

No. 538. Aporhyolyte.

The first rock in the bay east of Cow's Tongue point.
Ref. Annual Report, x, page 43.

Meg. This rock, both macroscopically and microscopically, is similar to No. 212, which is from the same locality.

One section.

Age. Cabotian. U. S. G.

No. 539. Basalt.

Short distance west of the mouth of Brulé river (see No. 220).
Ref. Annual Report, ix, page 56; Annual Report, x, page 43.

Meg. Brown, rather fine grained, with small irregular shaped mottlings of green.

Mic. The interstitial matter is a brown devitrified glass, which embraces now the feldspars and the augites, as well as certain altered ferruginous crystals that were probably olivine originally. It also contains many crystalliths and opaque grains, the latter probably of magnetite. The green spots are formed by irregular aggregations of a chloritic mineral which between crossed nicols shows a fibro-lamellar structure without affording distinct polarization.

One section.

Age. An old Cabotian surface flow. N. H. W.

No. 540. BASALT. *(Coarse.)*

A mile and a half east of the mouth of Brulé river (see No. 221).
Ref. Annual Report, ix, pages 57, 61; Annual Report, x, pages 43, 44, 45, 47; Bulletin ii, page 103.

Meg. A rather coarse, brownish-gray rock, composed of feldspar, which is sometimes in long striated crystals, and a shining black material which is often in long streams.

Mic. The section is composed largely of *feldspar* in tabular, rarely lath-shaped crystals of considerable size, and of less *augite* in grains which appear to be a little earlier than, or of about the same date as the feldspars. The feldspars show a tendency to an idiomorphic development, and thus give the section a porphyritic aspect. Twinning, both by the albite and pericline laws, is common. A determination of the feldspar by equal extinction angles on either side of the twinning line was unsatisfactory, owing to a lack of sections with the proper orientation. However, five crystals furnishing bisectrices were found, and these gave very similar results. Two sections having a positive bisectrix exactly perpendicular gave extinction angles of 8° and 9° respectively; while three sections cut almost perpendicular to a negative bisectrix gave extinction angles of 66°, 67° and 69° respectively. In the last three the bisectrix was removed only a little from the centre of the field of vision, but was well within this field. These results all agree in indicating that the feldspar is *andesine.*

Scattered all through the section outside of the large feldspars and augites, and penetrating the cracks, is a dirty yellowish brown, sometimes greenish material, which contains small feldspar microliths and a few small augite grains. Considerable of this material seems to be an alteration product from a former unindividualized base, but much of it still appears to be glassy areas of considerable size remaining perfectly black when rotated under crossed nicols. With this glassy material is some secondary *quartz*, and *apatite* and *magnetite* are common.

One section.

Age. Cabotian.

Remarks. There are two peculiar features in this section. The first is that the feldspar is *andesine* rather than labradorite, the usual feldspar of the basic Cabotian and Manitou rocks thus far examined. The second is that considerable unindividualized material, which is still glassy, is present. This rock is perhaps a part of the same mass as that represented by Nos. 221 and 223. U. S. G.

No. 541. Basalt. *(Zirkelyte.)*

Grand Portage island. A dike ten feet wide cuts the quartzyte and conglomerate, running E. 10° N. by needle, without displacing the bedding.
Ref. Annual Report, x, pages 45, 46.

Meg. Very fine-grained, nearly black.

Mic. The rock is fresh and undecayed. The *glassy residuum* is not abundant, but clear, although it embraces some *magnetite* rods and some polarizing crystalliths. The *augite* is in fine, isolated, roundish grains that antedate the feldspar for the most part, but which are occasionally broken by the feldspar, showing that these minerals were nearly cotemporaneous.

One section.

Age. Manitou. N. H. W.

No. 542. Diabase *(with olivine).*

Grand Portage island; on the east side of the island this is basaltic, rising about twelve feet. Stratigraphically it is the highest rock on the island, having a thickness of fourteen feet.
Ref. Annual Report, x, pages 45, 46, 47.

Meg. A gray, rather coarse-grained rock.

Mic. The *feldspars* are ophitically related to the *augite.* The *olivine* is rather fresh. There is a residuum of brownish substance, evidently non-differentiated base.

One section.

Age. Manitou. N. H. W.

No. 543. Basalt. *(Zirkelyte.)*

Grand Portage island. Immediately underlies the last, having a thickness that may be twenty feet.
Ref. Annual Report, x, pages 45, 46, 47.

Meg. The rock is amygdaloidal with light blue chalcedony (or with quartzine) and with calcite.

Mic. The *feldspar* is partly ophitic in the augite and partly later than the *augite.* It is also similarly surrounded by the *basaltic residuum.* Olivine is rather fresh, but not abundant. The basaltic residuum has changed partly to a brown substance in which some small feldspars and occasionally *apatite* are visible, and partly to minutely microlitic substance, in which the microliths are not spicular but round, and polarize like *mica.* They are densely packed. This kind of alteration is occasionally mingled with the brownish or greenish product already mentioned, but in several conspicuous areas it surrounds in narrow belts a greenish fibrous substance whose spicules are spherulitically placed, but which does not easily transmit light. The nature of this greenish fibrous substance is not determined, but it may be *thalite,* as its hardness is about the same as *saponite,* of which thalite is a form.

One section.

Age. Manitou. N. H. W.

No. 544. Basalt. (*Zirkelyte, globuliferous.*)

Grand Portage island. In a belt crossing the island east and west, but probably only a phase of rock No. 545. It is the last to run under the water at the west end, and at the east end it is the topmost rock in the bluff. Its thickness may be twenty feet.

Ref. Annual Report, x, page 45.

Meg. A curious, dark globuliferous trap-rock, disintegrating readily, the hard globules, which are of stony structure (not minerals), and nearly black, rolling out like shot, or bullets, and covering the ground after the rest of the rock is rotted to a greenish soil. The rock itself is chloritic and dark green.

Mic. The rock was consolidated before it crystallized. As a consequence there is a large amount of undifferentiated magma, which, however, is devitrified. It now embraces handsome spangles of *magnetite,* which is the only determinable mineral connected with the magma remnants. Other spaces of exceedingly irregular outline are filled with a pale yellowish, fibrous alteration mineral that resembles *thalite.* The most of the rock itself consists of small *augite* crystals or fragments of crystals, generally granular and sub-rounded, but not entirely so. Amongst these are a few fine *plagioclases,* and occasionally in the centre of a lot of alteration products is a little *quartz.* These, with considerable *calcite,* make up the rock.

Five sections.

Age. Manitou. N. H. W.

No. 545. Basalt.

"A bed of fibrous green trap, passing through the centre of the island [Grand Portage] and forming its highest parts, and also producing a long sloping beach on the southeast side running under the chalcedonic amygdaloid [No. 543]. In the centre of the island it appears like a burnt scoria or slag, due, perhaps, to the effect of Nos. 543 and 542, though these have been removed in the central part of the island, appearing now only along the south and southwest shores."

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

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

Mic. The section is composed largely of small, thickly crowded *augite* prisms. With these are numerous small *magnetite* crystals. These two minerals are set in a sparse background of *feldspar.* This is in comparatively small areas of later date than the other minerals and enclosing them poikilitically. The different feldspar areas are not sharply separated from each other; they infrequently show twinning, and their species was not determined. Scattered through the section are many green to yellow areas composed of a mineral in minute scales (serpentine). Some of these areas possibly represent old *olivine* phenocrysts, but many of them seem to be rather an altered part of the rock,—possibly originally glassy.

Two sections.

Age. Manitou. U. S. G.

No. 546. Sandstone *(or arkose)*.

Grand Portage island. Eight feet thick.
Ref. Annual Report, x, pages 46, 47. (Compare No. 256.)

Meg. A very fine-grained, purplish gray sandstone. Along one edge of the specimen is a band, about half an inch wide as far as shown, of an ashen gray color. This band seems to be of the same grain and composition as the rest of the rock.

Mic. The section is composed of small grains of *quartz* and *feldspar*, with a small amount of yellowish brown material between some of the grains. The grains are rounded or sub-angular and are closely crowded together. Some of the quartz grains show secondary enlargements and it seems probable that many more than show this feature distinctly have also been enlarged. The *feldspar* is largely cloudy and probably *orthoclase*, although a few *plagioclase* and less *microcline* grains are seen.

One section.

Age. Potsdam. U. S. G.

No. 547. Basalt. *(Zirkelyte.)*

Grand Portage Island. A bed of trap. This is sometimes brecciated or finely and irregularly jointed, with white nodules of saccharoidal calcite. Resembles rock No. 541. Probably an intrusive, thirty-six feet thick.
Ref. Annual Report, x, pages 46, 47.

Meg. Heavy, fine grained, nearly black.

Mic. The slide is characterized by porphyritically distributed small *augites*, lying in a *glassy* and microlitic base. The augites are somewhat radially grouped, as if twinned on one of the domes. There is but little of the non-crystallized magma. *Magnetite* in small cubes is frequent. Some microlitic feldspar and considerable *calcite*, with pale yellowish areas of a very finely fibrous alteration mineral, which is the same as mentioned in No. 544 as possibly *thalite*, are the only noteworthy features. The rock is similar to No. 544.

Two sections.

Age. Manitou. N. H. W.

No. 548. Quartzyte.

Grand Portage island. Five feet thick. (Compare No. 256.)
Ref. Annual Report, x, pages 46, 47, 48.

Meg. Sometimes with mica scales between the beds, of a dark color, but generally striped with brown-red, with thin laminations. In some parts it is gray.

Mic. The rock is composed of angular *quartzes* and *feldspars*, some of the latter being of *plagioclase*, and of devitrified *glass*, the last constituting about one-half. Other substances are present, but it is not possible to determine them, except *hematite* and *calcite*. There are some light-brown grains that may be of *augite*.

One section.

Age. Potsdam.

Remark. This ingredient of volcanic glass in this rock, indicates that it is not probably at nor near the base of the Animikie, for no such rock could be obtained in such quantities from the Archean. That had been completely crystallized before the opening of the Animikie. This rock, therefore, and the formation to which it belongs, carrying with it the underlying basal conglomerate, seems to be later than some Cabotian eruptives, and hence is probably nearer the bottom of the Potsdam. The only explanation of a possibly Animikie age would be the presumption of cotemporary volcanic action in early Animikie time by which such materials could be incorporated; but that presumption again is just as reasonable at the time of the earlier part of the Potsdam, and is negatived by the red rock material found in the underlying conglomerate which is a product of the Cabotian disturbance. N. H. W.

NO. 549. CONGLOMERATE. *(Breccia?)*

Grand Portage island. The cementing rock is a quartzyte or grit like No. 548, but coarser. Sixteen feet in thickness.

Ref. Annual Report, x, pages 46, 47.

Meg. The rock is a gray conglomerate, of rather coarse pebbles. The preponderating element is clear quartz, or gray quartzyte. In the case of the gray quartzyte the pieces are flat, slaty and firm, and can be referred directly to the quartzyte slates of the Animikie, which rises in the adjacent hills of Grand Portage to the hight of three or four hundred feet above the level of the lake. The rest of this conglomerate consists largely of finer debris of the same kind, but also contains numerous pebbles of red quartz-porphyry, red felsyte and red granite. This can also all be referred to the hills at Grand Portage.

Mic. The thin section not only confirms the megascopic appearance, but adds some interesting other facts, viz.: There is a considerable ingredient of originally volcanic material amongst the debris. This is in the form not only of devitrified glass grains, but of porphyry pebbles in which the feldspar crystals are still apparent by their forms, although their optical properties are lost by a profound change that has affected the conglomerate. In short, the conglomerate seems to have been formed subsequent to the origination, in that neighborhood, of acid lava flows and quartz-porphyries.

Another fact which is vividly revealed by the thin section is the calcification of the rock, and of all the elements of which it is composed except the quartz. The pebbles of igneous rock, and the porphyritic feldspars contained in them, are so permeated by calcite and so changed to kaolinic particles that they cannot be identified except by their structure and relations to surrounding portions. The feldspars do not extinguish, but present ever a lightness which is flecked with light and dark particles which under rotation shift and disappear and return again, making a constantly varying fine mosaic. Two sections.

Age. Puckwunge (basal Potsdam).

Remark. The greatly altered condition of the silicates in this conglomerate can be attributed to hot waters that resulted from the immediately succeeding surface lavas which were cotemporary with the formation in which they occur, and which are entirely distinct structurally from the intrusives. N. H. W.

No. 550. Diabase.

Grand Portage island. From a dike, thirty-four feet wide, cutting the quartzyte and conglomerate, near No. 541.

Ref. Annual Report, x, page 46.

Meg. A medium-grained, dark-gray diabasic rock. It contains some plagioclase crystals considerably larger than the most of the feldspars, thus giving a porphyritic aspect to the rock.

Mic. The section shows a much changed rock filled with confused dirty alteration products which are usually brownish. *Plagioclase* and *augite* are pretty well preserved, and it seem possible that *olivine*, as well as unindividualized matter, was originally present.

One section.

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

No. 551. Diabase *(or basalt)*.

From a dike crossing the southeast corner of Grand Portage island.

Ref. Annual Report, x, pages 46, 94, 112.

Meg. Medium-grained, dark-gray, heavy diabase.

Mic. The section shows lath-shaped *feldspars*, *augite*, *magnetite* and a confused mass of dirty, greenish alteration products. The feldspar shows equal extinction angles on either side of the albite twinning line as high as 25°, indicating *labradorite*. The augite is in grains rather than in plates and some of it is earlier than, or of about the same date as, the feldspar, while some is later than the feldspar. Magnetite, especially in rough rod-like forms, is abundant. There are also some areas which seem to represent altered *olivines*. It seems probable that some of the areas of alteration products came from an unindividualized base.

One section.

Age. Manitou(?)

Remarks. This rock is said to constitute a dike which crosses the southeast corner of the island. It is thus later than and cuts the igneous beds of this part of the island. The conglomerate and quartzyte do not occur on this part of the island.

Leaving out of consideration the actual age of the rocks of Grand Portage island and their relations to the rocks of the adjacent main land, it may be said that this island *appears* to hold three different rock masses, which may be arranged *provision-*

ally as follows: (1) The oldest of these is the conglomerate and quartzyte (or sandstone) represented by Nos. 254, 256, 546, 548, 549, 1831, 1832 and 1833. It is stratigraphically the lowest rock on the island and occurs only on its north or north-east side. (2) Overlying the conglomerate and quartzyte are certain igneous rocks which are in part, and probably in whole, surface flows. These are later than the underlying clastics, although it is possible that the lower part of these flows is interbedded with the clastics and thus cotemporary with them. These igneous rocks are represented by Nos. 255, 543, 544, 545, 547, 1834 and 1834A. (3) A later series of diabase dikes cutting both of the foregoing. These dikes are represented by Nos. 541, 542, 550 and 551. U. S. G.

NO. 552. QUARTZYTE. *(Plumbaginous.)*

Pigeon point, near the trail to Parkerville; sec. 32, T. 64–7 (see No. 270).
Ref. Annual Report, ix, page 65; Annual Report, x, pages 48, 58; Bulletin vi, pages 123, 420.

Meg. Quartz plainly constitutes the greater portion of this rock, but it is obscured by the colored elements. The graphite forms a metallic unctuous coating. The general aspect is black.

Mic. The *quartz* is secondary, separated areas extinguish simultaneously and the forms are angular.

Feldspar crystals are generally not observable, but in one case a striated feldspar of the first consolidation is well preserved, and some of the microliths can also be identified.

Sphene can be seen in numerous isolated highly polarizing grains and rods of irregular shape and strongly roughened surface on lowering the condenser. In reflected light it is opaque white.

Calcite also is not uncommon, the little roughness of the surface, visible on lowering the condenser, being sufficient to produce a minutely speckled polarization, the colors, even in a thin section (.02 millimeter), being red, blue, yellow, etc.

One or two grains of *zircon* are distinguishable by reason of bright green polarization in a very thin section, and rectangular outlines.

Several rods also highly doubly refracting and refractive, are probably *rutile.*

Pennine and *biotite* are abundant, and closely associated, the former showing its characteristic halos, and the latter varying to a translucent mica which polarizes in colors.

Graphite blackens the rock and the section, sharing this in a small degree, however, with *pyrite* and perhaps with magnetite. Two sections.

Age. Animikie(?)

Remark. This rock apparently is changed from the basic eruptives of the region by contact on the sedimentary rocks adjacent.

In another section, the rock, though bearing this number, is a granular quartzyte, with but little else besides quartz. Scatteringly disseminated are a few nests of biotite scales, somewhat radiatedly arranged and associated with chlorite. There are also a few spicules of magnetite.

The rock represented by this section is very certainly a condition of the quartzyte of the locality. N. H. W.

No. 553. Quartzyte.

Near the portage trail to Parkerville, at the north shore of Pigeon point.
Ref. Annual Report, x, page 48.

Meg. Firm, gray quartzyte.

Mic. The section consists essentially of angular and sub-rounded grains, lying in a matrix which consists of finer grains of the same, and of particles that are finely granular, as if from a composite rock. The latter are not so transparent, and often quite cloudy with a chloritic substance, and between crossed nicols remain nearly dark continually. They have a deceptive resemblance to devitrified glass.

One section.

Age. Animikie(?) N. H. W.

No. 554. Diabase.

From the east end of the most easterly island separating Washington harbor from Grace harbor, Isle Royale. It has somewhat the appearance of an imperfectly basaltic dike, but as it develops a few rods further north it appears as an overflow; at least it lies on other trap and amygdaloid. It forms a little harbor where fishing shanties are erected.
Ref. Annual Report, x, page 48.

Meg. A dark-brownish, fine-grained diabase. Scattered through the rock are small greenish areas (chlorite) and also reddish ones. To the latter is due the brownish cast of the rock.

Mic. The section shows a diabase composed of *feldspar*, *augite* and *magnetite.* The whole rock is much changed and now contains abundant dirty greenish and reddish alteration products. Part of these products are due to the change of the feldspar and augite, but it seems as if some of the reddish material was from an original glassy base.

One section.

Age. Cabotian. U. S. G.

No. 555. Sandstone. *(Red.)*

Isle Royale. Overlies the conglomerate of the west end of Isle Royale. Resembles No. 548 of Grand Portage island. Has regular bedding, with strata sometimes thirty inches thick, extends for several miles, making islands and points. Specimen is from Siskiwit point; dip 10° to 20° S.; apparently has a thickness of 300 or 400 feet. A gritty shale separates the quartzyte from the conglomerate.
Ref. Annual Report, x, page 49; Annual Report, xiii, pages 100 (No. 165) 103; Bulletin viii, page xxxiii.

Meg. Red, smoothly-weathering sandstone, which might be called a quartzyte.

Mic. The section contains not only *quartz* but considerable devitrified *glass*. The grains are not well rounded. The *hematite* coloring is evident.

One section.

Age. Potsdam. N. H. W.

NO. 556. SANDSTONE. *(Red, shaly.)*

South shore of Siskiwit bay, Isle Royale.
Ref. Annual Report, x, page 50.

Meg. A brick-red rock, fine grained, but holding small pebbles, all of which are reddened and many of which are hard and siliceous. The rock effervesces slightly in acid, showing the presence of some calcite.

No section.

Age. Potsdam. U. S. G.

NO. 557. CONGLOMERATE *(with copper)*.

"Cupriferous conglomerate, from the Island mine, Isle Royale, near the head of Siskiwit bay. This is also argentiferous."
Ref. Annual Report, x, page 50.

Meg. A coarse, red conglomerate. The pebbles are usually pretty well rounded and are of all sizes from very minute ones to those an inch or more in diameter; in fact the whole rock is largely composed of these pebbles, there being comparatively little siliceous cement. There is also calcite cement, and some native copper, although the hand specimen does not show the latter clearly. The pebbles are all red and in general can be said to be felsytes. Many of them are porphyritic with feldspars and resemble devitrified glassy rocks.

No section.

Age. Potsdam; probably the Puckwunge conglomerate.

Remarks. This rock is similar to the copper-bearing conglomerates on Keweenaw point, and also to No. 155. U. S. G.

NO. 558. DIABASE *(with olivine)*.

Near the stamping mill of the Island Mine, Isle Royale. Near the creek coming through the location [This mine is north from the head of Siskiwit bay, and perhaps 200 feet above the lake.]
Ref. Annual Report, x, pages 50, 51.

Meg. Gray, with lustre-mottled spots, medium grained; not a fresh rock.

Mic. The rock is ophitic, and the olivines are altered to a greenish substance, surrounded by much magnetite.

Two sections.

Age. Cabotian(?) N. H. W.

No. 558A. Thomsonite.

From cavities in No. 558.
Ref. Annual Report, x, page 50.

Meg. This mineral is light lilac gray, or a pinkish white or white, with a hardness 5 or 6. Its structure is massive, or fibrous and divergent, the rays becoming separated, acicular orthorhombic crystals. Some of the masses are two inches, or more, in diameter.

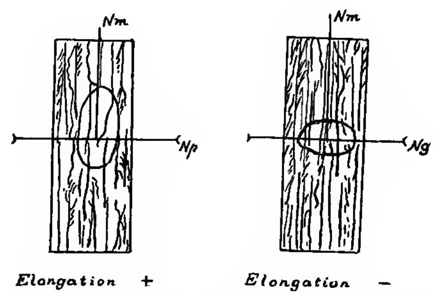

FIG. 24. ORIENTATION OF THE FIBRES OF THOMSONITE.

Mic. The structure is divergently fibrous, the fibres having both positive and negative elongation and a parallel extinction. The axial plane is perpendicular to the fibres. In a section of a lot of fibres showing n_g vertical, the axial angle is so small that the hyperbolas do not leave the field of the microscope. The double refraction is rather high, the fibres that are cut obliquely to n_m giving colors of blue and even green. The highest color (for the thickness of the section, which is about 0.03 millimeter) would be the second yellow, found in fibres cut perpendicular to their elongation. But few if any such appear in the slide. The fibres are coarse, compared to the zeolites which have passed as thomsonite for several years, derived from the vicinity of Grand Marais. They are not straight and rigid, but somewhat alternating and fluxuous, with a feathery structure often prevalent. Figures above show the position of the axes of elasticity and the cleavage.

One section.

Age. Cabotian(?) N. H. W.

No. 558B. Epidote and Calcite.

Veins in No. 558.
Ref. Annual Report, x, page 51.

In this green *epidote* is a little metallic *copper*. The *calcite* is in scattered nests.

No section.

Age. Cabotian(?) N. H. W.

No. 559. Diabase *(with olivine)*.

Immediately overlies the cupriferous conglomerate of the Island mine.

Meg. A much-rotted, gray, medium-grained rock.

Mic. This rock has the same characters as No. 558, of which it is probably a portion. This, however, contains, in the hand specimen, no amygdaloidal structure, but it is permeated with a serpentinous, greenish mineral whose hardness is about 2 or 3. This is yellowish-green in small masses, but is dark when thick. It appears to be *thalite*, having its vermicular structure and positive elongation. One section.

Age. Manitou. N. H.-W.

No. 560. DIABASE (*with olivine*).

Forms a bed under the cupriferous conglomerate No. 557; known as the "greenstone range," where it rises to the surface further north.

Ref. Annual Report, x, page 51.

Meg. Gray, medium-grained, specked with small nests of calcite, hence on the weathered surfaces somewhat porous, made up of a plagioclase and a rusty brown mineral, the product of alteration of either olivine or augite. Other ingredients are indistinct.

Mic. The rock is ophitic, but the augite is nearly lost by alteration, its form only remaining as a rusty, indefinite substance, embracing the feldspars. The olivine (which was in part later than the feldspars) is altered to the brown substance mentioned, which is only brown by reason of accumulated oxide of iron, being transparent in the centre of the grain, and even almost isotropic. These parts are as shown by the accompanying sketch, in which *a* represents the usual and familiar isotropic product of olivine alteration when not rendered opaque by iron. Extinction in the grain, especially visible in the part *c*, and faintly in *d*, is parallel with the longitudinal cleavages. The transverse cleavage in the section sketched is not precisely perpendicular to the longitudinal. In another grain, however, these cleavages are perpendicular to each other. This is the substance which has been referred to as *bowlingite* in several rocks. It seems to be monoclinic.

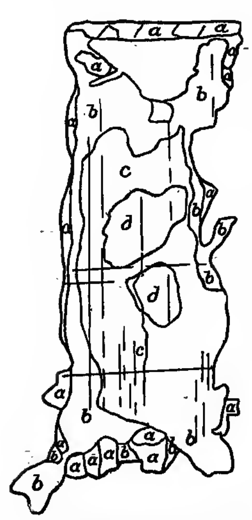

FIG. 25. CLEAVAGE OF BOWLINGITE IN ROCK NO. 560.

The *feldspar* is much altered and multitudes of highly refractive grains are crowded in it, some of which are *zoisite*, having a longitudinal extinction.

The *augite* is plainly preserved, but much destroyed.

Age. This is apparently from a Cabotian intrusive series rising in the form of grand dikes forming the most of the northern precipitous shore of Isle Royale. It is comparable to the dikes in the region of Grand Portage. N. H. W.

No. 561. CONGLOMERATE. (*Finer debris.*)

From the cupriferous part of the conglomerate at the Island mine, Isle Royale.

Ref. Annual Report, x, page 51.

Meg. Resembles an altered volcanic debris. It is light-colored and crumbling.

Mic. There is a profusion of microscopic grains, some of which (zoisite?) are of very low birefringence, and others, though fewer, which are bright, and extinguish parallel to their length (mica? and thomsonite?), while large areas that were once occupied by some crystals (augite?) are now green with rings and rosettes of chlorite (delessite?).

Age. Puckwunge (basal Potsdam?). N. H. W.

No. 562. BASALT *(with olivine).*

From a niche in the coast-line south of the east end of Siskiwit lake. This is under the sandstone that forms the peninsula south of Siskiwit bay, but above the conglomerate of the Island mine. Rises from the water with dip to the south. Associated with harder and also epidotic rock in patches.

Ref. Annual Report, x, pages 52, 53.

Meg. The specimen shows a homogeneous, somewhat decayed, medium-grained brownish rock, similar to numerous Keweenawan diabases.

Mic. An ophitic structure is apparent. There is not only fresh *augite*, but a ferruginous much altered mineral whose relation to the feldspar is ophitic, suggesting its derivation from augite or from glass; it resembles otherwise the brownish *bowlingite* which is derived from olivine. Careful inspection, however, shows that it has resulted from the alteration of both. When it occupies the areas of original olivines it has some translucency, and even birefringence, and its color is like that of hematite or it is replaced by an isotropic or faintly polarizing substance which between the nicols is sometimes blue (pennine?). When it is not derived from olivine it is formed of an irregularly disseminated magnetite powder, which is aggregated frequently in such quantities that the entire mass is opaque. When not abundantly massed it is seen to be in an isotropic or *glassy* matrix which is undoubtedly a residue from the magma. The *feldspar* is considerably penetrated with *epidote.*

Two sections.

Age. Manitou. N. H. W.

No. 563. DIABASE. *(Altered.)*

From one of the trap layers alternating with sandstone and shale at the entrance of Chippewa harbor, Isle Royale.

Ref. Annual Report, x, pages 52, 53.

Meg. Much changed, brown, apparently amygdaloidal and pseudamygdaloidal, spotted white with calcite. Shows also a finely radiated green mineral, apparently some form of chlorite, like delessite. The rock is firm.

Mic. *Feldspar* is filled with gray and yellow *epidote* or with general saussuritization. *Augite* is entirely lost by the severe alteration to which the whole rock has been subjected. No olivine is distinguishable. In place of these primary minerals are a lot of secondary minerals—*calcite, chlorite, hematite (?) quartz, epidote.* Two (poor) sections.

Age. Manitou. N. H. W.

No. 564. Thomsonite.

Zeolitic white mineral from the trap at Chippewa harbor.
Ref. Annual Report, x, page 52.

Meg. The structure is radiated and lamello-fibrous, rather coarse.

Mic. The thickness of the only section made is too great to permit of positive determination of the optic characters, being colored, in general, between crossed nicols, in the tints of the third or fourth order. About the edges, however, can be seen small fringes and patches of the brighter tints of the second order, indicating a high double refraction. This, taken with the outward resemblance to No. 558A, may be sufficient to indicate *thomsonite.*

One (poor) section.

Age. Manitou. N. H. W.

No. 565. Calcite, Quartz, etc.

From the beach, Chippewa harbor, Isle Royale.
Ref. Annual Report, x, page 52.

Meg. A piece from the trap composed chiefly of calcite and quartz, with a little of the rock matter attached, and embracing a radiated (coarse) green mineral whose hardness is about 3.

No section.

Age. Manitou(?) N. H. W.

No. 566. Chlorastrolite.

From an amygdaloidal bed of trap that disintegrates near the narrows of Chippewa harbor.
Ref. Annual Report, x, page 52; American Geologist, vol. xxiii, page 116.

Meg. The amygdules are, in size, up to half an inch in diameter, but the larger ones are composed of several radiating nests, appearing like chlorastrolite. The fibres are firm, and not easily broken, green in mass, but light-green in single. They are quite short, rigid and uniform, and also fine—finer than those of thomsonite, but about the same in coarseness as the fibres of mesolite. (Compare No. 570.)

Mic. The elongated fine fibres are not brilliantly polarized between crossed nicols. In the space of their elongation from the centre of a spherulith to its circumference, these fibres sometimes undergo variations of color. For instance, at the centre the tint is neutral (or bluish neutral); at a short distance from the centre the same rays, or others that have replaced them, are light yellow, still further the field is wholly of the neutral tint, same as at the centre; then a light-yellow supervenes, and at last the neutral tint returns,—making three recurrences of the same neutral tint, separated by intervals of light, or light yellow. These changes shift from one to the other, not abruptly, but by the gradual oncoming of streaks or spots of the other tint. The transitions between the yellow and the neutral tints are always through a narrow interval of white which blends on one side with the neutral and on the other with the yellow.

If the convergent light lens be used it is at once apparent by the nature of the interference figure, that the fibres that undergo these changes of color are all situated uniformly in the same position with respect to the section, from the center to the circumference of the spherulith. They may all give the bisectrix n_g. Or, in another spherulith or in another part of the same spherulith, while these same variations are exhibited, the interference figure seen is that indicative of n_p from one end of the fibres to the other. It is inferred therefore that these variations of color are not due to a shifting of the fibres with respect to the position of their axes, but to an overlapping succession of fibres cut obliquely, producing a section that might be compared to the layering of shingles on a roof.

It is also apparent that the fibres are parallel to n_m, and hence that the axial plane is perpendicular to the elongation, as in thomsonite.

The specific gravity of this mineral is found to be 3.155.

Lacroix has investigated chlorastrolite from an optical point of view* and reached the conclusion that it should be associated with thomsonite. Hawes considered it a variety of prehnite, but the optical properties distinctly show that it belongs with the group of thomsonite, in so far as its optical plane is transverse to to the elongation. According to Dana,† who follows Hawes, it is not a homogeneous mineral, and he places it in an appendix to the zeolites, with doubtful species and synonyms. The specimens examined by us, however, are pure and optically uniform in all their characters. There are seen smaller spheruliths which are green and which between the nicols appear uniformly blue, embraced scatteringly in the fibres of the chlorastrolite, but, as they are probably a radiated chlorite (delessite?) their presence does not affect the purity of the surrounding fibres. Lacroix also mentions inclusions of quartz and oxide of iron, and an amorphous substance occupying the centre of the spheruliths. These, however, make no part of the mineral. They would, however, be very likely to be embraced in any chemical analysis which might be made; and this is the only plausible explanation which we can make of the analyses which vary, and of the view of Hawes that the mineral is not homogeneous. Such chemical analyses have no validity as a guide to the nature of the mineral. The mineral has a strong fibrous character, structurally, and a constancy of optical orientation which give it an individuality of its own, and until chemical analysis of some of the pure

* *Bulletin de la Société de Minéralogie de France*, x, p. 147.

† *System of Mineralogy*, p. 610 (sixth edition), 1892.

minerals shall be made we prefer to keep it distinct both from prehnite and from thomsonite. With the latter it is allied in the position of its axial plane, but this fact alone is not sufficient to destroy its distinctness from thomsonite, for it is found also in other zeolites, such as mesolite and sometimes in laumontite. One section.

Age. Manitou. N. H. W.

No. 567. Diabase *(with olivine).*

From Lucky bay, south side of Isle Royale. (Lucky bay is represented on plate III, Tenth Annual Report.) *Ref.* Annual Report, x, page 53.

Meg. A porphyritic trap-rock, specked with a green radiated mineral and with brown, and apparently with epidote.

Mic. The *feldspar* is triclinic, but permeated with decay. *Zoisite* particles are scattered through it, and a little *calcite.* The zoisite has low birefringence; indeed, shows only gray and white colors. It is thus distinguished from *epidote*, which is abundant in the slide, and sometimes is embraced in the feldspar. A little *chlorite* is also embraced in these decayed feldspars.

Quartz appears as a product of alteration.

Epidote is abundant, both fibrous and regularly cleaved, in independent crystals, the former being the more refractive. It does not show the "intense polychroism" which is characteristic of the Sulzbach crystals, but rather a steady straw-yellow color, which rarely disappears, although it fades on rotation. The spheruliths are irregular, and are rather more like patches of curved or distorted crystals, showing between crossed nicols a transition from light yellow upward to orange yellow, red, blue, green, as the point of observatlon passes from the periphery of a spherulitic mass to the centre, thus changing from parallelism to perpendicularity with the fibration. This also indicates that the axial plane is transverse to the fibration.

Olivine has almost entirely given place to a finely fibrous "serpentine," or thalite which is almost isotropic.

Apatite remains in its original crystals, and is abundant. It is in the *titanite,* the epidote and the plagioclase. The crystals are sharp and perfect, frequently showing hexagonal sections. They are surrounded by a coating of *hematite*, or of *limonite.*

Chlorastrolite is closely associated with some of the epidote, forming radiated nests similar to the description given under the last number, surrounded generally by epidote.

An occasional brightly polarizing needle, seen in the epidote grains, remains undetermined.

Rutile, more or less altered by stains of hematite, and apparently changed to *leucoxene*, forms some conspicuous masses. Some of these grains are so large that they occupy the whole field of the microscope. In one grain the intersecting twinning is rectangular, and the form revealed is quite like the quadrillage of microcline. This section is parallel to the base. In another grain the section is oblique, and the interpenetrating twinning is not so close. Three cleavages are brought into view conspicuously, which intersect so as to form isosceles triangles throughout the section. These grains are, in general, brown, but they have areas between the cleavages that are sub-translucent. This rutile is no doubt an alteration product after ilmenite.

Augite is abundant. It shows the anomaly of being comparatively fresh, while all the other original minerals (excepting apatite) are much changed. It crystallized early, in part at least, for some of the grains are perfect crystals, and, cut perpendicular to the vertical axis, show their characteristic cleavages and peripheral faces and angles. Other grains formed after the feldspars, and these are more altered.

Three sections.

Age. Manitou. N. H. W.

NO. 568. DIABASE. *(with olivine).*

Saginaw mine, near Conglomerate bay, Isle Royale.
Ref. Annual Report, x, page 53.

Meg. A rather fine-grained, dark-greenish, gray rock, apparently considerably decayed. The only minerals noticeable are a greenish gray one (feldspar) and a black to reddish glistening one.

Mic. The section shows a rather fine-grained olivine diabase, somewhat decayed. The *augite* is violet to straw colored, is sometimes very slightly pleochroic, and frequently occurs in plates of considerable size holding many of the small *feldspar* laths. The *olivine* is now completely altered to *chlorite.* Filling in what were apparently cracks in the original olivine grains is a reddish-brown material. The whole section is more or less altered and now contains alteration products, chief among which is *chlorite.* Iron ore (*ilmenite* or *magnetite*) is quite common.

One section.

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

NO. 569. EPIDOTE. *(Rock).*

Saginaw mine, near Conglomerate bay, Isle Royale. This rock is the ore of the vein and was mined for copper.
Ref. Annual Report, x, page 53.

Meg. A mass of epidote, with some quartz and considerable copper.

Mic. The section is in large part composed of *epidote.* In many places are small areas which appear like a fine-grained diabase or similar rock composed of small feldspar laths in a sparse groundmass of altered *augite* or *glassy* material.

These areas are not very sharply separated from the epidote, and it seems possible that the epidote has replaced the mass of the rock. However, what at first glance appears like altered augite or glass is in reality largely *native copper*, and the apparent feldspars are composed of fibres of *thomsonite*. A little *quartz* is present in the section.

One section.

Age. Cabotian(?)

Remarks. The section apparently shows a basic rock replaced by epidote, copper and thomsonite, although the evidence from this one section is not sufficient to demonstrate this fact. U. S. G.

No. 570. Amygdaloid.

From the rock at the light-house at the entrance to Rock harbor.
Ref. Annual Report, x, page 53.

Meg. A brown amygdaloidal trap showing calcite, laumontite, chlorastrolite and chlorite; also apparently a little thomsonite.

Mic. The *augite* and *feldspar* microliths are ophitic. The olivine is almost wholly converted to *bowlingite* which is partly brown and partly almost isotropic, in the latter case approaching *thalite*, of which there is a considerable quantity, some of it being in spherulitic masses.

Two sections.

Age. Cabotian(?) N. H. W.

No. 570A. Chlorastrolite.

From the beach at Rock harbor, Isle Royale. These are weathered from the trap of the region and accumulate with the gravel on the beach. Compare No. 566.
Ref. Annual Report, x, page 53; American Geologist, vol. xxiii, page 116.

Mac. When this zeolite has its perfect development, without impurities and without inclusions, the exterior surface of the isolated pebbles presents a stellated and radiated coloration in green of two shades. Blocks of dark green, having a polygonal or irregular periphery, are separated from each other and surrounded by narrow bands or lines of a light green, the two shades blending rapidly at the contacts. Thus the pebbles, which have a sufficient hardness, possess a rich, flecked network of green, and a beauty which has caused their adoption as an ornamental gem. They vary in size from about half an inch downward to mere specks.

The specimens, however, which have this character in perfection, are not abundant. Many of the pebbles are not beautifully marked, but have a dull green color in general, and doubtless should not be allowed the name of chlorastrolite. This general greenness is sometimes quite dark, and in other cases it seems to fade into a very light green, resembling lintonite, in the same way that mesolite fades into lintonite. Outwardly this light green substance is structureless, quite hard and polishes well. In a similar manner it fades out into a white structureless substance whose hardness is less, but also sometimes into a pinkish zeolitic substance which resembles mesolite. The idea is suggested by the examination of a large number of such transitions, that the green structureless substance is a transition stage between chlorastrolite and mesolite or thomsonite, the iron element prevailing on one side, and not on the other. It seems likely that this green structureless mineral may be that which has been analyzed and named zonochlorite, by A. E. Foote (American Association for the Advancement of Science, 1873). Probably no definite mineral composition or structure can be detected in this green substance, the extremes only being identifiable, viz.: mesolite on one side and chlorastrolite on the other. That the two minerals are closely allied in origin, structure and composition, differing principally in the content of iron, is evident not only from the chemical composition and optic characters, but also from their intimate association often in the same amygdule. Such association sometimes illustrates a sudden transition from one to the other, and sometimes a gradual one, with a considerable amount of the amorphous green mineral. The re-examination of zonochlorite by Hawes (American Journal of Science, x, 24, 1875) shows that it is not a homogeneous mineral. He describes it as having green earthy particles as impurities disseminated in a white mineral. It is evident also that the material examined by Hawes, under the name chlorastrolite, was not a fair sample of that mineral.

As has been remarked under No. 566, this mineral has a well-marked individuality, structurally, while its chemical composition is quite different from that of thomsonite, viz.:

Thomsonite (Table mountain, Colorado, Hillebrand).		Chlorastrolite (Isle Royale, Whitney).*	
SiO_2	40.52	SiO_2	36.99
Al_2O_3	29.22	Al_2O_3	25.49
Fe_2O_3	0.79	Fe_2O_3	6.48
CaO	12.43	CaO	19.90
Na_2O	4.31	Na_2O	3.70
H_2O	12.79	K_2O	0.40
		H_2O	7.22
	100.06		100.18

Mic. The marked superficial characteristics are expressed on the interior by a finely radiated fracture, the fibres of which start from points and run unequally to the right or left, so that the spherules are eccentric and the fibres of one spherule abut transversely or obliquely on those of another.

Extinction takes place parallel and perpendicular to the fibres.

The fibres are parallel with the mean axis of elasticity (n_m) and hence sometimes where they have their elongated sections, they show a positive and sometimes a negative sign, the axial plane being transverse to the fibration.

* *Geology of the Lake Superior Land District*, part ii, p. 97, 1851. *Journal Boston Society of Natural History*, vol. v, p. 488, 1847.

In a section whose thickness is less than 0.03 millimeter the double refraction shows a coloration only when the fibres are cut perpendicularly, and then a straw yellow color. The actual double refraction is therefore somewhat less than 0.015.

Five sections.

Age. Cabotian(?)

Remark. In the trap rock at Rock Harbor every transition can be seen between the amorphous green mineral ("lintonite"?) to thomsonite and to chlorastrolite. A variety of pebbles gathered on the beach (No. 570B) illustrates this. In some of the amygdaloidal cavities prehnite also seems to have been formed, and it is associated with metallic copper, as noted at French river (rock No. 80). N. H. W.

No. 571. Diabase *(with olivine).*

From the Siskiwit mine, Isle Royale, near Rock harbor.
Ref. Annual Report, x, page 53.

The *feldspar* is specked and even crowded with *zoisite*, but its albite twinning is very well preserved. Extinction on n_p is 43°, indicating labrador-bytownite.

Augite is almost lost by decay which has entered along the cleavages, leaving a grouping of isolated grains which extinguish in unison, having an ophitic relation to the feldspars.

Olivine has changed into two products which occupy the places of the original grains, viz.:

1. A brown opaque substance which resembles *bowlingite.*
2. A translucent but nearly isotropic substance.

In natural light the former often forms ferruginous veins which penetrate the latter, and by encroaching on it in greater and greater amount either occupies the whole of the space of the original olivine, or leaves only a nucleus which remains translucent. The translucent mineral, in natural light, has sometimes about the color and forms of the original olivine.

This nearly isotropic product of alteration of olivine has been met with frequently in the traps of the state, in the course of this examination, and it has frequently been called serpentine. But, as Prof. Lacroix shows (Minéralogie de France et de ses Colonies, page 417), it is a name without definite mineral significance, and had better be reserved for *the rock* in which these products constitute the mass, and the products can be assigned to more definite mineral substances. In this case the substance is hardly isotropic but seems in some cases to have a vague, coarsely felted extinction which approaches to a parallel fibrous extinction, and in others its fibrous structure is more evident, and it then resembles thalite.

Quartz as a secondary product is in grains of considerable size, embracing other minerals poikilitically. It is not common.

Thomsonite in small amounts in one section.

Titanite has resulted from alteration of ilmenite, but it is very rare in the section examined.

Delessite forms spherulitic clusters liable to be mistaken for chlorastrolite, from which it is distinguishable by its pleochroism (light green and white).

There is also a finely fibrous, translucent, colorless mineral, whose appearance and structure in general is like that described in No. 140, which may also be [illegible]ite.

Three sections.

Age. Cabotian(?) N. H. W.

No. 572. DIABASE. *(Gabbroidal.)*

The rock of Scovill's point, Isle Royale.
Ref. Annual Report, x, page 53.

Meg. Diabase considerably decayed, amygdaloidal with a flesh-red zeolite resembling laumontite, medium-grained brownish.

Mic. The *feldspars* are thickly charged with kaolinic substances, and they have sometimes lost their triclinic characters.

Olivine is altered as usual, and consists now of the substance which is usually seen as the product of such alteration, surrounded by brown borders and crossed by brown cleavage cracks or fissures in which the ferruginous oxide has gathered.

Delessite, a green, finely radiated mineral is gathered in other places, remote from the olivines, which between crossed nicols shows a parallel extinction and a bluish color.

Augite is in fine grains that antedated the feldspar. There is a much ferruginated mineral which shows an ophitic relation to the feldspar, which if not a later generation of augite is probably a glassy remnant of the magma, now entirely devitrified. The original augites are well preserved.

One section.

Age. Cabotian(?) N. H. W.

No. 573. THOMSONITE AND PREHNITE.

From the trap at Scovill's point, Isle Royale; picked up on the beach.
Ref. Annual Report, x, page 53.

Meg. Mostly radiated, nearly white, pebbles, averaging nearly an inch in diameter, occasionally tinted with gray (when fresh).

Mic. The fibration consists apparently of two (or three) minerals, one much coarser than the other. The coarse fibres are visible in natural light, but the fine ones are not. Between crossed nicols their double refraction when viewed perpendicular to their elongation is low—the section being less than .03 millimeter in thickness—and the colors do not rise above the first order. But in sections that are transverse to the elongation the double refraction is higher, giving blue of the first order. In certain parts of the slide the long, coarse fibres show their rectangular, almost square, cross sections. These become inclined in other places and their sections are elongated, running to points at each end, and in others the elongation is almost, or quite, parallel to the direction of the section. This association is illustrated by figure 10, plate I. The mineral being biaxial, these rectangular basal sections indicate an orthorhombic crystalline structure, and the higher basal double refraction also indicates that the axial plane is perpendicular to the fibration. This position of the axial plane is shown also by the appearance of both optic axes and bisectrices in sections cut parallel with the elongation, as well as by the direction of retreat of the hyperbolæ in sections perpendicular to the bisectrices. This is shown by figure 24.

This mineral has parallel extinction. It occurs not only as coarse fibres but shares in the finer, fresher network which occupies the space between the radiating coarse fibres. The more decayed older fibres show high relief (or absorption) in convergent light on lowering the lower nicol in contrast with that of the fine network. Micro-chemical test gave lime and soda, indicating *thomsonite*.

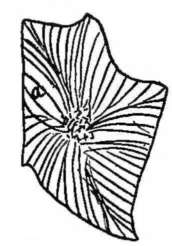

FIG. 26. MANNER OF GROUPING OF PREHNITE FIBRES.

Figure 26 shows the manner of grouping of the minute fibres of *prehnite* in the network between the coarser fibres.

Interlaced between these coarser fibres are fine radiating nests of a brightly polarizing mineral whose fibrous arrangement may be represented as stated by figure 26. So far as observable, these fibres are continually negative in elongation, but they frequently are cut perpendicular to n_m, giving for that reason their bright colors. They are, probably, in part, a finer condition of the mineral represented by figure 24. But as they never show, so far as observed, their highest coloration at the centres of the nests, but in the spreading rays (a), the axial plane is not perpendicular to the fibration. This mineral is markedly distinct from thomsonite (above) on lowering the lower nicol, owing to the partial decay of the thomsonite and not because of the difference of refractive index. The thomsonite appears to be the more refractive, but by the Becke process it is easily seen that the characteristic white band separating two grains adjacent, of the two minerals, moves, on raising the objective, toward the lighter colored mineral. Hence, the lighter colored mineral, lying between the coarse thomsonite needles, has all the necessary characters to show that it is *prehnite*, of which there is a notable amount in the rocks of this neighborhood.

There is, however, still another mineral in this slide. It is in long single fibres, and has no parallel extinction, but extinction occurs at a maximum of 45°. Such a section shows n_g, oblique, but these fibres exhibit an irregular and undulatory extinction, and their elongation is sometimes positive and sometimes negative. In the same fibre a small change (in the direction of elongation) in the point of observation will sometimes alter the interference figure from an optic axis to an axis of elasticity. These fibres are nearly always negative in elongation, but sometimes the same individual fibre changes from positive to negative at a cleavage or fissure which crosses it nearly at right angles, or quite obliquely. This indicates the optic plane is transverse to the fibration, as in thomsonite; yet a nearly square transverse section of one of the fibres shows an optic axis and is less doubly refractive than some of the fibres cut parallel to their length. This may be *scolescite,* although the maximum angle of extinction is much too large.

These anomalous fibres cannot be distinguished, in point of view of absorption, from the coarse fibres of thomsonite. They seem to be thomsonite in all points of view except in the wandering positions of the optic plane, which is sometimes even longitudinal.

One section.

Age. Cabotian(?)

Remark. This intimate mixture of two fibrous minerals shows how futile would be a chemical analysis for determination of the species. Many of these pebbles appear on the beach; the survey collection, already depleted by donation and exchange, still contains about seventy-five specimens.

A Boricky test gave, along with abundant crystals of fluosilicate of lime a few small rods of fluosilicate of soda. When powdered these minerals together do not gelatinize in HCl. It appears probable that thomsonite prevails over prehnite in these pebbles. N. H. W.

No. 574. Diabase.

Extremity of Blake's point, east end of Isle Royale.
Ref. Annual Report, x, page 53.

Meg. A medium-grained diabase, apparently considerably decayed. What was evidently augite originally, now seems to be chlorite, and the feldspars are pinkish and greenish gray in color.

Mic. The section is too thick for careful study. It shows that the rock is a decayed diabase. The feldspars are cloudy and almost opaque, much radiating *chlorite* has been developed in the rock, and most of the augite has disappeared. Considerable iron ore *(ilmenite* or *magnetite)* is present, and there are stains of *hematite.* Possibly some olivine was originally present.

One section.

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

No. 575. Thomsonite.

From the beach on the north side of Isle Royale, about two miles southwest from Locke's point.

Meg. Pebbles of zeolitic minerals weathered from the trap-rocks of the region. They resemble those of No. 573, except that the majority of them have a tendency toward red, becoming pinkish and purplish, and in this respect they approach more nearly to the pebbles that have been distributed widely from Grand Marais under the name thomsonite. Still, they fall far short of being so brilliantly colored. Their structure is divergently fibrous.

Mic. The microscopic characters are the same as already noted for thomsonite under Nos. 161B, 535 and 573. So far as examined, these pebbles are without prehnite, but the slide shows some *delessite*. Two sections.

Age. Cabotian(?)

Remark. In this large collection some of the pebbles are white, or cream-white, and some are variously blotched with a green substance similar to lintonite The white pebbles are probably thomsonite, perhaps sometimes mingled with prehnite. A thin section made from one of the sub-translucent green pebbles, without evident fibrous structure, proved to consist wholly of the same mineral, but massively and finely fibrous.

A few other pebbles in the same collection are evidently of prehnite.

Analysis of No. 575. This zeolite was analyzed by Prof. J. A. Dodge, with the following result. The material used seems to have been considerably altered by weathering:

Silica,	45.47 per cent.		45.47
Alumina,	21.01 "		21.01
Oxide of Iron,	3.60 "		3.60
Lime,	24.09 "		18.87
Magnesia,	.16 "		.16
Potash,	.21 "		.21
Soda,	.93 "		.93
Water,	.83 "		.83
Carbonic Acid,	4.10 "	Carb. of Lime,	9.32
	100.40 per cent.		100.40

Regarding the carbonic acid as united with a portion of the lime, we have carbonate of lime 9.32 per cent, and we have left of the lime 18.87 per cent, which is to be considered as in combination with the silica, alumina, etc., as it stands in the right-hand column.

N. H. W.

No. 576. Prehnite and Copper.

From a little bay at the eastern extremity of Fish island, north side of Isle Royale from the beach.
Ref. Annual Report, x, page 53.

Meg. The prehnite has served as a cement to angular fragments of amygdaloidal diabase, probably derived from a vein in the near vicinity, not seen. The color is light, grayish green, and the fracture is angular and vitreous.

Mic. The single section at hand serves only to indicate the high double refraction, which is sufficient to bring out colors of the fourth order, owing to its thickness. One section.

Age. Cabotian(?) N. H. W.

No. 577. Melaconite.

Minong mine, Isle Royale.
Ref. Annual Report, x, page 54.

Meg. With soda, on charcoal, this gave a bead of *metallic copper.* The ore is purplish black, in form of a powder, associated with some *malachite.*

Age. In Cabotian(?) rock. N. H. W.

No. 578. Copper. *(Stamp ore.)*

Minong mine, Isle Royale.
Ref. Annual Report, x, page 54.

Metallic copper is spread through a brownish-red rock in a manner similar to that of the Calumet and Hecla mine, on Keweenaw point, though not plainly conglomeratic. It is more or less coated and accompanied by small deposits of cuprite. The rock appears to have been a somewhat open porphyryte, and the copper has entered its cavities, and at the same time a change has come upon the rock by reason of which a pseudamygdaloidal spottedness pervades it, *i. e.*, foreign minerals have been generated in nests at points in the mass of an originally non-amygdaloidal rock subsequent to consolidation. In these nests sometimes is a central core of metallic copper.

No section.

Age. Cabotian(?)

Remark. The existence of copper in the Cabotian (*i. e.*, in a dike in the Animikie) was first noted by A. C. Lawson in the Thunder Bay region. (American Geologist, vol. v, page 174, 1890.) The environments of the copper deposits at the old Minong mine, at the head of McCargo's cove, Isle Royale, are apparently not identical with those described by Lawson, but approach nearer those in Keweenaw point, and it may be discovered that this copper is, instead, in a conglomeratic outlier of the base of the Potsdam. The line of strike of the basal conglomerate at the west end of Isle Royale probably would carry the northern boundary of the Manitou and Potsdam to the vicinity of Conglomerate bay west of Rock Harbor.

N. H. W.

No. 579. Serpentine(?). *(Cupriferous.)*

Minong mine, Isle Royale. Nodules in No. 578.
Ref. Annual Report, x, page 54.

Meg. This is a massive, green, fine-grained rock, carrying nests and spangles of metallic copper in a manner similar to No. 578, but less abundantly. Across the rock run veins consisting of a finely fibrous, silky mineral which stands vertical to the walls, apparently a form of asbestos. The source of this rock may have been from change of a basic pyroxenous mass included in No. 578. Indeed there is reason to believe that both Nos. 578 and 579 are parts of a general basal conglomerate into which the copper was introduced at some later date.

No section.

Age. Cabotian(?) (Perhaps in the basal, or Puckwunge, conglomerate of the Potsdam). N. H. W.

No. 580. Amygdaloid.

Minong mine, Isle Royale. Adjoins the copper-bearing rock.
Ref. Annual Report, x, page 54.

Meg. Coarse, green amygdaloid, the cavities being filled with chlorite and geodic quartz, coated with green, sometimes also with calcite and laumontite. The amygdules make up more than one-half the bulk of the whole.

Mic. The rock is very fine grained, and was apparently originally in part glassy, the crystalline condition being due in part to devitrification. The chloritic rosettes give the black cross of spheruliths. Owing to the thickness of the only available sections no careful study is possible.

Three sections.

Age. Cabotian(?)

Remark. The fresh aspect of this loose amygdaloid resembles some of the Cabotian surface eruptives already described on the lake Superior shore in the vicinity of Duluth and eastward. So far as can be judged from the hand samples collected of Nos. 578, 579 and 580, they are from surface igneous rock, and appear to belong in the Cabotian red-rock and surface lavas. They would thus represent the southward flows from some great Cabotian dikes that occurred further north. The writer did not make sufficient examination to warrant him in holding a positive opinion as to the age of this copper-bearing rock. N. H. W.

No. 581. Copper.

Minong mine, Isle Royale.
Ref. Annual Report, x, page 54.

Spreading, frond-like, crystalline, partially coated with malachite and cuprite, and bearing a little calcite. N. H. W.

No. 582. Copper and Silver.

Minong mine, Isle Royale.
Ref. Annual Report, x, page 54.

A small slab, or scale, about an eighth of an inch in thickness, and about two inches in length by an inch in width, but of irregular shape, consists principally of copper, but there are eight separate masses of silver lying in the copper. These small masses vary from the size of a pin-head to that of a field-bean. They are roughened, like the copper, by reason of deposition on some rough surface. There being small calcite grains still existing in some of the depressions, it appears that this metallic sheet was deposited on a calcite coating, or between two calcite surfaces, since both surfaces are roughened in the same manner, as if by fine calcite teeth, or rhombs.

Remark. The singular fact that in the lake Superior region copper and silver are thus associated without being alloyed, was first noted by Dr. C. T. Jackson,* and has been confirmed by several other geologists since. When they are alloyed, as sometimes occurs in pieces extracted by the ancients, it is probably due to fusion at the time of extraction, since it is a matter of history that the Indians obtained copper in that region by applying heat to the rocks.† N. H. W.

NO. 583. COPPER *(with attached crystals of calcite and adularia).*

Minong mine, Isle Royale.
Ref. Annual Report, x, page 54; American Geologist, vol. xxiii, page 317.

Metallic copper is crystalline, in slender rods that are flanged and pointed like a spear-point, the alternating twins furnishing dull corners, slightly barb-like, which increases the resemblance to spear-heads. The calcite is in large masses, conspicuously cleaved and involved with the copper. It is not apparent which is the older. Upon these is an abundant deposition, as a coating, of fine crystals, which are flesh-red, which are so numerous that they constitute sometimes a massive mineral, whose free surfaces, as in the small cavities, are the only parts in which the crystalline facets appear. This mineral is insoluble and infusible, or difficultly fusible. In tube it gives no water.

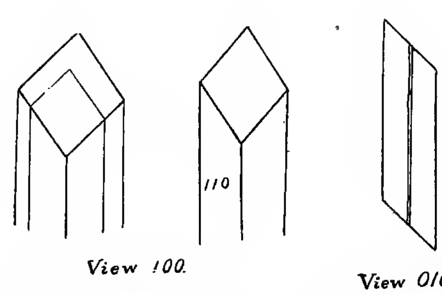

FIG. 27. CRYSTAL FACES OF ADULARIA IN NO. 585.

Mic. The mineral has a glassy transparency between crossed nicols, but contains numerous particles of non-translucent impurities. Its fracture is irregularly conchoidal, but is governed partially by the cleavage. The crystals, broken at random, give more numerous cleavages in which the axis n_m is vertical, indicating the basal cleavage, while fragments that show the axis n_g vertical are rare. The crystals are confusedly mingled, and sometimes twinned, or compound by parallel growths.

In the geodic cavities are innumerable compound faces, bounded by prismatic

*Report on the geological and mineralogical survey of the mineral lands of the United States in the state of Michigan, 1849, pp. 386, 461. Compare, also, *Fourteenth Report of the Minnesota Survey*, for 1885, p. 319.

† *Voyage du Sieur de Champlain*, Paris, 1613, p. 246.

edges, showing a monoclinic form, in which the clinopinacoid is reduced to a very narrow surface, or is obsolete, as shown by figures 27 (page 436) and 28. It is seen occasionally as a narrow face running the whole length of the crystal. These crystals are about 1 or 1.5 millimeters in transverse section.

From a coarse powder, mounted in balsam, the double refraction is seen to be rather low. A bisectrix (n_p) is in the acute optic angle, making the sign of the mineral *negative*. A fragment, represented herewith (figure 28), shows extinction at an angle of about 9° from the principal cleavage.

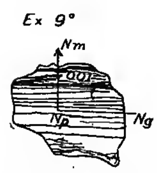

FIG. 28. FRAGMENT OF ADULARIA.

By means of a good thin section, the following characters were determined: The refraction and double refraction are low, about that of the feldspars. The acute bisectrix is n_p, and the optic angle is so small that the mineral appears almost uniaxial. The easy cleavage is perpendicular to n_m, and another is about perpendicular to n_g. The crystals are made up of a number of parallel columns, caused apparently, by the two cleavages, which allow them to be dislodged, and they do not all extinguish at the same moment, though essentially in their true positions. The optic plane is parallel with the diagonal of the transverse section. There is frequently a distinct division of the transverse section into four or more sectors, by planes of parting, running from the centre to the angles, and their somewhat irregular and striped manner of extinction seems to be due to a prevalent structure of that kind. There are also many subordinate divisions of the sectors into quadrilateral small areas which extinguish sooner along their edges than at their centres, or at one side sooner than at the opposite side. These conditions are probably peculiar to the multiple manner of development and interpenetration.

Micro-chemical test by the Boricky process gave evidence of much potash, and a trace of both soda and lime. A similar examination by the method of Behrens showed only potash and also the presence of alumina.*

The specific gravity of these crystals is 2.544.

A goniometric measurement of the surface prism angles gave the following:

$\bar{1}\bar{1}0 \wedge 110 = 61° 30'$.

These characters conspire to show that the mineral is near orthoclase, of the form *adularia*.

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* The micro-chemical search for alumina by the Behrens method is very direct and simple, viz.: a powdered portion of the pure crystals was dissolved in hydrofluoric acid and evaporated to dryness on a sand bath, in a small platinum crucible. The residue is dissolved in sulphuric acid, and again evaporated to dryness, bringing the mineral into the state of sulphate, soluble in water. After adding a few drops of water, and warming, a small portion of the solution may be placed on a glass slide, and a grain as large as half a pin's head of chloride of cæsium, in powder, added to the solution on the slide, when immediately are formed crystals of sulphate of alumina and cæsium which can be examined under the objective of the microscope. If the crystals form too rapidly they are simply crystalliths in form of a cross (+) with ragged arms; but with further time they develop into octahedrons.

The test for potassium is equally direct: a small portion of the original solution is neutralized (*i. e.*, its excess of sulphuric acid) by a grain of acetate of soda. On a glass slide, by the addition of a drop of chloride of potassium, are formed immediately yellow octahedrons of chloride of potassium and platinum, which can be examined as they float in the liquid.

A test for soda was made as follows, without result, viz.: A drop of the original solution was evaporated to dryness on a glass plate, and to it was added first a drop of acetic acid and afterwards a drop of acetate of uranium. Had soda been present there would have formed tetrahedral crystals of acetate of uranium and sodium.

Remark. This mineral appears to be the same as that noted by J. D. Whitney* at the Copper falls and Douglass Houghton mines on Keweenaw point, where it occurs implanted on quartz and copper, and which gave on analysis the following composition:

Silica,	65.88
Alumina,	17.35
Oxide of iron,	.57
Potash and soda.	16.20 (by loss)
	100.00

He made no direct determination of the alkalies, not having been able to obtain enough of the substance for such analysis.

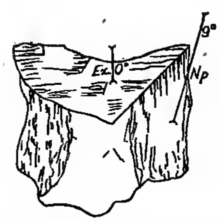

FIG. 29. ADULARIA, CUT PERPENDICULAR TO n_p.

In still another section it appears that in crystals cut perpendicular to n_p there are four sectors which, while extinguishing approximately in unison have partial extinctions somewhat out of unison, and also exhibit an imperfect microcline structure. The mineral has too small an optic angle for microcline. The figure attached shows the grain cut perpendicular to n_p. There is no evidence of twinning on the Baveno plan, as the whole section has n_g in the same direction. These variations of extinction must be attributed to irregularities of development.

Samples in the General Museum are Museum Nos. 1900, 1389 and 1370, where it is implanted on epidote, lining irregular cavities. N. H. W.

NO. 584. COPPER.

Minong mine, Isle Royale.
Ref. Annual Report, x, page 54.

Battered thin scales, from half an inch to two inches in greatest dimension. Found in the mines about the large masses worked by the ancients. N. H. W.

NO. 585. DIABASE *(with olivine)*.

Minong mine, Isle Royale.
Ref. Annual Report, x, page 54; Popular Science Monthly, vol. xix, page 601.

In the form of rounded beach-stones, used as hammers by the ancient miners. Probably transported from the north mainland, where they are common. They evidently got their form by the action of the waves on the beach. They are not withed. They are found in the debris about the old mines.

Three sections. N. H. W.

**Report on the Lake Superior Land District*, part ii, p. 102, 1851.

No. 586. Wood.

Minong mine, Isle Royale.
Ref. Annual Report, x, page 54.

Found in the ancient mines. For an account of these ancient miners, by N. H. Winchell, the reader may consult the Popular Science Monthly, September, 1881.

N. H. W.

No. 587. Calcite and Galenite.

Silver Islet.
Ref. Annual Report, x, page 55.

Meg. A mass of crystals of *calcite* and *galenite*, with a very little pyrite. The crystals of galenite show combinations of the cube and octahedron, the latter usually being better developed.

Age. Vein in Animikie rocks. U. S. G.

No. 588. Galenite.

Silver Islet.
Ref. Annual Report, x, page 55.

Meg. A mass of octahedra of *galenite.* The largest of these crystals is over two inches across.

Age. Vein in Animikie rocks. U. S. G.

No. 589. Graphite.

Silver Islet.
Ref. Annual Report, x, page 55.

Meg. The hand sample is apparently a mass of much decayed rock which has been impregnated and partly replaced by *graphite.* The original nature of the rock is not clear; it now contains a little *calcite.* The hand sample resembles somewhat the graphitic quartzyte from Pigeon point (No. 270). Probably a third, or possibly half, of the rock is graphite.

No section.

Age. In a vein in the Animikie. This is from the great vein at Silver Islet.

U. S. G.

No. 590. Diabase.

Silver Islet, Thunder bay. From the great dike at the bottom of the mine, 720 feet below the level of lake Superior.*
Ref. Annual Report, x, page 55; Bulletin ii, page 116.

Meg. A medium-grained, gray, massive rock, crossed by several thin veins of calcite.

Mic. The minerals are all considerably changed, notwithstanding the great depth from which the specimen was obtained, a circumstance which may be attrib-

*For an account of the discovery and working of the silver deposits of Silver Islet, the reader may consult Macfarlane, *Transactions of the American Institute of Mining Engineers*, viii, p. 226.

uted to the nearness of the great vein on which the mine was operated, and which is also corroborated by the small calcite veins which cross the specimen.

Quartz forms micropegmatyte in the *feldspars*, and also isolated, independent grains. *Sericite (?)* and other gray substances are distributed through the feldspars, rendering them so obscure that their albite twinning is almost destroyed. *Biotite* is surrounded occasionally by *chlorite*, which also spreads more widely, especially in some of the feldspars. Olivine is not distinguishable, and the *augite*, which is detected by its ophitic relation to the feldspars, is changed to a dirty, fibrous, ferruginous substance that in some places may approach hornblende, but in general is greenish, and related to some *chlorite*. *Apatite*, *magnetite* and a small amount of *titanite* also appear, the last forming groups of tapering, lath-shaped crystals with high refraction and high double refraction, having much the color and irregularity of cleavage seen in ferruginous olivine.

One section.

Age. Cabotian dike in the Animikie.

Remark. The condition of this rock, at 720 feet below the surface, cannot be attributed to ordinary weathering. It is the most obvious inference that it is due in some way to the presence of the great dike which here is known to cross the vein and the country rock. Whether it can be attributed to the greater ease with which surface waters could enter along the walls of such a fissure, or to the heat imparted to the walls, resulting in an action and retroaction of the walls on the dike, is apparently the only question that need be considered. The mineral contents of the vein seem to show that the mineral solutions came from below rather than from above, and the presence of considerable amounts of graphite indicate a high temperature. It seems, therefore, that the condition of the igneous rock is due to a reaction from the country rock. In that respect this dike illustrates what has been inferred from an examination of several dikes on Pigeon point and elsewhere, viz., the entrance of quartz cotemporary with the alteration of all the minerals of the dike during the process of cooling. N. H. W.

No. 591. Marble.

Silver Islet. From the vein worked for silver.
Ref. Annual Report, x, page 55.

Meg. This is massive *calcite*, varying in color from gray-white to flesh-red-white. In the gray portion is visible some *galena*, and in the flesh-colored some *pyrite*.

Mic. There is a little *quartz*, in angular grains, isolated in the mass.

One (thick) section.

Age. Vein in the Animikie. N. H. W.

No. 592. Breccia *(of slate)*.

Silver Islet. From the vein of the Silver Islet mine.
Ref. Annual Report, x, page 55.

Meg. Angular fragments of slate are cemented by the gangue rock No. 591.

Mic. A section of the marble shows a confused massive growth of *calcite*, with a small amount of *quartz*, and a single grain that appears to be *titanite*, resembling the titanite of No 590.

One section.

Age. Vein in the Animikie. N. H. W.

No. 593. Diabase.

From a breccia in the vein of the Silver Islet mine.
Ref. Annual Report, x, page 55; Bulletin ii, pages 118, 120.

Meg. This rock appears identical with No. 590, from the bottom of the shaft.

Mic. There appears to be an element of *leucoxene* in the changed *augites*, giving, along with a loss of polarizing power, a sub-transparency which is also specked with opaque particles which are probably *magnetite;* otherwise the section is comparable to that of No. 590.

One section.

Age. Vein in the Animikie. N. H. W.

No. 594. Slate.

Silver Islet. The rock that encloses the vein.
Ref. Annual Report, x, page 55.

Meg. Argillaceous slate, in which the laminæ are due to the original sedimentation.

Mic. One thick section only affords the determination of a narrow vein of granular quartz that crosses it. The rock is crowded with opaque substances.

One section.

Age. Animikie—Taconic. N. H. W.

No. 595. Diabase *(with hypersthene)*.

Cores of the diamond drill at the bottom of the Silver Islet mine.
Ref. Annual Report, x, page 55; Bulletin ii, pages 59, 92; Wadsworth, Bulletin ii, page 59.

Meg. A diabase of medium grain, firm and gray.

Mic. This rock is more nearly in its original condition than No. 590, but has suffered some change similar to that seen in that rock. *Quartz* appears as a secondary product both as micropegmatyte in the feldspars and as isolated grains between the other minerals. *Apatite* is quite abundant piercing all the other minerals. The *feldspars* are somewhat zoned and are twinned on the albite and pericline types.

The olivine has quite disappeared, as such, and its spaces are filled with more or less indeterminate ferruginous substances, and by *biotite.*

The pyroxenic element is nearly intact, but ferruginous opaque substances have gathered about it, and in its basal fissures. It is orthorhombic, and hence is either enstatite or hypersthene. Its high double refraction seems to indicate hypersthene, but its very slight pleochroism is nearer to that of enstatite. At the same time the acute angle of the optic axes seems to embrace n_p, which stands perpendicular to the face 100. This mineral, in the same slide, having been determined as enstatite by Wadsworth, we prefer to accept his decision provisionally, until better material is at hand.

One section.

Age. Cabotian dike in the Animikie.

Remark. This rock shows to what extent, under favorable conditions of access of heated waters, the massive rocks may be affected by alteration, this being taken from about 730 feet below lake Superior.

On having made another section, thinner than that examined by Dr. Wadsworth, it is apparent that the pyroxene above is hypersthene. This is indicated by the high double refraction in a section perpendicular to n_m, which reaches red of the first order, in a section not over, but rather less than, 0.03 millimeter in thickness. This hypersthene is older than most of the feldspars, and it was frequently encased in augite, at least in a highly doubly refracting rim which is much altered and which has the fibration of a diallagic alteration of augite. This rim, as well as other isolated augites, was generated, for the most part, later than the feldspars, and approximately cotemporary with the zoning of the latter. N. H. W.

No. 596. Breccia (*cemented by calcite*).

"Stamp ore," Silver Islet.
Ref. Annual Report, x, page 55.

Meg. The fragments are partly from the slate and partly from the dike rock. There seems to be but little reason for using such rock as stamp ore.

Mic. The slide consists of the elements of the dike rock, and of the slate. But of the former the feldspars only remain identifiable. *Quartz*, *hematite* and chloritic substances have arisen as products of decay, while veinings of *calcite* also cross the slide.

One section.

Age. Vein in Animikie rocks. N. H. W.

No. 596A. Huntilite.

From the Silver Islet mine.
Ref. Annual Report, x, page 55; Engineering and Mining Journal, vol. xxvii, page 55, 1879,

An arsenide of silver, dark gray to massive, dull, often porous and crumbly. Described by Dr. Wurtz, this mineral consists of two varieties. The two were analyzed together, and while essentially an arsenide of silver, contained some antimony, mercury, sulphur, cobalt, nickel, iron, zinc and water. The mineral is sub-sectile, sub-malleable, and has a hardness about 2.5. N. H. W.

No. 597. Shale.

Silver Islet landing.
Ref. Annual Report, x, page 56.

Meg. This red and buff fissile shale is conglomeratic below, and has a thickness of forty feet. No section.

Age. Upper Cambrian. N. H. W.

No. 597A. Conglomerate. *(Cherty.)*

From the bottom of No. 597.
Ref. Annual Report, x, page 56.

Meg. The general aspect is fine-grained, both of the fragments and of the matrix. Siliceous, calcareous and gray, blotched with angular chert pebbles from the size of a pin-head to two inches in diameter, this rock represents apparently a non-conformable passage from some part of the Keweenawan to a later formation.

Mic. The section is very fine grained. The cement is partly of *calcite*, but siliceous spherules which give a black cross, and rhombic sections that are probably of *calcite*, are scattered through it. Except for these forms the section appears like a fine fragmental chert. Two sections.

Age. Upper Cambrian. N. H. W.

No. 598. Sandrock.

From a stratum thirty-five feet thick, underlying No. 597.
Ref. Annual Report, x, page 56; Bulletin vi, pages 123, 420.

Meg. Light-red dolomite, sandrock, mixed with red sandrock.

Mic. Fragmental *quartz* grains compose the bulk of this rock, the cement being colored by iron. One section.

Age. Upper Cambrian. N. H. W.

No. 599. Conglomerate. *(Pebbly.)*

From a stratum lying below No. 598; five feet thick.
Ref. Annual Report, x, page 56.

Meg. The pebbles are well rounded by beach action. Many of them are red, appearing to be of taconyte. This rock resembles the Puckwunge conglomerate, and perhaps holds the same chronologic place.

Age. Potsdam(?) N. H. W.

No. 599A. Pebbles *(from No. 599).*

Ref. Annual Report, x, page 56.

Meg. The pebbles are red and hard.

Mic. Two sections made from different pebbles are alike in consisting essentially of fine-grained quartz, but they differ in microscopic aspect by reason of the distribution of the coloring matter. They are both originally composed of grains of sand, such sand being itself a fine-grained quartzyte. About these grains grew secondary quartz in coarser grains, filling the interstices completely. In one of these sections that would conclude the description, but in the other there is a concentric banding of the coloring matter, making the secondary quartz bands appear oölitic, the coloring matter forming entire circuits about the original nuclei and passing independently through all the coarser secondary quartzes without deviation from the contours of the original muclei, although the quartzes embraced in the encircling band have various orientation. In general the width of the band is less than the diameter of the contained grain, but in a few instances it is equal to it, thus increasing the apparent pebble 200 per cent in its shorter diameter. The belts of impurities that can be counted are sometimes six or even ten, depending on the minuteness with which they are differentiated. In a few instances the nuclei of these concentric bands are of other substances, calcite or magnetite, but the quartzyte nuclei are always of the same character. They are themselves made up of secondary quartz growths, which took place at an earlier date, and may be referred to aporhyolyte, from which they cannot be distinguished, except that they are not known to show a fluidal structure, or to taconyte, which is also made up, in its last phase, of minute secondary quartz grains.

Age. Puckwunge(?) (Basal Potsdam). N. H. W.

No. 600. Slate.

Silver Islet landing, a short distance north of the lake.
Ref. Annual Report, x, page 56.

Meg. Greenish or grayish, aluminous, but rather coarse and quartzose slate. From the lower portion of the beds exposed. The higher beds are softer.

Mic. The quartz grains are angular and the cementing material is opaque.

One section (too thick).

Age. Upper part of the Animikie (Grand Portage graywacke).

Remark. In the fall of 1896 a considerable thickness of this slate, or what is presumed to be at this horizon, was noted in the Puckwunge valley (compare Nos. 2070, 2071, 2073), and was named subsequently the Grand Portage graywacke. So far as could be learned from the exposures near Silver Islet landing there is a gradual transition from hard quartzyte upward into this rather fragile and slaty graywacke.

N. H. W.

No. 601. Diabase. *(Porphyritic.)*

From a dike about a mile north of Silver Islet landing. This rock gradually passes into No. 602, the interval of transition being perhaps two feet, and the two run in the same direction as the Silver Islet dike. The whole width is about forty-five feet, evenly divided between Nos. 601 and 602.

Ref. Annual Report, x, page 56; A. E. Barlow, Ottawa Naturalist, vol. ix, pages 25-46, 1895 (Review in the American Geologist, xvi, 1895, page 119).

Meg. A medium-grained diabase, with coarse porphyritic crystals of a light-colored feldspar scatteringly disseminated through it, the crystals in some cases making about one-fourth of the entire rock.

Mic. The rock is holocrystalline. The section shows only the groundmass. The *feldspar* and the *augite* are ophitic in their relation to each other, the latter also being sometimes distorted by dynamic movements. The rock shows the usual characters of a somewhat weathered coarse diabase.

One section.

Age. Cabotian eruptive.

Remark. Rock similar to this is seen frequently about the western environs of Gunflint lake, in the form of sills and dikes in the Animikie of that region. Compare Nos. 1314 and 2051. These coarse feldspars were named huronite by Dr. J. J. Bigsby, but seem to be a saussuritized condition of the coarse labradorites of the rock, the secondary grains being of high single refraction and probably of *zoisite*. N. H. W.

No. 602. Diabase.

About a mile north of the "Landing" at Silver Islet; a dike.

Ref. Annual Report, x, page 57; Bulletin vi, plate XV.

Meg. An ordinary diabase, of rather fine grain and quite heavy.

No section.

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

No. 603. Diabase.

Extremity of Pigeon point.

Ref. Annual Report, ix, page 69; Annual Report, x, page 56. Compare Nos. 287, 291, 1843.

Meg. A coarse-grained rock appearing more like a gabbro than a diabase. The minerals are plagioclase, augite and olivine. Sometimes a few subporphyritic feldspars are seen.

Mic. The section shows a diabase of coarse grain composed of *plagioclase*, *augite*, *olivine*, iron ore and alteration products. The rock is a good representative of the diabase (or gabbro) of Pigeon point described by Bayley (U. S. Geol. Survey, Bulletin cix, pages 32–38), who gives analyses of the rock as a whole, of the feldspar and of the augite. The feldspar is *labradorite*. The olivine is generally altered to a brownish or greenish material (bowlingite?). The augite is in places also altered, the secondary products being *biotite*, *chlorite* and *quartz*. The augite is, as a rule, later than the labradorite, and the olivine appears to be older than either. However, one compound olivine grain was seen which was later than some of the surrounding feldspar. This structure in rock No. 258 (Hat point) is illustrated on page 285.

Age. Cabotian.

U. S. G.

FIG. 30. LITTLE PORTAGE BAY, PIGEON POINT.

No. 604. Slate.

Near the "little portage" on Pigeon point, south of the dike (No. 605) on the point next east of the little bay on the south shore whence the portage starts out. The portage trail is eighty-seven paces from shore to shore.
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, page 57.

Meg. Fine grained, black, with conchoidal fracture, a hardened fragmental.

Mic. The section shows angular *quartzes*, also sub-rounded, impacted in an ill-defined matrix, which is dark, and evidently holds some iron oxides and other opaque substances. One section.

Age. Animikie.

Remark. Figure 30 shows the structural relations of rocks Nos. 604 to 616.

N. H. W.

No. 605. Diabase *(with olivine)*.

Little portage of Pigeon point. A dike twenty-five feet wide, cutting the slates and quartzyte; south end of the portage.
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, page 57.

Meg. Medium-grained diabase.

Mic. The *augite* is, in part, distinctly and beautifully ophitic on the *feldspar*, but in part also was earlier than the feldspar. The rock is fresh. One thick section.

Age. Cabotian intrusive in the Animikie. N. H. W.

No. 606. Gneiss *(with hypersthene)*.

Rock extending next north of the dike No. 605, in contact with it, but forming the surface.
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, page 57; Wadsworth, Bulletin ii, Minnesota Geological Survey, page 120.

Meg. The rock is medium-grained, uniform, "pepper and salt" color.

Mic. Consists largely of secondary *quartz* in form of micropegmatyte in the *feldspars* and of isolated grains of much altered feldspar, whose triclinic nature can hardly be established, owing to a cloudy and grayish diffusion of alteration products through it, of *hornblende*, which is greenish, fibrous, and somewhat dichroic, of *biotite*, *apatite*, *chlorite*, and perhaps other secondary minerals, the whole indicating a metamorphic condition of a clastic rock or a silicified selvage of a basic one. Two sections.

Age. Animikie (metamorphosed).

Remark. This is one of the "intermediate rocks" mentioned by Bayley. (Bulletin cix, U. S. Geol. Survey.)

The section examined by Wadsworth, contains, in addition to the minerals mentioned above, *hypersthene*, which is of dark yellow color and characterized by parallel extinction and pleochroism. This mineral can hardly be recognized in the section made later and above described, but certain much altered, evidently pyroxenic, grains, now consist of *biotite* (showing sometimes a greenish or chloritic tendency), and of *hornblende*, may have resulted from that mineral. The mineral hypersthene was apparently among the earlier minerals of the rock. It does not hold an ophitic relation to the plagioclases, and therefore preceded them in generation. It seems, therefore, that the magma that cooled to form this rock was derived essentially from the clastics, probably with only partial fusion, and perhaps with basic intermixture from the gabbro, forming an intermediate magma in respect of acidity, before the generation of this hypersthene.

On the other hand, this rock, which in color and general appearance approximates the dark gabbro of Pigeon point, may be looked upon as an altered condition of that rock. Its environment is such that it must have been permeated, on that supposition, very readily by the acid elements of the adjoining country rocks. It is also a common observation, under such conditions, to see the basic rocks thus affected, as at Duluth, at Wauswaugoning bay, and at Silver Islet. N. H. W.

NO. 607. QUARTZYTE. *(Altered.)*

Pigeon point. Next rock north of No. 606, and underlying it.
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, pages 57, 58.

Meg. The hand sample shows one of the phases of the altered quartzyte of Pigeon point. The sample varies some in grain and color, and is composed of *quartz*, red to gray feldspar, hornblende and chlorite.

Mic. The rock is composed of *quartz* and *feldspar*, which is clouded and more or less red; these two minerals are sometimes intergrown to form micropegmatyte; yellowish-green *hornblende*, *chlorite* and *biotite* are also common, some *magnetite* and a few almost opaque rough rods, whose exact nature is not clear. Two sections.

Age. Animikie. U. S. G.

NO. 608. QUARTZYTE. *(Metamorphosed.)*

Pigeon point. Apparently a modification of the quartzytes. Lies below No. 606.
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, pages 57, 58.

Meg. Fine grained, reddish, quartzose. (See figure 30.)

Mic. The abundant *quartz* grains are wholly the result of regeneration and rearrangement of the quartz of the original clastic rock. About one-third of the rock is of other material, viz.: *feldspar*, containing many inclusions, seldom showing a polysynthetic striation, *biotite*, sometimes greenish, these two embracing the quartzes as in a pervading matrix, and accommodating themselves to their forms. The red color of the rock comes from the hematite which stains the feldspar.

Age. Altered Animikie. N. H. W.

No. 609. QUARTZYTE. (*Metamorphosed.*)

Pigeon point. Similar relation to the dike No. 605, but further from it than No. 608.
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, pages 57, 58.

Meg. The weathered surface is spotted irregularly with red and gray. The interior is spotted in the same way, but in some places, on fresh fracture, appears like a red granite.

Mic. The elements of the clastic rock seem to have been wholly recrystallized, in some parts of this rock. The *quartz* shows no remaining traces of evident clastic origin, but is angular and fresh, its form being imprinted in the surrounding feldspathic portion. The feldspathic portion is red and was later to take position than the quartz. It is so clouded with ferruginous matter that it can simply be said to be crystalline, darkening regularly, but its cleavage and striation of twinning (if it had it) are invisible. It is presumed to be orthoclastic. While these compose the most of this rock, it also contains *biotite* and *chlorite*, while *hematite* serves as pigment generally. One section.

Age. Animikie. N. H. W.

No. 610. QUARTZYTE. (*Metamorphosed.*)

Pigeon point. Near the same place as the last, but further from No. 605.
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, pages 57, 58.

Meg. This rock is very similar to the last, but has more of the red element.

Mic. The microscopic characters are not observably different from those of No. 609. One section.

Age. Animikie. N. H. W.

No. 611. QUARTZYTE. (*Metamorphosed.*)

Pigeon point. Near the same place as the last, but further from the dike No. 605.
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, pages 57, 58.

Meg. This is a more crystalline rock, appearing like an imperfect red syenyte.

Mic. Along with the foregoing minerals mentioned in No. 609, can also be seen here a striated *feldspar*, much stained with the same ferruginous substances, and a single angular small grain that resembles *sphene*. One section. (See figure 30.)

Age. Animikie.

Remark. As the metamorphism increases in receding from No. 605, it is probable that it is not due, on the north side of the dike, wholly to that dike, but rather to the main dike or axis of Pigeon point, which, however, is not visible at this place. These rocks, from No. 606, succeed each other in a downward order of apparent stratification, receding northward from the dike No. 605. N. H. W.

No. 612. QUARTZYTE. *(Metamorphosed.)*

Pigeon point. Near the same place, at the little bay at the south end of the "Little portage."
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, pages 57, 58.

Meg. Appears like the last but perhaps is more uniformly crystalline and uniform in grain, and in color, though not so red as the last.

Mic. Reddened *feldspar*, occasionally striated, is the most abundant element. *Quartz* is also abundant. Next is mica, apparently *muscovite*. These three are mutually interlocked in a granitic fashion, one being occasionally isolated within a mass of the other. The mica sometimes is replaced by a greenish fibrous or plated mineral, probably chloritic, with low double refraction and strong pleochroism. In some considerable areas *pennine*, finely fibrous, with a dark-blue color of double refraction is closely mingled with the feldspar and with the muscovite. These, with a few grains of *sphene* and the coloring matter *(hematite)* constitute the rock.

Age. Modified and crystallized Animikie.

Remark. The relations of Nos. 607–612 to the dike and to the quartzyte cannot be stated positively, for the whole situation is confused, yet the position of the beds from which they are derived is such that they would succeed each other in descending order northward. No. 604 seems to be the quartzyte hardened. It forms a surface sloping to the lake. It is cut by No. 605, but as No. 605 rises five or six feet above the lake it comes in contact on the north side with No. 606, which while so situated as to be the apparent continuation of No. 604, has a very different lithology. It is more like the rock No. 603, in its color and outward general character, but differs microscopically. It is coarser grained than No. 604, but has free quartz and hornblende. No. 606 overlies the numbers following to No. 612. These last cannot be said unqualifiedly to come in the order numbered, but probably do approximately. The layers are in strata that dip south or southeast, weathering out thin-bedded. The samples did not come from successive beds, but rather at increasing distances along the beach, somewhat descending in the strata. The most fragile of these layers (Nos. 611 and 612) are at once followed by the pebbly beach where the portage trail passes over to the north side. It was doubtless owing to the occurrence of these soft beds, which rot and easily chip into pieces under the action of the water and ice of the lake, that the break-down in the peninsula occurs here. They are due therefore to the action of the main dike which forms the axis of Pigeon point, rather than to the dike No. 605 in contact with which they are found at the south side of the point. This would imply the existence of a fault at the north side of the dike No. 605, running parallel with it. (Compare figure 100, vol. iv, report on the Pigeon Point plate; repeated above by figure 30.) N. H. W.

No. 613. Quartzyte. *(Metamorphosed.)*

Pigeon point. West side of the little bay at the south end of the "Little portage."
Ref. Annual Report, ix, pages 69, 70; Annual Report, x, page 58.

Meg. Rock is gray, but otherwise appears much like some of the foregoing.

Mic. There is a trace of the clastic origin of some of the quartz grains in this slide. They have interior forms outlined by lines of impurities, on which later growth of quartz has taken place, both parts extinguishing at the same instant.

One section.

Age. Animikie. N. H. W.

No. 614. Diabase.

Pigeon point. At the extremity of the west point of the little bay from which the "Little portage" starts, south side of Pigeon point.
Ref. Annual Report, ix, page 69; Annual Report, x, page 58.

Meg. Fine grained, nearly black, resembling No. 604.

Mic. The rock consists of the elements of the diabases of the country, at least *augite*, microlitic *feldspars*, the former being cotemporary or earlier in date than the feldspars, and of *magnetite*.

One section.

Age. Sill(?) in the Animikie.

Remark. The outward resemblance of this rock to No. 604, and its similarity of position with respect to the little bay, one on either of the points that enclose the bay, would lead one to consider them of the same rock mass. But one is a hardened clastic, and the other is a finely crystalline irruptive. This idea would not be weakened by the fact that a coarser diabase dike cuts each of them. The dike which cuts this point, however, has not the direction of that cutting the other point, but runs into the lake southeast, while the other seems to run into the bay, lying to the north of this. This dike, moreover, is about one-third the width of that. N. H. W.

No. 615. Diabase.

Pigeon point. Dike twelve feet wide which cuts No. 614 above.
Ref. Annual Report, ix, page 69; Annual Report, x, page 58; Bulletin ii, page 108.

Meg. Medium-grained diabase.

Mic. This rock, which is rather fresh, shows, like numerous others that have been examined, two generations of *augite*, viz.: one is earlier than the plagioclases, and is considerably decayed, and the later is fresh and ophitic, though occasionally a little diallagic. This distinction is not sharp. The section also shows some *quartz* in large isolated grains.

One section.

Age. Cabotian(?) dike. N. H. W.

No. 616. QUARTZYTE. *(Metamorphosed.)*

Pigeon point. West side of the same little bay, north of the last.
Ref. Annual Report, ix, page 69; Annual Report, x, page 58.

Meg. Spotted red and dark gray, medium grained. An incipient granite, resembling some rock on the east side of the bay.

Mic. *Quartz* is abundant, but the matrix of the grains is stained red with oxide of iron. The *feldspars* are unidentifiable as to species. N. H. W.

No. 617. QUARTZYTE.

Pigeon point. From near the base of the hill about half a mile west of the "Little portage," at the south shore.
Ref. Annual Report, x, page 58.

Meg. A brown, hardened sandstone.

Mic. *Quartz* grains, in a reddened cement, compose the most of this rock, but amongst the latter may be seen some fibrous grains that are *chloritic* or *hornblendic*, as well as some of *mica*.

One section.

Age. Animikie. N. H. W.

No. 618. QUARTZYTE. *(Metamorphosed.)*

Pigeon point. Near the summit of the same hill.
Ref. Annual Report, x, pages 58, 59.

Meg. Gray quartzyte.

Mic. This rock contains much granular *quartz*, constituting about two-thirds of the whole, and some fine grains of *plagioclase*. Owing to the presence of several *hypersthene* crystals, which are, so far as discovered hitherto, characteristic of the contact belt between the basic irruptives and the clastics of the region, as well as the existence of remains of older plagioclases, this rock may have originated as one of the "intermediate rocks" (of Bayley), *i. e.*, it may have solidified from a new magma produced by the fusion of some of the sedimentaries and the mingling of this matter with the magma that rose from a deep source. The gray color of the rock is not in keeping with that of the rock that results from the simple metamorphism of the clastics, which produces a red rock. At least, hypersthene, as a mineral of the basic rocks when cooling near the reactionary rim of the clastics, seems to point to this rock as a changed basic rather than as a changed quartzyte. One section.

Age. Animikie at contact on a Cabotian intrusive. N. H. W.

No. 619. Granite. *(Porphyritic, granophyric.)*

Pigeon point. From the same hill as the last, but from the south side where the structure is basaltic. Compare No. 1845.

Ref. Annual Report, x, page 59.

Meg. Red, granitic rock, somewhat porphyritic with feldspar and with quartz.

Mic. The *quartz* permeates the *feldspars* in a micrographic manner, which is sometimes spherulitic. It also forms many grains which are sometimes aggregated like the grains of a fragmental quartzyte. Quartz phenocrysts of much larger size also appear, forming bipyramidal crystals like those of a quartz-porphyry. Occasionally such phenocrysts show embayments into which the molten rock entered. In one such case is seen a beautiful illustration and demonstration of the very early origin of the granophyric and pseudo-spherulitic structure. This is illustrated by figure 11 of plate I. The embayment was filled with the original (molten?) magma, and on consolidation this has also become crystallized and has assumed an imperfectly granophyric structure. This is continuously traceable through the neck of the embayment and into the surrounding rock mass, and in the latter the same structure is developed on a more perfect scale. It is impossible but that the material filling the embayment and that surrounding the phenocryst were in the same molten condition at the same time. They must have assumed simultaneously these low crystalline structures at once on consolidation, or very soon thereafter. If the consolidated matter were at first glassy, and this structure were then developed as a result of devitrification it might be considered a secondary structure, but it was probably not glassy, since in the near vicinity of this quartz phenocryst, and generally distributed through the section, are other minerals whose outlines are confusedly linked in with the outlines of the granophyric figures. These are *biotite* and an occasional indistinct form of *feldspar*. There are also many quartzes, as already mentioned, which must date from the second consolidation. The section illustrates one of the steps in the transition from a quartz-porphyry to a granite, being not fairly referred to either. One section.

Age. Acid Cabotian.

Remark. In the foregoing it is assumed, as is usual, that the existence of bipyramidal quartz crystals is demonstrative of the former molten condition of the quartz-porphyry in which they occur; and that is perhaps assuming too much, inasmuch as such crystals are known to arise in the aqueous transformation (with heat) of quartzytes of Pigeon point in portions adjacent to the great dikes, and in which there is no possibility of a former molten condition, since the most of the rock retains its rounded clastic grains. This rock may therefore have resulted from a clastic which was transformed by hot solutions, but was not molten, and hence the quartz phenocrysts may be of secondary origin. N. H. W.

No. 620. Aporhyolyte.

Eastern palisades.
Ref. Annual Report, ix, page 58; Annual Report, x, page 59. Compare No. 230.

Meg. The hand specimen is red in color, and is much fissured and in places decayed. Small porphyritic quartzes and feldspars are embedded in an aphanitic groundmass which shows distinct flow structure.

Mic. In section the *quartz* phenocrysts are seen to be much corroded and sometimes show embayments of the groundmass. The *feldspar* phenocrysts are highly altered and reddened and their species cannot be determined. The groundmass is brownish red in color and in places appears homogeneous under a low power, but under a high power it is seen to be not glassy, but is probably composed of very minute quartzes and reddened feldspars, the product of devitrification. Some areas show larger quartzes, probably of secondary origin. Another section shows the groundmass to be composed of small, irregular quartz areas holding the feldspathic part of the groundmass poikilitically.

Two sections.

Age. Cabotian. U. S. G.

No. 621. Mesolite, etc.

Gathered from the beach at Lover's bay, S. W. ¼ sec. 32, T. 61-1 W. (compare Annual Report, ix, page 50).
Ref. Annual Report, x, page 59.

Meg. These pebbles are somewhat varied, but are of a light or pinkish white color. They may be compared to Nos. 535B and 535C, and are probably from the same general trap-sheet, which was apparently a surface flow, extending from Cascade river, at least, to Good Harbor bay.

No section.

Age. Manitou. N. H. W.

No. 622. Stilbite, Mesolite, etc.

Mouth of False Poplar river; from the rock.
Ref. Annual Report, x, page 59.

Meg. These zeolites have the color and cleavage of stilbite, and embrace a small amount of what appears like mesolite.

No section.

Age. Manitou. N. H. W.

No. 623. Diabase.

From the upper layer of the point that encloses Eclipse beach on the east. This is two and a half feet thick.
Ref. Annual Report, ix, page 49; Annual Report, x, pages 59, 60.

Meg. Medium grained, greenish gray, non-amygdaloidal, but chloritic from decay, *Mic.* The section shows an ophitic rock, but interspersed in the mass of the rock are areas filled with a very fine aggregately polarizing substance, and others that are green in common light. The former are quite translucent in common light, but nearly dark between crossed nicols, though crypto-crystalline. The latter, green in common light, are occasionally so macro-crystalline that they lighten and extinguish throughout their whole area.

The green areas are largely derived from alteration of the original *olivines*, but not wholly, for some of them appear to be associated with *augite* of the first generation. *Bowlingite* is probably the mineral which, when greenish, or brownish, still gives distinct general extinction.

Thomsonite and some *saponite* (thalite) also are seen in this section.

One section.

Age. Manitou (same as the rock forming Terrace point). N. H. W.

No. 624. Amygdaloid.

Underlying No. 623. This bed, by its easy disintegration, forms two small harbors, one protecting from the northeast, and one from the southwest. This bed is about eight feet thick, but varies some, as the characters of No. 623 fluctuate up and down.

Ref. Annual Report, x, page 59.

Meg. Brownish red, fragile, charged with thalite and laumontite, both in the rounded cavities and in veins.

Mic. An ophitic structure is apparent, but some of the *augites* also preceded the *feldspars*. The olivine is either entirely lost or remains only in the form of a brownish mineral, resembling *bowlingite.* Occasionally a distinct cleavage perpendicular to the extinction is visible in this mineral.

One section.

Age. Manitou. N. H. W.

No. 625. Diabase.

Eclipse beach, sec. 26, T. 60-3 W. From this bed are derived the "thomsonites" of Eclipse beach. Thickness cannot be made out, as it forms the coast line eastward. It has a close relationship with Nos. 623 and 624, and in many places they probably could not be separated from each other stratigraphically. At this point, however, No. 625, in general, lies below Nos. 623 and 624. It is nearly, if not exactly, on the same horizon as the amygdaloid at Terrace point, judging from the run of the beds as they extend along the coast from that place. The same horizon extends to Poplar river without much deviation.

Ref. Annual Report, ix, page 49; Annual Report, x, page 60.

Meg. The rock itself is dark green, amygdaloidal, but not so easily distintegrating as No. 623. It is blotched with fine and coarse thalite masses, which are frequently coated with a red scale of some zeolite, perhaps of heulandite. It also embraces the mineral which has been generally known as thomsonite, but which does not exhibit the optic characters of that zeolite. This is sometimes in large masses.

Mic. This rock, or others like it, has been described already. It is ophitic, the *olivine* is not preserved, but has contributed to the formation of the abundant *thalite.*

Owing to the abundance of this green substance, which is crypto-crystalline and has replaced some earlier idiomorphic mineral, it is probable that *augite* of an earlier generation has shared in its formation. The later augites are well preserved. They embrace many microlitic *feldspars* and occasionally some of the thalite areas. It is to be noted also that, while most of these green areas have shapes showing they are changed from an early generation of some mineral, either olivines or first augites, there are a few that are ophitic in their relation to some of the feldspars. These probably resulted from an alteration of small portions of the magmatic residue. This is evident from the fact that the ophitic augites are all quite fresh. *Heulandite* appears in clear grains in the slide.

One section.

Age. Manitou. N. H. W.

No. 625A. Mesolite.

Picked from the rock at Eclipse beach.
Ref. Annual Report, x, page 60.

Meg. Strongly but finely radiated, pinkish white, filling large cavities in the trap (No. 625). The fibres are strong, straight and rigid, but fine, differing from those of thomsonite and scolescite, which are coarser and have a glassy reflection and greater transparency.

Some of the masses of this mineral are three or four or even ten inches across; but in the case of large masses the mineral lies rather in sheets with radiating points on the upper and lower contact surfaces. Some large masses two inches across have also two or three points of radiation. When polished on the beach the pieces that result from the disintegration of the larger masses are pyramido-triangular, but there are also many round and oval which have not been broken on separation from the rock. These show the circular radiating eyelets of different colors on the outer surfaces when polished on the beach. The colors are pink, red, white and green—at least the same green mineral is found here, always smaller than the others, as is found at Terrace point. This green mineral ("lintonite") often surrounds the pink and white radiating masses. It is itself not evidently radiated, the radiations of the mesolite penetrating it. Sometimes little nests and rosettes of lintonite grow in the mesolite, prevailingly about the peripheries of the mesolite masses.

Mic. In very thin section this mineral is nearly unresponsive to all changes of the stage, whether in parallel or convergent light. All the sections made from this number seem to contain two minerals very intimately intermixed. The sub-opaque white fibres are interspersed with parallel translucent ones, but between crossed nicols these translucent fibres are constantly dark and are generally much coarser than the sub-opaque ones. Indeed these transparent larger fibres show geometric crystalline forms. They lie in and also cut obliquely or even perpendicularly across the mass of the finer fibres. Their cross sections are quadrilateral and sometimes rectangular, in proportion as they are cut more or less obliquely. The fine opaque fibres are so densely compact that their crystalline forms cannot be made out. These both have positive elongation. Between crossed nicols the fine fibres are the only illuminated portion of the section, as enough light gets through to render them distinctly separable from the transparent fibres which in that condition are wholly dark. In natural light, however, the larger transparent fibres are the more illuminated. The mass of finer fibres, which are sub-opaque, are seen to be charged with minute dark impurities, and these are sometimes so large as to indicate that they are iron-stained, and are probably due to partial decay. The larger, transparent fibres are free from such impurities, but show a scant cleavage nearly or or quite perpendicular to the elongation. The specific gravity of this substance is 2.26.

Micro-chemical test (Boricky) gives evidence of the presence of considerable soda, along with lime, or lime and magnesia. The rods (hexagonal) of fluosilicate of soda are innumerable, but so fine that they are likely to be overlooked in the presence of the conspicuous monoclinic crystalliths of the alkaline earth. They are brought out to view by removing the upper nicol and lowering the lower nicol, when they seem to equal, if not exceed, in total amount, the crystalliths of lime. This prevalence of soda indicates a zeolite of the natrolite group, in which Dana has only three recognized species, viz.:

Natrolite (or mesotype).
Scolescite.
Mesolite.

These are all subject to ready alteration and to partial or total loss of the power to polarize light.

1. Natrolite is orthorhombic.
2. Scolescite is monoclinic.
3. Mesolite is monoclinic (or triclinic, Descloizeaux).

The first contains soda only as a base; the second contains lime only, and the third has lime and soda. The Boricky test determines this of these three, to be the last, viz.: *mesolite.*

It seems quite possible, if not probable, that two zeolitic minerals of the natrolite group of Dana are here concerned, viz.: mesolite the finest and somewhat altered, and *mesotype* the clear and transparent, the latter being older than the former. Both kinds of fibres have a close striation or parallel cleavage, and a distant fissuring perpendicular to their elongation.

Age. Manitou.

Remark. These numbers (625A and 625B) also cover other zeolitic minerals.

N. H. W.

No. 625B. Scolescite, Thomsonite(?), Lintonite, etc.

From the same place as No. 625A, but gathered from the beach.

Meg. Structure and general appearance the same as of No. 625A.

Mic. A good section made by Marchand, shows two minerals closely mixed. One has sharp, rigid fibres, which pierce the other, running through several individuals, forming about one-half of the whole. This is of low double refraction, negative elongation and oblique extinction, and can be safely taken to be *scolescite* or *mesolite.*

The other mineral is so thickly pierced by the fibres of the former that it appears to have a similar fibrous structure, but that is illusory. Still, when the coarse fibration is wanting in any one of these grains, this mineral nevertheless reveals a very fine and dense fibration by reason of the black bars of a cross which it gives between crossed nicols, which remain on rotation of the stage. These fine fibres, which also give to the grains an imperfect elongation and which are invisible even on lowering the condenser, have a positive elongation. The axial plane is parallel to these fine fibres, and the optic angle is so small that the bisectrix n_p appears like a constant black cross, only being dislocated sufficiently to detect the opening between the hyperbolas. It occurs, hence, that some of the broad longitudinal sections are nearly dark continually, and some show color. The double refraction appears to be but little more than that of quartz; yet, when, in some parts of the slide, the axis n_m is perpendicular, the color reaches yellow or yellowish red. This may be due to variation in the thinness of the section. The mineral contrasts greatly with the fibres which pierce it, in its range of coloration and of light which pierces it parallel to n_m, and especially in its habit, which is blunt, roundish, spreading, and, as cut in the slide, approximating granular. It might be mistaken for quartz, were it fibrous and not biaxial with n_p in the acute angle, or for thomsonite were not its axial plane parallel with its elongation. Some of its forms are very much like the spreading fans of thomsonite. It remains unidentified. (Compare thomsonite found on Isle Royale, Nos. 573 and 575.)

The slide also shows a little lintonite, and another contains only lintonite.

Some of the pebbles from the beach are small, hard, fine grained and light green in color. They consist of *lintonite.* They have n_g for acute bisectrix, the optic axes being very nearly together (2 E=about 60°), the elongation is positive and negative, and hence, the axial plane is transverse to the elongation, resembling thomsonite in that respect.* The double refraction of lintonite is but little more than that of quartz. For the purpose of making an approximate measure, a slide was prepared on which were ground simultaneously, to the same thinness, four plates of barite,

*In a discussion of lintonite in the *American Geologist,* vol. xxii, p. 349, the writer inadvertently stated that the axial plane of this mineral is parallel to the elongation.

two of scolescite and a pebble of lintonite, the last being in the centre. In the fine, short-fibred lintonite the highest color, being that presented by sections parallel to the axial plane, compared with the color given by barite in the same position, showed that the double refraction of lintonite is about 0.017 to 0.018, that of thomsonite being 0.028. A comparison with scolescite cut in the same position gave the same result. The single refraction of lintonite is also less than that of thomsonite. Its specific gravity is 2.372.

In a thin section of lintonite the negative fibres are more light than the positive, the latter being nearly dark. Indeed, the negative fibres are nearly as highly doubly refractive as those which present n_m, and can be distinguished from them only by their shapes, the n_m sections being squarish. Five sections.

Age. Manitou. N. H. W.

No. 626. AMYGDALOID AND TUFF. *(Submarine.)*

About midway between Poplar and Temperance rivers (Nos. 177 and 178). This lies in regular beds of a few inches, or less than an inch, like a sedimentary rock. The specimens may represent the red amygdaloid of several miles along here, though the sedimentation is not so plain in all cases. Over these layers is a heavy bed of trap, massive or coarsely jointed, which forms arched purgatories and tables extending into the lake, the amygdaloid being eaten out by the friction of the beach line under the action of the waves.

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

Meg. Pinkish, red, or brownish, specked with laumontite, and sometimes largely made up of secondary minerals, frequently zeolitic. Evidently consisting principally of eruptive matter originally, perhaps in the form of coarse ash, but distributed by water. Some parts, however, are completely pumiceous, the cavities filled now by laumontite. Fragmental, red, shaly matter is mingled confusedly more or less in these layers. Probably represents the so-called "ash-bed diabase."

Mic. The fine, rusty, groundmass is crowded with micolitic *plagioclases.* In many spaces, which appear to have been occupied originally by porphyritic feldspars, are grains of *laumontite* whose optic axial angle (2 E) is quite small, apparently not over 10°, which causes the interference figure in convergent light to present, on rotation, a deceptive approach to the manner of revolution of a unaxial interference figure. The axial plane is parallel with the fibration, and consequently some of the grains show the bisectrix n_p and some n_m, while the most of them are cut intermediate between those axes; and the elongation is hence continually positive.

There is also a sparse representation of what appears to be a *pyroxenic* mineral. The section being of a thickness of about .035 millimeter, the highest polarization color of this mineral is greenish blue, the fringes running downward through red and yellow, thus indicating *augite.* It is a remarkable illustration of the preservation of that mineral in the same mass where the original feldspars are wholly replaced by a zeolite. One section.

Age. Manitou.

Remark. This thin section, necessarily from one of the more firm parts of this rock, does not bring out the fragmental characters. N. H. W.

No. 627. Diabase. *(Amygdaloidal.)*

Three-fourths of a mile west of Cross river. Forms an arched rock at the shore.
Ref. Annual Report, ix, page 32; Annual Report, x, page 61.

Meg. This rock is hardly amygdaloidal, originally, but it contains many grains of secondary minerals, such as *stilbite*, *heulandite*, *thalite* and *calcite*, making partially a pseudamygdaloid.

Mic. The rock is ophitic, with large *augites* which embrace numerous *plagioclases*. The *olivine* is replaced by opaque ferruginous products. *Thalite*, with a very finely fibrous structure, fills some spaces.

One section.

Age. Manitou. N. H. W.

No. 628. Diabase. *(Gabbroidal.)*

Mouth of Manitou river. At this place about thirty feet of trap that shows red surfaces in falling to pieces, lies on an amygdaloid conglomerate, the two together forming precipitous bluffs on either side of the river, with lower stretches where the trap, which is somewhat basaltic, runs unbroken down to the water. This kind of coast extends east at least to the west point of Pork bay and west to Little Marais. (Compare No. 160.)
Ref. Annual Report, ix, pages 41, 42; Annual Report, x, pages 61, 63.

Meg. Compact, medium grained, gray or grayish brown, with a slight tint of chloritic green.

Mic. The rock is not ophitic, yet the numerous *augites* were mainly thrust aside by the generation of the *feldspars* so as to lie thickly alongside of the feldspars in a pseudophitic embrace and are sometimes embraced within the feldspars. The *olivine* is charged and the feldspars are stained by chloritic accumulations.

One section.

Age. Manitou.

Remark. This rock was probably a surface flow, and assumed a basaltic columnar structure in part, on cooling. A few small porphyritic augites can be seen in the hand sample, but none are cut by the slide. N. H. W.

No. 629. Conglomerate.

Mouth of Manitou river.
Ref. Annual Report, ix, page 41; Annual Report, x, pages 61, 63.

Meg. Crumbling, soft, red, amygdaloidal, the form and original structure of the pebbles being obscured or lost. The pebbles are mainly of basic and sometimes apparently of amygdaloidal trap, but occasionally they embrace a piece of red shale.

Mic. The section, which is too thick, shows a scoriaceous rock, in the vesicles of which are *laumontite* and *calcite*.

One section.

Age. Manitou. N. H. W.

No. 630. Diabase.

Two miles west of Little Marais point; forms perpendicular cliffs. Resembles the rock of Eclipse beach.
Ref. Annual Report, ix, page 41; Annual Report, x, page 62.

Meg. Grayish, with medium grain.

Mic. Ophitic, and charged with *thalite.* The olivine is lost. The abundant thalite in a thick section shows, along with parallel extinction, a coloration about the same as the plagioclase, but a trifle higher.

One section.

Age. Manitou.

Remark. This probably lies below the Little Marais conglomerate, since the heavy trap sheet on the east point of Little Marais, which lies on the conglomerate, strikes (westward) from the shore at an angle and disappears in the lake, letting the western shore line on to lower strata.

No. 631. Amygdaloid.

Same place as No. 630.
Ref. Annual Report, ix, page 41; Annual Report, x, page 62.

Meg. The cavities are filled with *thalite* and *calcite,* the latter lying frequently within the former.

Mic. The rock is ophitic, and was evidently the superficial portion of an eruptive flow. One section.

Age. Manitou. N. H. W.

No. 631A. Basalt (?)

From No. 631. Occurs in the form of veins accompanied by stilbite and calcite. Seems to be foreign to No. 631.
Ref. Annual Report, x, page 62.

Meg. Very dense, brown or reddish brown.

No section.

Age. Manitou. N. H. W.

No. 632. Basalt.

From a point of rock on sec. 29, T. 57-6, separated from the green trap No. 630 by a conglomerate thirty-five feet thick. Thickness, twelve feet.
Ref. Annual Report, ix, page 41; Annual Report, x, pages 62, 63.

Meg. Dark, brownish red, dense, blotched with red, on account of the red partings along all the joints, crossed by siliceous red seams and veins like those seen in No. 631, and contains large lumps and geodes of quartz.

Mic. The minute *feldspars* and *augites* lie in an abundant *residuum* of the magma, which appears to have been consolidated as a *glass*, but is now filled with indistinct crystalliths.

One section.

Age. Manitou. N. H. W.

No. 632A. Clasolyte.

From a point about half a mile west of No. 630.
Ref. Annual Report, x, page 63.

Meg. Vein about half an inch wide, composed of a central band about one-fourth of an inch wide of hard, granular substance of a brown color, and on each side a band of reddish "chalcedonic" quartz, each about an eighth of an inch wide. The first appears to be composed of fine clastic materials, but the quartz band on either side of it is evidently of chemical deposition and is in wavy layers similar to the layering in agates.

Mic. The framework of the clastic grains is dark with iron oxides. The grains are partly of *quartz* and partly of *plagioclase*, and there are occasionally areas of greenish thalite (?) These grains are sometimes rounded and sometimes angular.

One section.

Age. Manitou.

Remark. The term clasolyte is adopted from Wadsworth (Michigan Geological Survey Report, published 1893, page 147), which is applied by him to a fragmental rock which fills fissures in an older rock from above. N. H. W.

No. 632B. Quartz. (*Geode.*)

In the same beds as No. 632A. Quartz geodes in basalt, with some amethyst and agates. Lying just above a conglomerate.
Ref. Annual Report, x, page 63.

Meg. The specimen consists of the quartz crystals of a siliceous geode presenting their terminal facets, becoming massive quartz and finally agate-like bands, the last serving as attachment to the basalt in which the geodic mass was originally formed.

No section.

Age. Manitou. N. H. W.

No. 633. Amygdaloid.

Immediately underlies No. 632. Thin, irregular beds of amygdaloidal trap containing red amygdules graduating into No. 634.
Ref. Annual Report, x, page 63.

No section.

Age. Manitou. N. H. W.

No. 634. Amygdaloid.

Immediately underneath No. 633, near the top of the conglomerate.
Ref. Annual Report, ix, page 41; Annual Report, x, pages 63, 64.

Meg. Contains agate, stilbite, laumontite and chlorite. The red coatings, which are apparently of heulanditic material, prevail along the red seams that cross and recross the rock. In some cases the red material penetrates the whole, and is disseminated generally through the mass, especially coating the amygdules and sometimes filling them.

No section.

Age. Manitou. N. H. W.

No. 634A. Heulandite, etc.

Amygdules picked from No. 634. They consist of heulandite, agate, stilbite, calcite and thalite(?)
Ref. Annual Report, x, pages 63, 64; Annual Report, xi, pages 171, 181.

Meg. These vary in size from that of a mustard seed to masses two or three inches across. They are usually coated with red.

Heulandite, which, though resembling stilbite, is distinguished from it readily by the interference figure, which is that of a bisectrix, which its cleavage plates afford in convergent light, is the most abundant of these amygdaloidal minerals. Its cleavages give a bright, even silvery, lustre, and they are so small sometimes that they can only be discerned with a magnifier. This mineral fills some large openings in the rock. It also becomes granular and then is reddened by ferric oxide, and in this condition it gives color to large surfaces, lining veins, coating the globular bodies that are detached from the rock and at the same time coloring more or less the molds from which they are loosened.

Stilbite is in large masses and also becomes red, passing through a light flesh-red tint. It also becomes confusedly lamello-fibrous, and fibrous with radiated structure, when it presents the characters of *puflerite*, and in this form it also coats the outer surfaces of the detached amygdules, except that the fibrous structure is then not so perfect, passing, probably in association with more or less of heulandite, to finely granular. A thin section cut so as to cross both the lamellar and the reddened and fibrous portions indicates that the whole is still in more or less distinct lamellæ, which always show a negative elongation, but lose their optic characters in places in consequence of the prevalence of much *hematite.*

The stilbite is in large masses. Sometimes its undulating cleavage surfaces give a colored iridescence, which is doubtless owing to the action of the highest double refraction, which takes place perpendicular to the cleavages. This phenomenon is not observed in heulandite.

The siliceous secretions are in the forms of banded agate and coatings. A banded, agate-like layer frequently was the first deposit on the walls of the cavities, particularly the larger ones. Next within this is frequently stilbite, but between the banded siliceous layer and the stilbite is also frequently a band of massive or granular quartz. The globular agates are finely and exquisitely striped.

In a thin section, which is mainly red, a greenish thalite(?) is permeated and pierced by slender spicules of red hematite(?)

Age. Manitou.

Remark. The association of these trap sheets with amygdaloidal conglomerates and fine crumbling clastic material, which is wholly wanting, so far as known, from the Animikie, is the guide to their age.

Prof. J. A. Dodge made an analysis of this red mineral with the following result (Annual Report, xi, page 171):

		Oxygen.		Oxygen ratio.
Silica,	62.73	33.45		14.61
Alumina,	13.62	6.35	6.87	3.00
Oxide of iron,	1.75	.52		
Lime,	5.87	1.67	2.52	1.10
Magnesia,	.65	.26		
Soda,	1.83	.48		
Potash,	.68	.11		
Water,	12.25	10.89		4.71

The composition seems to bring this mineral under the species *mordenite*.

N. H. W.

No. 635. Basalt.

Immediately underlies No. 634. Nos. 633, 634 and 635, together, have a thickness of only three or four feet, and are variously affected by proximity to the conglomerate. They seem to have constituted a single thin lava sheet. This rock also has stilbite of the fibrous kind above mentioned. Heulandite coats all seams and joints.
Ref. Annual Report, ix, page 41; Annual Report, x, pages 63, 64.

Meg. The rock is dense and nearly black, though sparsely vesicular.

Mic. Resembles rock No. 632.

Age. Manitou.

Remark: There are here three beds of crumbling conglomerate separated by trap sheets which were surface flows, cotemporary with the accumulation of the conglomerate.

N. H. W.

No. 635A. Amygdaloid.

A part of No. 635.
Ref. Annual Report, x, page 63.

Meg. Coarsely amygdaloidal with all the minerals mentioned under No. 634A, the agates being conspicuous and producing a knobbed exterior surface.

No section.

Age. Manitou.

N. H. W.

No. 636. Granite. *(Pegmatitic.)*

Sec. 1, T. 56–7. Makes a high point with a perpendicular face toward the south. It occupies but a small area at this place, but appears at a number of other places along this part of the shore, and on one or two islands. Compare Nos. 119, 134, 157, 526 and 643.
Ref. Annual Report, ix, page 40; Annual Report, x, pages 64, 66.

Meg. Light-red, very quartzose granite, with no apparent ferro-magnesian minerals, but with small inclusions of what appear to be portions of a basic porphyryte (xenoliths). The coarseness of the grain varies much.

Mic. The *quartz* and *feldspar* have a coarse micro-pegmatitic structure, each mutually surrounding areas of the other, the adjacent portions extinguishing in unison. The feldspar is much obscured by oxide of iron, but it can be observed that extinction is about parallel to the cleavages, indicating *orthoclase*.

There is also a small amount of accessory *epidote*, and apparently of *biotite*.

Two sections.

Age. Cabotian.

Remark. This rock might be called pegmatyte, except for the fact that is in a massive bulk instead of being in form of a vein. It was probably formed by solution rather than fusion. It may represent a transformed basic rock. N. H. W.

No. 637. Labradorite. (*Anorthosyte.*)

From a large detached mass, one of several at the west point of Beaver bay (see No. 120).
Ref. Annual Report, ix, page 32; Annual Report, x, pages 64, 140; Bulletin vi, plate XV; Final Report, vol. i, pages 196-199; American Association for the Advancement of Science, vol. xxx, page 163.)

Meg. Gray, coarse, fresh, glittering with cleavage surfaces, one of which is an inch in length. Consists apparently wholly of feldspar.

Mic. The section shows nothing but *labradorite* feldspar, except as accessories, along a fissure, some ferruginous accumulations and *calcite.*

It is hardly necessary to repeat observations on this feldspar. The plate at hand is large and presents a beautiful section of this beautiful rock. However, in a slide, 010 gives extinctions in three different crystals, respectively 20°, 24° and 31°. There are no good sections, n_p or n_g, but in one instance an oblique section on n_g gives extinction at 54°, and one on n_p, at 55° 30′, both indicating *anorthite.* Still, the preponderance of evidence is in favor of a labradorite, as before.

Three sections.

Age. Cabotian. N. H. W.

No. 637A. Thomsonyte and Mesotype.

From seams in No. 637. This mineral comes off the joint surfaces of the rock No. 637 as a scale about a quarter of an inch thick, but sometimes half an inch.
Ref. Annual Report, x, page 64; Annual Report, xi, pages 172, 181.

Meg. Light flesh-colored or white, finely fibrous divergently, with numerous points from which the fibres radiate, situated in the walls of the fissure. Thus the growths from opposite sides of the fissure meet along the centre of the seam. Scattered calcite crystals were formed on the walls of the fissure before the zeolite was deposited, and these were then buried under the zeolite. On weathering out they leave their hexagonal impress as molds in the compact and hard zeolite.

Mic. This mineral is both positive and negative in elongation, and has rather high double refraction and parallel extinction. It is plainly quite pure. A microchemical test showed lime and soda. The zeolite may therefore be pronounced thomsonite, which is a prevalent mineral in situations where labradorite alone seems to have contributed to its formation.

There is another section, numbered "637A, across the vein," which appears different, and it is probable that one or the other is misnumbered. This mineral has n_g parallel with the fibres, and hence always positive elongation and parallel extinction, with quadrangular basal sections in which n_p runs to the angle, as seen in figure 31, between the sides, as in *mesotype.* (See Dana's System of Mineralogy, figure 1, page 600.) A micro-chemical test of this gives only soda. Prof. Lacroix, in connection with this determination considers this specimen illustrates the same structure as figured by him in Minéralogie de France et de ses Colonies, figure 7, page 265. It is possible both slides are from this vein, but it is not probable. This is the first identification of mesotype in Minnesota.

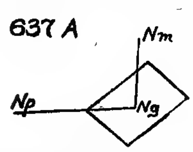

FIG. 31. BASAL SECTION OF MESOTYPE.

Analysis by Prof. J. A. Dodge resulted as follows:

		Oxygen.		Ratio.
Silica,	47.25	25.19		6.47
Alumina,	24.78	11.54	11.68	3.00
Oxide of iron,	.48	.14		
Lime,	1.23	.35	4.52	1.16
Magnesia,	.71	.28		
Soda,	15.05	3.19		
Potash,	traces			
Water,	10.37	9.22		2.37
	99.87			

N. H. W.

No. 638. Diabase.

Rock at the base of Encampment island, on the north side. Compare No. 106.
Ref. Wadsworth, Bulletin ii, page 110; Annual Report, ix, page 28; Annual Report, x, page 64.

Meg. A dark, heavy diabase, rather coarse.

Mic. The ophitic structure is conspicuous, and green spots appear to have resulted from alteration of non-differentiated portions of the magma, as remarked by Wadsworth. The spherulitic polarization which appears in some places in this slide is probably produced by a zeolitic mineral, such as *scolescite.* This radiated fibrous zeolite is surrounded by another, which is probably *thomsonite,* as its confused fibres are elongated, sometimes positive and sometimes negative, and its double refraction is near that of thomsonite.

One section.

Age. Cabotian. N. H. W.

No. 639. Diabase *(with olivine).*

One mile east of the mouth of Silver creek. Forms a high bluff (see Nos. 105, 819.)
Ref. Wadsworth, Bulletin ii, page 104; Annual Report, ix, page 28; Annual Report, x, page 64.

Meg. Similar to the last.

Mic. *Augite* is ophitic with respect to the feldspars, and is fresh; also, in the same manner it surrounds the *olivines,* which are considerably altered to a yellowish green, sub-opaque, or sometimes brownish substance, which frequently goes by the name of serpentine. There is also a considerable amount of the same greenish alteration product which is referable to the original magma. This is ophitic in its relation to the feldspars, and imperfectly so in respect to the augite, yet there are inclusions of it and other microlitic forms in the feldspars, which date probably from the last consolidation of the magma.

In general, this rock, and the last, are fresh, the minerals all being clear and fresh, except for the slight effects of the reactions resulting from the hot waters and gases that accompanied the intrusion and the congealation.

One section.

Age. Cabotian.

N. H. W.

No. 640. Basalt.

At the water level under the hill formed by No. 639, about a mile east of Silver creek. Separated from No. 639 by a red amygdaloid (as seen at Two Harbors*), eighteen or twenty feet thick.

Ref. Annual Report, x, page 64.

Meg. Dense, fine-grained, nearly black rock.

Mic. This rock resembles Nos. 632 and 635. In the section examined, with an abundant matrix of devitrified glass, which is brownish and charged with fine opaque matter *(magnetite?)*, are many microliths of *feldspar*. These are the only identifiable original minerals. No augite nor olivine can be seen. In some areas, however, has been generated secondary *quartz*, which sometimes embraces poikilitically some of the rock matter adjacent. Quartz does not generally permeate the rock, but the undifferentiated magma serves throughout as a cement for the feldspars.

One section.

Age. Cabotian(?)

Remark. It seems likely that this basalt is a thin lava sheet cotemporary with those that alternate with amygdaloidal conglomerates, as noted, westward from Little Marais. (Compare Nos. 629–632; also No. 117.) Still, it may be distinct from them, and may prove to run below the Beaver Bay diabase, by reason of a fault.

N. H. W.

No. 641. Amygdaloid.

Mouth of Knife river at the lake shore.

Ref. Annual Report, ix, page 24; Annual Report, x, page 64.

Meg. Like No. 91. Grayish green, much amygdaloidal, with thalite.

Mic. The section examined is not much amygdaloidal, but exhibits the ophitic structure on a grand scale. The *augite* is considerably altered, but extinguishes sufficiently to show the size and orientation of the crystals, which embrace generally a large number of *feldspar* microliths, comparable to the illustration by Irving in plate IX, of his Monograph on the Copper-Bearing Rocks of Lake Superior. The similarity is still further seen in the existence in both rocks of a large amount of

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*Two Harbors, as here referred to, is not the town of Two Harbors, since established and grown into an important shipping point of iron ore, but a small double bay, known by this name in 1877 and 1878, just west of Splitrock river. The name is here preserved, as it has entered into the literature of the survey, while the locality of Two Harbors (since named) is designated Agate bay, as long known and as referred to in the survey reports.

devitrified glass. A dissimilarity exists in the absence from No. 641 of olivine. Irving's rock is, however, from near the same place, viz.: S. E. ¼ sec. 9, T. 51–12 W., about four miles southwest from the mouth of Knife river.

One section.

Age. Cabotian. N. H. W.

No. 642. GRANITE *(fine and red)*.

"From about one mile north of the centre of T. 62–1 E. on Mayhew's trail;" perhaps in section 17, near the present Grand Marais and Rove Lake road.

Ref. Annual Report, x, pages 66, 67.

Meg. A very fine-grained sample of the red rock; reddish brown on a fresh fracture and brick-red on weathered surfaces. Small reddish feldspars mixed with a greenish and a black mineral and small amounts of quartz.

Mic. The section is composed of *feldspar*, *quartz*, *magnetite* and yellowish and greenish alteration products. The feldspar, as is usual in the red rocks, is clouded and reddened and frequently is developed in lath-shaped forms. It frequently shows a zonal structure which is indicated by the disposition of the reddened parts; some of the crystals have a red exterior, then a band of transparent substance and a centre of red. In one case such a crystal appeared to be entirely replaced by quartz, but this is not the case with all of them. The feldspar shows practically no polysynthetic twinning and appears to be orthoclase, although its species was not determined with certainty. The quartz is sometimes in small grains, but is more usually intergrown with the feldspar to form the micropegmatyte which is so characteristic of these red rocks. One side of the slide shows an area which perhaps represents part of a porphyritic feldspar now highly altered.

One section examined.

Age. Cabotian.

Remarks. The original nature of the rock is not certain, but, if the quartz is assumed to be largely original, the rock would best be called a very fine-grained red granite. U. S. G.

No. 643. GRANITE *(with augite)*.

Hill range in the north tier of sections in T. 62–1 E. Probably near the northwest corner of section 3 on the present Grand Marais and Rove Lake road.

Ref. Annual Report, x, pages 66, 67.

Meg. There are two small hand specimens of this rock. One is of a brick-red color and drusy texture; it is a medium-grained aggregate of reddish feldspar and quartz, the compact mass of feldspar making the quartz appear as almost porphyritic. There are a few feldspars, brighter red in color, which are sub-porphyritic. The other specimen is of the same general character but is of a flesh color. The quartz is not in such prominent grains and there are a few scattered grains of a black mineral (augite). The slides examined were made from this second specimen.

Mic. The section shows one of the usual medium-grained red rocks, the only uncommon feature being the presence of practically fresh, green augite. This occurs in small grains of irregular outlines. The feldspar is the usual clouded, but little reddened, variety and is very intimately and abundantly intergrown with quartz to form micropegmatyte.

Two sections.

Age. Cabotian. U. S. G.

NO. 644. GABBRO. *(Altered.)*

From the top of the hill mentioned under No. 643. Probably from the top of Pine mountain in S. W. ¼ sec 34, T. 63-1 E. This rock may be a dike protruding through No. 643.
Ref. Annual Report, x, pages 66-68; Bulletin ii, pages 79, 80.

Meg. A rather coarse-grained granitoid rock, pale reddish-brown in color, composed of feldspar, a black mineral (augite) and small amounts of quartz.

Mic. The following is the description of this rock, written by M. E. Wadsworth:*

"In the section the feldspars are seen to be much altered, showing aggregate polarization, while much of the area is taken up by the graphic arrangement of secondary quartz in a feldspathic groundmass. Considerable augite with some diallage was observed. The latter is largely altered to a greenish-brown fibrous product, which retains the extinction point of the remaining diallage. Part of the augite shows the common prismatic cleavage, but in other portions of the same crystal the fibrous alteration of the diallage is to be seen, thus supporting the views of those authors who hold that diallage is derived, in part at least, from the alteration of augite. Apatite and magnetite are common, and some biotite was observed.

"From this section and others observed, the writer has but little doubt that most, if not all, of Irving's augite syenytes are altered conditions of gabbro and diabase the same as this rock is. This view, Irving's language would indicate, he partially shared."†

Two poor sections examined.

Age. Cabotian. U. S. G.

NO. 645. GRANITE. *(Red.)*

"'Red granite,' like No. 642, from this hill range, S. W. ¼ sec. 35, T. 63-1 E., on a little creek."
Ref. Annual Report, x, page 67.

Meg. A brownish-red rock of medium grain composed essentially of red feldspar and a black (magnetite) and a yellowish mineral.

Mic. The slide shows *feldspar, quartz, magnetite,* yellowish alteration products and a little greenish material. The feldspar is very highly clouded and reddened,

* *Bulletin ii*, pp. 79, 80.
† *Copper-Bearing Rocks*, 1883, pp. 112-124.

and it is intergrown with the quartz to form the beautiful micropegmatyte so common in these red rocks.

One section examined.

Age. Cabotian. U. S. G.

No. 646. Granite. *(Red.)*

"'Red granite,' southeast corner T. 63-1 E."
Ref. Annual Report, x, page 67.

Meg. A rock quite similar to No. 645, only a little darker colored and of some finer grain.

Mic. Section composed of reddened *feldspar*, *quartz*, much yellowish alteration products and a little *magnetite*. There is much fine-grained micropegmatyte and many of the feldspars are almost completely saturated with quartz.

One section examined.

Age. Cabotian. U. S. G.

No. 647. Apotrachyte.

"Red rock, like Nos. 643 and 645, making hills in the northwest corner of T. 62-2 E. and the northeast corner of T. 62-1 E."
Ref. Annual Report, x, page 67.

Meg. This rock is very similar macroscopically to No. 645, but a little finer grained.

Mic. The texture of the rock is clearly porphyritic, the porphyritic crystals being of clouded and reddened feldspars, small in size and sometimes arranged in irregular clusters. The groundmass is also reddened, and consists of an intergrowth of *quartz* and *feldspar*, with some *magnetite* and yellowish alteration products. Under crossed nicols this groundmass breaks up into the irregular "patchy" areas, which are frequently seen in the devitrified groundmass of the acid rocks.* The patches are composed of poikilitic quartz areas in which are crowded small, much altered feldspars.

Age. Cabotian.

Remarks. This rock is thought to have had an original glassy groundmass, which has now devitrified to the "patchy" aggregate of quartz and feldspar. Compare Nos. 68 and 129, and see figure 3 of plate I. U. S. G.

No. 648. Gabbro *(with quartz).*

Same locality as No. 647.
Ref. Annual Report, x, pages 67, 68; Bulletin ii, page 78.

Meg. A medium-grained, dark-gray, dioryte-like rock, made up of flesh-colored feldspar and much black material which appears to be both magnetite and augite.

* Cf. F. Bascom: *U. S. Geol. Survey, Bulletin cxxxvi*, plate XVII, figure *b*, 1896. R. D. Irving: *U. S. Geol. Survey*, Mon. v, plate XIII, figures 13 and 14, 1883.

Mic. The section shows a rock of granitoid texture, somewhat altered. The minerals are *feldspar, quartz, augite, hornblende, biotite, apatite, magnetite, pyrite* and greenish and yellowish alteration products.

The feldspar is in places considerably altered to a fibrous mass appearing like sericite, and in other places is gray and almost opaque. Albite twinning is rather common and one of the fresher grains gives equal extinctions of 26° on both sides of the twinning line, which would indicate a feldspar at least as basic as acid labradorite with the composition Ab_1An_1. Another grain cut approximately perpendicular to a gives an extinction angle of 64°, and another approximately normal to c gives 4°; the first of these angles would indicate a feldspar near *labradorite*, and the second a more acid one, but neither of these two measurements is entirely satisfactory, as neither section was cut exactly perpendicular to the bisectrix.

The augite is largely decomposed to a mass consisting of hornblende, biotite, magnetite and confused greenish and yellowish alteration products. The yellowish material is in part of the nature of a stain which has penetrated the cracks in the feldspar. A little unaltered augite is present.

Quartz is quite common, sometimes appearing in grains which might be original and sometimes among the alteration products of the augite and also intergrown with feldspar (micropegmatyte) and apparently replacing some of the more altered feldspars.

Magnetite is abundant, and associated with it is a little pyrite. Apatite needles are common.

Two small sections examined.

Age. Cabotian.

Remarks. This rock is now a quartz gabbro and is so designated. But it is not intended by this to affirm that the quartz, or part of it, is original, although such may be the case. On the other hand all of the quartz may be of secondary origin; some of it at least is of that nature. U. S. G.

NO. 649. PORPHYRYTE *(with augite?).*

"Sample of the rock seen in loose pieces along the trail going north between sec. 36, T. 63–1 E. and sec. 31, T. 63–2 E. A high hill runs along the east of the trail, the trail being west of the town line."

Ref. Annual Report, x, pages 68, 69; Bulletin ii, pages 78, 79.

Meg. A brownish-red rock, showing elongated grayish feldspars and irregular elongated dark masses (augite) in a reddish groundmass; but the distinction between the groundmass and the rest of the rock is not very sharply marked. It might be called sub-porphyritic in texture.

Mic. The section shows many elongated feldspars, which are in general highly altered (but are gray instead of reddened), and *augite* in a groundmass composed of rather fine-grained, opaque, reddened feldspar and some *quartz* with *magnetite*, *apatite* and the usual alteration products. The augite does not appear to be idiomorphic, although its alteration would more or less obscure any idiomorphic tendency which it might have had originally. The feldspar in places shows that it is older than the augite.

One section examined.

Age. Cabotian.

Remarks. This specimen, as well as others (Nos. 644 and 648) in this general vicinity (and for that matter many in northeastern Minnesota), can be explained by assuming that the basic gabbro magma absorbed from the surrounding rocks more or less acid material. In the specimen here described the porphyritic feldspars, which appear to be lime-soda feldspars, although from their altered condition this point was not determined with certainty, and the augite, *i. e.*, the more basic minerals, crystallized out first as porphyritic crystals, and the rest of the rock—the more acid part —solidified later under different conditions as acid feldspar and quartz.

In this connection it is of interest to note that it appears to be only the acid feldspar which alters to the opaque red material so common in the red rocks of the north shore of lake Superior, while the more basic feldspar does not alter in this manner. U. S. G.

No. 650. Melaphyre.

"This is so abundant that it must be in place near, but cannot be seen." Evidently from approximately the same place as No. 649.

Ref. Annual Report, x, page 68; Bulletin ii, pages 101, 102.

Meg. A dark-gray rock, apparently granitoid in texture, composed of gray feldspar and much black material.

Mic. The following is the description of this rock written by M. E. Wadsworth:*

"Is a dark grayish brown, somewhat porphyritic rock, whose section is composed of lath-shaped and tabular feldspars, with *augite*, *olivine*, *quartz* and *biotite*, lying in a brownish groundmass. The feldspar is both orthoclase and plagioclase, while part is secondary. The groundmass is now the replacement of a former basaltic groundmass, together with part of its porphyritically inclosed minerals. At the present time this groundmass is the same as that of many quartz-porphyries, and is composed of a confused aggregation of quartz, feldspar, ferrite, magnetite, microliths, mica scales, etc. The section, in certain portions, with its larger secondary quartz, could well pass for a felsyte or quartz-porphyry. The augite is brownish and shows a strong tendency to alter into pale yellowish grains and irregular crystals associated with feldspar and quartz. This is seen most commonly in the vicinity of magnetite masses. The pale yellowish grains and crystals show the general characters of

**Bulletin ii*, pp. 101, 102.

olivine, as well as the interference figures of orthorhombic crystals. They are also positive, with strong double refraction. They are therefore referred to olivine. However, their general appearance is slightly different in coloration, etc., from the common basaltic olivines, and this is naturally the case since one cannot suppose a mineral formed by secondary agencies to be identical with one formed primarily, even if chemically and mineralogically they are the same. This olivine appears to represent a case parallel to the secondary olivine of the St. Paul's rocks as described by the present writer.*

"Another alteration product is shown in the formation of scales and masses of biotite, which partially replace the augites, which in most cases remain, forming an elongated central band. The augite, in the earlier stages of alteration, is filled with a brown dust and sometimes it is feebly pleochroic, the color varying from chiefly brown to yellow. Apatite microliths are common, not only in the secondary groundmass, but also transfixing the olivine crystals."

We fail to see why Dr. Wadsworth regarded the olivine as secondary. It has all the appearance of the original olivines of diabases or gabbros, and at times has a tendency to assume a crystal form. The large feldspars are usually of earlier date than the augite. They are evidently andesine-labradorite, showing equal extinction angles in sections perpendicular to 010 as high as 21°; moreover, a section cut almost exactly normal to the least axis of elasticity gave an extinction of 12°, and another closely normal to the greatest axis of elasticity gave 64°.

One section examined.

Age. Cabotian.

Remarks. Perhaps a mixture of a basic and an acid magma, the latter being represented by the groundmass of quartz and reddened feldspar. See remarks under No. 649. U. S. G.

NO. 651. GABBRO. *(Rich in magnetite, with olivine.)*

"From boulders, seen along the same trail, twenty to thirty rods north of the last (No. 650). This same rock forms a hill along the right of the trail."

Ref. Annual Report, x, pages 68–70; Bulletin ii, page 90.

Meg. A rather coarse-grained, dark-gray rock, evidently containing feldspar and much magnetite.

Mic. The section shows a rather coarse-grained granitic aggregate of *feldspar*, *magnetite*, *olivine* and *augite*. The feldspar and magnetite are the most abundant minerals, and the latter makes up fully one-third of the rock. The rock itself is not attracted by the magnet and it is probable that the magnetite, like most of this mineral in the Minnesota gabbros, contains a considerable amount of titanium. In addition to the usual albite twinning the pericline twinning is common in the

**Science*, 1883, i, 590–592; *Lithological Studies*, 1884, pp. 123–125.

feldspar, which is probably near *labradorite* in composition. In one part of the section is a small area composed of smaller lath-shaped plagioclases and small, more or less rounded augite and magnetite grains.

One section examined.

Age. Cabotian. U. S. G.

NO. 652. GABBRO (*with hornblende*).

"From a point about one-fourth mile from the Brulé river and half a mile west of the town line." Evidently from near the centre of N. ½ sec. 36, T. 63-1 E.

Ref. Annual Report, x, pages 68-70; Bulletin ii, pages 102, 103.

Meg. A medium-grained, dark-gray, granitoid rock composed of gray feldspar and much black material.

Mic. The following is M. E. Wadsworth's description of this rock:*

"A grayish-brown crystalline aggregation of *feldspar*, *augite* and *magnetite*. In the section the feldspar is partly altered and replaced by kaolinized material interstitially arranged with graphic quartz. Part of the feldspar is distinctly plagioclase, and part of the augite has been changed to brown hornblende and brown biotite. Apatite rods and microliths are to be seen associated with the graphic or eozoön quartz."

The main mass of the feldspar is plagioclase, and equal extinction angles in sections normal to 010 run up to 33°, indicating a feldspar as basic as *labradorite*. Another section was made. This shows the presence of some olivine which has considerably altered to a yellowish-brown substance—perhaps *bowlingite*.

Two sections.

Age. Cabotian. U. S. G.

NO. 653. APOTRACHYTE.

"From the Brulé, some west of the town line." Evidently from the S. E. ¼ sec. 25, T. 63-1 E.

Ref. Annual Report, x, page 68.

Meg. A dark, brownish-red rock with small, porphyritic red feldspars, and a little of a yellowish material. The groundmass of the rock is very fine grained.

Mic. The section shows much reddened, almost opaque, porphyritic feldspars in a groundmass which is also reddened, consisting of *quartz*, *feldspar*, *hematite*, *magnetite* and a greenish alteration product. Under crossed nicols the groundmass breaks up into the irregular patches of poikilitic quartz which are so frequently found in the "red rocks" of northeastern Minnesota.

One section examined.

Age. Cabotian.

Remark. This rock is very similar to No. 647. See, also, figure 3 of plate I for the "patchy" groundmass. U. S. G.

* *Bulletin ii*, pp. 102, 103.

No. 654. Diabase. *(Fine grained.)*

"This sample is from a ridge rising about one hundred and seventy-five feet, crossed by the section line running east, S. E. ¼ sec. 18, T. 63-2 E."

Ref. Annual Report, x, page 69.

Meg. A very fine-grained, dark, greenish-gray rock of uniform composition, except for a very few areas of sub-porphyritic feldspar.

Mic. The section is composed essentially of *feldspar* and *augite.* The former is in small lath-shaped individuals which are polysynthetically twinned; equal extinction angles in sections normal to 010 are as high as 33°, indicating *labradorite.* The augite is in small grains between and within the feldspar laths, and only rarely do larger grains, showing a tendency to the ophitic texture, appear. The slide also shows *magnetite* and a green alteration product which, perhaps in part, represents original olivine.

One section examined.

Age. Cabotian.

Remark. This rock, quite probably, is a dike rock cutting the earlier gabbro and red rock, but whether it is of Cabotian or Manitou age is uncertain. It resembles some of the Keweenawan dike rocks found on the lake Superior shore. U. S. G.

No. 655. Granite. *(Red, fine grained.)*

N. E. ¼ sec. 20, T. 63-2 E. Appears in a low ridge:

Ref. Annual Report, x, page 69.

Meg. A fine-grained reddish rock, somewhat mottled and of a porous texture. The cavities, which are irregular in outline, are more or less filled with quartz and a dull green earthy mineral (perhaps chlorite).

Mic. The section shows one of the usual fine-grained "red rocks" composed of *quartz*, reddened *feldspar*, *magnetite*, *hematite* and yellowish alteration products. Micropegmatyte is common.

One section examined.

Age. Cabotian. U. S. G..

No. 656. Apotrachyte.

A short distance east of No. 655.

Ref. Annual Report, x, page 69.

Meg. A fine-grained reddish rock of porous texture. Many small light-gray porphyritic feldspars are present. Macroscopically this rock is quite similar to No. 655, but lacks the quartz.

Mic. A few small, much altered, porphyritic feldspars are seen in a fine-grained groundmass composed of a confused aggregate of *quartz*, reddened *feldspar*, *magnetite* and *hematite.* In the section there are a number of sharply outlined cavities.

One section examined.

Age. Cabotian. U. S. G.

No. 657. Andesyte *(with quartz)*.

South line of sec. 16, T. 63-2 E., just east of a creek.
Ref. Annual Report, x, pages 69, 70.

Meg. A fine-grained, dark-brown rock, reddish brown on weathered surfaces, containing a few small scattered porphyritic plagioclases.

Mic. The section consists of a few much altered porphyritic feldspars in a groundmass composed of a more or less confused aggregate of *feldspar*, *quartz*, *epidote*, *magnetite*, *hematite*, indistinct green alteration products, and a few *apatite* needles. Two of the porphyritic crystals are not particularly reddened, but are partly altered to a gray cloudy material and to epidote; these two feldspars are evidently plagioclases, but the species could not be determined.

The feldspar of the groundmass occurs in the form of small more or less lath-shaped crystals and in grains of irregular outline; these two forms, however, are not sharply separated from each other. In reflected light, the lath-shaped feldspars in general are seen to have altered to a gray cloudy material, while the rest of the feldspar is somewhat reddened. These laths are quite commonly polysynthetically twinned, and extinction angles in sections approximately normal to 010 do not indicate a plagioclase more basic than *andesine.* Much of the other feldspar shows no polysynthetic twinning and is perhaps orthoclase, but owing to the alteration of both forms of the feldspar, and also to the small size of the grains, satisfactory determinations of the species cannot be made.

The green alteration product and the epidote of the groundmass gave no certain evidence as to the original material now represented by them, but it seems probable that this was a mineral (either augite or hornblende) rather than a glassy residue. The green alteration product is one of the chlorites, and from its double refraction is thought to be most probably *clinochlore.*

One section examined.

Age. Cabotian or Manitou.

Remark. In this, as in many of the altered post-Animikie rocks of the north shore of lake Superior, it is quite probable that the quartz of the groundmass is secondary. If this be the case, the original rock was an andesyte. U. S. G.

No. 658. Apotrachyte. *(Spherulitic.)*

Near, probably a short distance east of, No. 657.
Ref. Annual Report, x, pages 69, 70.

Meg. A fine-grained rock, porous in texture and of a reddish-gray color. A few small red porphyritic feldspars occur. The groundmass is indistinctly mottled with small reddish and greenish-gray areas. This rock resembles macroscopically Nos. 655 and 656.

Mic. Porphyritic feldspars, much altered and reddened, probably *orthoclase*, are seen in a groundmass which consists of reddened feldspar, *quartz*, *hematite*, indistinct greenish-yellow alteration products, *chlorite*, *magnetite* and a small amount of *epidote*. The most noticeable feature of the groundmass is the presence of many spherulitic areas, which are usually more apparent in ordinary than in polarized light. The spheruliths have a distinct concentric, as well as the radiating, structure. The different zones are not clearly developed in each individual, but the most perfect ones show the following zones, beginning with the centre: (1) A nearly opaque mass showing an indistinct radiating structure. Under crossed nicols this structure disappears, and sometimes the mass breaks up into a fine mosaic, probably of quartz and feldspar. (2) A more transparent zone, without radiating structure, and showing under crossed nicols a very fine-grained mosaic of probably quartz and feldspar. (3) An opaque greenish-yellow band. (4) A more transparent zone, similar to the second zone just mentioned. (5) A broad zone, commonly the largest part of the spherulith, somewhat opaque and of a red color. The radiating structure is very pronounced, and under crossed nicols the less reddened spheruliths give in this zone the arms of a black cross. The fibres of this radiating zone show approximately parallel extinction and a negative elongation; they can thus be orthoclase elongated in the direction of the inclined axis (a).

It is quite frequently the case that the porphyritic feldspars are surrounded by spherulitic growths in which the central nearly opaque zone mentioned above is immediately in contact with the feldspars.

Aside from the spheruliths, which make up a large part of the rock, the groundmass consists of the minerals already mentioned. In places a fine mosaic of quartz and feldspar is evident, most likely a product of devitrification, and in other places larger quartz grains occur; these commonly show undulatory extinction and some of them exhibit a tendency to a radial structure. There are some altered areas of the groundmass which appear to have been originally biotite.

Two sections examined.

Age. Cabotian.

Remark. This is the first specimen known to us of the red rocks in Minnesota containing spheruliths. With such a large number of occurrences of acid surface rocks along and near the north shore of lake Superior, it is a little surprising that spherulitic structures have not been found. It is to be expected that future search will reveal such occurrences. (Compare Nos. 686 and 687.)

In rock No. 132A a spherulitic structure is described in red rock inclusions in a basic eruptive.

U. S. G.

No. 659. Porphyryte. *(Diabase.)*

"This rock appears to be in place, but can be seen only in the form of numerous loose pieces. It has the appearance of constituting the top portion of the ridge (No. 658). * * * This ridge runs east and west nearly, on the north side of the trail, and rises about two hundred feet." This specimen is evidently from a trail on the south line of sec. 16, T. 63-2 E., and east of Nos. 657 and 658.

Ref. Annual Report, x, pages 69, 70.

Meg. The rock is markedly porphyritic, with numerous white feldspar crystals. The groundmass is of quite fine grain, dark gray in color, and consists of feldspar and a black material. Some of the feldspar, both the porphyritic and that in the groundmass, has a pinkish shade.

Mic. The section shows porphyritic *feldspars*, usually lacking in crystal outline, in a groundmass consisting of smaller lath-shaped feldspars, *augite*, *magnetite* and alteration products. Almost all the feldspars are highly altered, gray and almost opaque, sometimes showing *epidote*. The alteration products of the groundmass are a green material (mostly chlorite), quartz, apparently feldspar much reddened, magnetite and hematite. It seems probable that the alteration products of the groundmass represent in part something besides augite, but just what, it is impossible to say. Notwithstanding the highly altered nature of the rock there is still considerable augite remaining.

One section examined.

Age. Cabotian or Manitou. U. S. G.

No. 660. Porphyryte. *(Diabase.)*

From the trail at the crossing of the line between ranges 2 and 3 east. Evidently at the extreme southeast corner of sec. 13, T. 63-2 E.

Ref. Annual Report, x, page 70.

Meg. Macroscopically this rock is very similar to No. 659.

Mic. This section resembles that of No. 659, except for the facts that the feldspars of the groundmass are not so markedly lath-shaped and that the augite has entirely disappeared.

One section examined.

Age. Cabotian or Manitou. U. S. G.

No. 661. Trachyte (?)

"One mile east of the town line (S. E. corner of sec. 13, T. 63-3 E.) is a reddish crystalline rock in place, and this continues east two miles from the town line."

Ref. Annual Report, x, page 70.

Meg. A reddish-brown rock, consisting of numerous small, red, porphyritic and sub-porphyritic feldspars and a darker groundmass.

Mic. Porphyritic feldspars are seen in a groundmass of *feldspar*, *quartz*, yellowish and greenish alteration products (among which are *chlorite* and *epidote*), *magnetite* and *hematite*. The rock has been considerably altered and the feldspars are much reddened, the porphyritic ones, however, less than those of the groundmass.

One section examined.

Age. Cabotian. U. S. G.

NO. 662. ANDESYTE.

S. W. ¼ sec. 14, T. 63-3 E.
Ref. Annual Report, x, page 70.

Meg. A very dark gray rock with an aphanitic groundmass and a few gray to reddish porphyritic plagioclases.

Mic. The porphyritic plagioclases are not very abundant and are considerably altered,—in part to *epidote* and *chlorite;* the species was not determined. The groundmass is composed of very minute, altered, elongated feldspars and a black, opaque material usually in small rounded or irregular grains. Much of this material is *magnetite*, some of it is *hematite* and part of it may represent an unindividualized base. In places this black material is collected in irregular areas, almost or entirely free from the minute feldspars, and this gives a blotched appearance to the section. A little epidote also occurs in the groundmass. One area of chlorite was seen surrounded by a rim of magnetite; this may represent an original ferro-magnesian porphyritic constituent such as hornblende.

One section examined.

Age. Cabotian or Manitou. U. S. G.

NO. 663. PORPHYRYTE. (*Diabase.*)

"S. W. ¼ sec. 19, T. 63-4 E., on McFarland's trail. Here is a short east and west ridge, rising about fifteen feet, in which the rock is the stellar porphyry seen in pebbles on the lake (Superior) shore. It is fine grained and brown, but is beautifully set with intersecting tabular crystals of flesh-colored feldspar."
Ref. Annual Report, x, page 70.

Meg. A rock composed of numerous gray to flesh-colored porphyritic feldspars and a very dark gray, almost aphanitic groundmass.

Mic. Considerably altered porphyritic plagioclases are seen in an altered groundmass composed largely of feldspars, many of which are lath-shaped in form. Besides the feldspar there are *magnetite*, *hematite*, *quartz* and green alteration products (mostly *chlorite*). There are also a few opaque grains, flesh-colored in reflected light, which are perhaps the alteration products of ilmenite. Some of the chlorite areas, by their relation to the lath-shaped feldspars, suggest altered ophitic augites. There are also some areas of chlorite which may represent altered olivines.

One section examined.

Age. Cabotian or Manitou. U. S. G.

NO. 664. DIABASE. *(Coarse.)*

"A little more than two miles from Horseshoe bay (north shore of lake Superior)." Evidently from McFarland's trail, and probably near the southwest corner of sec. 4, T. 62–4 E.

Ref. Annual Report, x, pages 70, 71, 140; American Association for the Advancement of Science, vol. xxx, page 163; Bulletin ii, pages 97, 98.

Meg. Hand specimen not found.

Mic. M. E. Wadsworth's description of this section is as follows:*

"Has a section composed of brownish *augite* dissected by divergent *feldspars* and containing *magnetite* and some secondary products. As a rule the augite is a clear brown or yellowish brown, containing rows of magnetite, vapor cavities, and other inclusions arranged along fissures. It also shows in places the fine parallel cleavage of *diallage.* This is usually towards the edges or in altered portions of the crystal. Yet these points are of very minor importance compared with augite proper, which occupies about two-thirds of the section. The feldspar is plagioclase and in some places shows kaolinization. Both the pyroxene and the feldspar are traversed by numerous fissures which are bordered by yellowish and brownish ferruginous stainings. A serpentinous material forms brownish patches which may possibly be pseudomorphs after olivine, but it, with *apatite,* appears oftener to be formed by the alteration of the original interstitial base of rock.

"The section is traversed in one portion by a brownish and greenish vein of serpentinous material.

"The magnetite is either of foreign origin or was the earliest mineral to crystallize. This is followed by the feldspar, and lastly by the augite; the interstital base being left an uncrystallized and easy altering material. In structure and character there is no reason this rock should not be called a gabbro, except that the pyroxene is essentially augite. The structure is decidedly granitoid."

The plagioclase shows abundant twinnings, and approximately equal extinction angles in sections cut nearly normal to 010 are as high as 31.° Two sections cut normal to a gave extinction angles of 61° and 60° respectively. The feldspar is thus clearly near to labradorite of the composition $Ab_1\ An_1$.

There is chance for a difference of opinion in regard to whether that which is spoken of above as the interstitial base is really such; it seems possible that it is decomposed augite.

The texture of the rock is markedly ophitic, the augite occurring in the large plates which inclose the feldspars. The name diabase is therefore especially appropriate.

One section examined.

Age. Cabotian. U. S. G.

**Bulletin ii*, pp. 97, 98.

No. 665. Diabase. *(Lustre-mottled.)*

From the hill back of Grand Marais and 800 feet above lake Superior. This specimen was taken on the old trail ("Iron trail") which ran from Grand Marais north and northwestward past South Devil Track lake. The locality of the specimen is not certain, but it probably was obtained from near the northwest corner of sec. 17, T. 61-1 E.

Ref. Annual Report, x, pages 65, 71.

Meg. A quite fine-grained rock of a dark-brown color. It shows clearly the lustre-mottled character due to augite plates of considerable size.

Mic. The most noticeable feature of the section is the presence of large plates of augite thickly studded with small lath-shaped *plagioclases.* The *augite* plates do not usually touch each other, and between them the feldspar is more abundantly developed and the lath-shaped individuals are not sharply separated from a background of more or less allotriomorphic plagioclases. Besides the augite and plagioclase there are considerable amounts of a black opaque substance which is largely *magnetite* and *hematite* and which may in part represent an unindividualized base and in part possibly olivine. This black substance occurs in areas of irregular shape in the spaces between the augite plates, and some of it represents decomposed augite. *Chlorite* and *apatite* are also present. From extinction angles in sections normal to 010 the feldspars appear to be as basic as *labradorite.*

One section examined.

Age. Cabotian or Manitou. U. S. G.

No. 666. Rhyolyte.

From the northeast side of South Devil Track lake; E. ½ sec. 31, T. 62-1 E. Many loose pieces of this rock occur here, but no rock is seen in place.

Ref. Annual Report, x, page 71.

Meg. A fine-grained, reddish-gray rock containing a few small porphyritic quartzes and feldspars.

Mic. The section shows rounded porphyritic *quartzes* in a fine-grained groundmass of quartz and the usual reddened *feldspar*, *magnetite* and *hematite.* It is possible that this groundmass is a product of devitrification, although we do not think that this is the case. In ordinary light many needle-like transparent areas are seen to penetrate the groundmass in all directions; they remind one somewhat of apatite needles, but in polarized light they are seen to be quartz which extinguishes in connection with the surrounding quartz areas.

One section examined.

Age. Cabotian. U. S. G.

No. 667. Granite *(with augite).*

Beach on south shore of Devil Track lake at the Iron trail; S. W. ¼ sec. 30, T. 62-1 E. This rock is not in place, but from its abundance and its fresh angles it is evidently the country rock.

Ref. Annual Report, x, page 72.

Meg. A dark reddish-brown, fine-grained, compact rock with a few small red porphyritic feldspars and sub-porphyritic areas of a dark mineral. The weathered surface is pitted by the more rapid decay of the dark mineral.

Mic. The section is composed of the usual reddened *feldspar, quartz, augite, magnetite, hematite, hornblende, chlorite* and confused greenish and yellowish alteration products. The quartz and feldspar are most frequently intergrown to form beautiful micropegmatyte, and commonly this takes a radiating structure around the feldspar grains. This is evidently a coarse form of the granophyric texture. This feature of the specimen is well represented in Mon. v, U. S. Geol. Survey, plate 14, figures 1 and 2.

The augite is in grains of considerable size and frequently shows a decidedly idiomorphic tendency. This mineral is of earlier date than the feldspar and quartz, some of the longer individuals extending through one or more feldspar grains in a manner similar to the diopside in rock No. 132A. The augite is almost colorless to green and usually shows no pleochroism. It has altered in places to an almost opaque yellowish material. A few small dark-green pleochroic grains appear to be hornblende, perhaps original, and there is also some secondary hornblende and chlorite.

One section examined.

Age. Cabotian. U. S. G.

No. 668. Granite *(with augite).*

"About one-third way across the portage from Owl lake to Little Pine lake." Probably a short distance north of the centre of sec. 1, T. 62–1 W.

Ref. Annual Report, x, pages 73, 74, 140; American Association for the Advancement of Science, vol. xxx, page 165.

Meg. A compact rock of red color, rather fine grained and granitoid texture. The minerals are red feldspar, sometimes sub-porphyritic, quartz and a dark greenish-yellow mineral. The weathered surface of the specimen is pitted, due to the weathering out of the last mineral.

Mic. The section shows one of the characteristic red rocks of rather coarse grain, *i. e.*, coarse for these rocks. The important point of difference between this section and most of the other red-rock sections is the presence of green augite, which is more or less altered.

One section examined.

Age. Cabotian. U. S. G.

No. 669. Diabase. *(Lustre-mottled.)*

"Is from what appears to be a dike, about half way between Owl lake and Little Pine lake, though the exposure is not sufficient to show whether a dike or not." Probably in N. E. ¼ N. W. ¼ sec. 1, T. 62–1 W.

Ref. Annual Report, x, page 73.

Meg. A dark-gray rock of fine grain and showing lustre-mottling. It weathers to a much lighter gray.

Mic. The section shows small lath-shaped feldspars and large ophitic *augites*, also *magnetite* and the usual alteration products. Some of the altered areas may quite probably represent original olivines. The section resembles that of No. 665.

One section examined.

Age. Cabotian. U. S. G.

No. 670. DIABASE. *(Coarse.)*

"From one-fourth mile south of lake Abita, in the large hill over which the trail passes." N. E. ¼ N. E. ¼ sec. 28, T. 63-1 W.

Ref. Annual Report, x, page 74; Bulletin ii, pages 76, 95.

Meg. M. E. Wadsworth's description of this rock is as follows:* "It is a rusty brown coarsely crystalline rock, discolored by surface weathering. Composed macroscopically, chiefly of brownish ferruginous stained feldspars and dark silicates traversed by hexagonal apatite needles."

Mic. "The section is composed of feldspar *(plagioclase* chiefly) pyroxene, secondary *hornblende*, and *magnetite.* Much *limonite* occurs, lining the fissures and staining the feldspars. The *pyroxene* is brownish and has the characteristic fractures and general characters of augite, but in portions of its mass the structure of *diallage* is clearly to be observed, as a secondary structure arising through the alteration of the augite."

One poor section examined.

Age. Cabotian. U. S. G.

No. 671. GRANITE *(with augite).*

From the hill near the south shore of lake Abita; S. E. ¼ S. E. ¼ sec. 21, T. 63-1 W. Not certainly in place.

Ref. Annual Report, x, page 74.

Meg. A reddish-gray rock of rather fine granitoid texture. The minerals are quartz, feldspar and a black mineral (augite).

Mic. One of the characteristic red rocks, but having some augite still remaining. This section is similar in general character to No. 668.

One section examined.

Age. Cabotian. U. S. G.

No. 672. GABBRO *(with hornblende).*

From the same locality as No. 671, but near the top of the hill.

Ref. Annual Report, x, page 74; Bulletin ii, page 78.

Meg. A coarse-grained gray rock, granitoid in texture and composed of flesh-colored and gray feldspar, magnetite and a black substance (mostly augite).

Mic. M. E. Wadsworth's description of this rock is as follows:† "The section is composed of partially altered *plagioclase*, *augite* partially changed to *diallage*,

**Bulletin ii*, p. 76.

†*Bulletin ii*, p. 78.

magnetite, and secondary *hornblende*. Considerable secondary eozoön or graphic quartz was observed in the feldspathic material, giving the rock there the structure of a graphic granite. Some pyrite occurs associated with the magnetite which, in places, is surrounded and penetrated by the pyrite. Considerable *apatite* was observed in the section."

One poor section examined.

Age. Cabotian. U. S. G.

No. 673. Granite. *(Red.)*

Top of Brulé mountain; N. ½ sec. 21, T. 63–1 W. This rock is not well seen *in situ*.
Ref. Annual Report, x, pages 74, 75.

Meg. A brick-red, granitoid rock of medium grain, composed of red feldspar, a little quartz and considerable of a black mineral.

Mic. A few small porphyritic feldspars, much reddened, are seen in the fine-grained groundmass of the red rocks. Certain dark areas in the slide, which probably represent original augite, are filled with secondary products, among which magnetite is important. It seems quite probable that the slide of this number was not made from the specimen of similar number; the slide shows a finer-grained rock than the hand sample.

One section examined.

Age. Cabotian. U. S. G.

No. 674. Granite *(with augite)*.

"A rather fine-grained deposit, with quartz, which occurs on the north face of Brulé mountain, forming a perpendicular wall about twenty feet high, but is only seen (so far as examined) a little east of but near the trail. It is 240 feet below the top of the mountain, and makes a more or less continuous jog or shoulder." Perhaps in S. ½ sec. 16, T. 63–1 W.
Ref. Annual Report, x, page 75.

Meg. A gray rock of medium grain, granitoid texture, and composed of gray to flesh-colored feldspar, augite and quartz.

Mic. The section is composed of *feldspar*, *augite*, *quartz*, *magnetite*, *hornblende*, *biotite*, *apatite* and brownish, yellowish and greenish alteration products.

The feldspar occurs in two ways: First, as nearly idiomorphic crystals which appear to be *oligoclase* and *orthoclase;* and second, intergrown with quartz to form micropegmatyte, which frequently surrounds the other feldspars. The low equal extinction angles in sections cut normal to 010, or nearly so, and the presence of two sections, each of which gives an extinction angle of 2°, cut practically normal to c indicate that the first form of feldspar is not more basic than *oligoclase* or *oligoclase-andesine*. The feldspar of the micropegmatyte is usually altered to an almost opaque cloudy mass, while the other feldspar is much less altered; none of it is reddened.

The augite is older than the feldspar and sometimes shows an idiomorphic form. It is usually light green in color, but some of it approaches to the clear cinnamon color so common in the augites of the associated diabases and gabbros. A considerable part of the augite has altered and among the alteration products hornblende is common.

Quartz is common and occurs in well-defined grains and also in the micropegmatyte. Biotite is rare and is secondary. Apatite occurs in needles of considerable size. Areas of brownish semi-opaque alteration products are common; at times these show marked absorption and possibly are of the nature of *bowlingite*. Magnetite is abundant.

One section examined.

Age. Cabotian.

Remark. See under No. 675. U. S. G.

No. 675. GRANITE *(with hornblende)*.

"In the northern face of Brulé mountain, 300 feet below the top, about south from the east end of the westerly lake in Brulé river. This reddish granitoid rock forms a perpendicular wall of sixty feet in hight." Probably near the southwest corner of sec. 16, T. 63–1 W.

Ref. Annual Report, x, pages 75, 142; American Association for the Advancement of Science, vol. xxx, page 165; Bulletin ii, page 81.

Meg. A pinkish-gray rock of medium grain and granitoid texture, composed of pink feldspar, horblende and quartz.

Mic. The section very closely resembles that of No. 674, except for two particulars: First, the augite is very largely altered and the hornblende is more abundant; and second, much of the feldspar, especially that of the micropegmatyte and the outer parts of the partly idiomorphic individuals, is reddened in a manner similar to the feldspar of most of the red rocks. Much of the larger feldspar individuals show polysynthetic albite twinning and low extinction angles in sections normal to 010, or nearly so. One section cut almost exactly normal to $\mathfrak{a}$, gave an extinction angle of 78° and two others cut practically normal to $\mathfrak{a}$ gave angles of 80° and 81° respectively. The feldspar in part is thus clearly oligoclase, and no evidence of a more basic plagioclase was seen. One section examined.

Age. Cabotian.

Remark. This rock and the preceding (No. 674) are interesting from the fact that they represent facies of the red rocks which are coarser grained than usual and which appear to be approaching the gabbros. The latter appearance, however, is less evident on a study of the rock. Augite is present in large amounts; thus these specimens differ from the main mass of the red rocks, which, even in their freshest conditions, show a comparatively small amount of augite. There is no necessity for considering the quartz as largely secondary, and the feldspars are clearly alkaline acid species rather than the more basic lime feldspars of the gabbros. There thus seems to be no good reason for regarding these rocks as altered gabbros. U. S. G.

No. 676. Gabbro.

"At a lower level another perpendicular wall of rock is found on the north side, a little west of the section line between sections 16 and 17 (T. 63–1 W.), rising about seventy-eight feet. This rock resembles No. 674, but the bluff cannot be said to consist entirely of this." Near the same place as No. 675.

Ref. Annual Report, x, pages 75, 76.

Meg. A somewhat crumbling, brownish-gray rock of medium grain, composed of feldspar and a black mineral (largely augite).

Mic. The section is composed essentially of *plagioclase, augite* and *magnetite.* The plagioclase is *labradorite.* Yellowish stains are common throughout the section and yellow and brownish alteration products are abundant. One large grain, considerably altered and stained, appears to be *olivine,* and some of the areas of brownish alteration products may also represent this mineral. In texture the rock is quite similar to the gabbros, although there is frequently a tendency to an idiomorphic development of the feldspar, and in general the augite is of later date than that mineral.

One section examined.

Age. Cabotian. U. S. G.

No. 677. Gabbro. *(Fine, granulitic.)*

In a hill about 100 feet east of the trail from the western lake in Brulé river, and a little more than half way from this lake to Little Trout lake, and south of Little lake; near the centre of the N. ½ sec. 8, T. 63–1 W.

Ref. Annual Report, x, pages 76, 81.

Meg. A fine-grained, compact, dark-yellowish, gray rock appearing considerably like a quartzyte.

Mic. The section contains feldspar, *augite, olivine* and *magnetite,* all in abundance, and *biotite* and *apatite* in small amounts. Under a low power the augite and olivine present rounded outlines, but on careful examination with a higher power the augite is seen to have less rounded outlines than the olivine, and frequently the former mineral forms with the feldspar a completely allotriomorphic aggregate. The feldspar was, however, in general the last mineral to crystallize. It uncommonly shows polysynthetic twinning and is allotriomorphic in form except for a very few individuals which have a tendency to a lath-shaped development. The species was not determined with certainty, although it seems to be near *labradorite.* Sections cut nearly normal to a bisectrix failed to show any cleavage or albite twinning, and sections cut normal to 010 and showing the albite twinning are scarce. Moreover, the thickness of the section, causing the different grains to overlap, renders a careful determination of the feldspars difficult.

The olivine is less abundant and in larger grains than the augite. The magnetite frequently shows crystal outline and a few of the larger grains are moulded on or inclose olivine grains. The biotite usually is seen surrounding magnetite grains. The rock is very fresh, even the olivines showing very little alteration. It is illustrated by figure 3, plate II.

One section examined.

Age. Cabotian. U. S. G.

No. 678. Diabase.

"This hill extends to Little lake, and along the southeast side, where the superposition of the strata can be made out in descending order, the highest stratum being of the 'red granite.' Thus (with a dip 10° S. W.):

"Red granite (not actually seen in place),	
"No. 678, in a regular bed of the thickness of	15 feet
"No. 676 [679], porphyry with red feldspar	4 "
"No. 679A, porphyry with gray feldspar	8 "
"No. 680, fine-bedded, crumbling, seen	18 "

"The foregoing does not include all the strata, some being invisible, both at the top and at the bottom."

The specimens are from the southeast side of Little lake, which is a small lake near the centre of the north line of sec. 8, T. 63-1 W.

Ref. Annual Report, x, pages 76-78, 96; Bulletin ii, page 114.

Meg. A dark greenish-gray rock of medium grain, composed of feldspar and a greenish, black substance.

Mic. The section shows an ordinary diabase. The feldspar is in lath-shaped forms clearly earlier than the *augite*, which is in irregular grains and in ophitic plates of rather small size for a rock of this grain. The feldspar is near *labradorite.* The rock has been considerably altered, the feldspar is in part kaolinized and the augite replaced by a green alteration product (fibrous hornblende and chlorite), although much fresh augite remains. *Magnetite* is abundant, and *apatite* and secondary quartz occur in small amount. It is possible that some of the green alteration product represents an original unindividualized base.

One section examined, which possibly may not have been made from this hand sample.

Age. Cabotian. U. S. G.

No. 679. Porphyryte. *(Diabase.)*

Same locality as No. 678, which see.

Ref. Annual Report, x, page 76.

Meg. Numerous reddish to brownish porphyritic feldspars occur in a compact, very fine-grained, almost black groundmass.

Mic. The section consists of numerous crowded *feldspar* phenocrysts in a rather sparse groundmass. The phenocrysts are much altered and frequently somewhat brown in color; some of them still show polysynthetic twinning and in others the alteration has gone so far that twinning cannot be seen, even if present originally. The groundmass is a confused greenish aggregate largely made up of alteration products. Some small lath-shaped feldspars are present in the groundmass, also much *magnetite.* Most of the green material is *hornblende* and *chlorite.* It is impossible to determine whether the groundmass was originally holocrystalline. Two small sections examined.

Age. Cabotian. U. S. G.

NO. 679A. PORPHYRYTE. *(Diabase.)*

Same locality as No. 678, which see.
Ref. Annual Report, x, page 76.

Meg. Numerous brownish-gray porphyritic feldspars occur in a compact, very fine-grained, almost black groundmass.

Mic. The section is closely similar to that of No. 679, but differs slightly in having fewer phenocrysts and in the fact that the lath-shaped feldspars of the groundmass are more numerous, more sharply defined and a little larger.

One section examined.

Age. Cabotian. U. S. G.

NO. 680. TUFF. *(Volcanic.)*

Same locality as No. 678, which see.
Ref. Annual Report, x, pages 76, 77.

Meg. There are two small hand samples with this number. One is a very fine-grained, compact, reddish-brown rock with a few small red and gray porphyritic feldspars; the rock is perhaps an andesyte. The other sample is of a brown color and is thickly spotted with minute white areas. There are also some red feldspar crystals. On closer examination the rock presents a fragmental aspect. The section was evidently made from this second sample.

Mic. The fragmental character of the section is evident at a glance. The fragments are of very irregular outlines and they vary in size from mere shreds to those about an eighth of an inch across. In color they vary from brownish semi-transparent ones to those which are opaque and black. All the fragments have the appearance of having been glass originally, but now are in part at least devitrified. Some of them have a vesicular texture, the vesicles being filled with the materials which make up the cement between the fragments. A few minute elongated feldspars are seen in some of the fragments, and in one these feldspars are arranged somewhat as in a flow. One fragment contains a twin crystal, evidently of a glassy feldspar cut nearly normal to an optic axis. A reddened feldspar is also among the fragments. The cement of the rock is colorless to brownish or greenish, and is composed largely of very fine-grained *quartz*, *chlorite*, a little *epidote* and probably *feldspar*.

It seems clear that this tuff is not an acid one, although its exact nature is not evident. It seems quite likely, however, from its general nature and from the character of the associated rocks that it is a rather basic andesyte tuff.

One section examined.

Age. Cabotian.

'emark. This adds another one to the few occurrences of volcanic tuff in the nimikie rocks of northeastern Minnesota. Other tuffs have been reported by thors from Duluth,* and Dr. A. H. Elftman has collected similar tuffs from the ,y of Baptism river on the north shore of lake Superior. (See figure 4, plate II.)

U. S. G.

No. 681. Andesyte.

The hill at the right of the portage from Little lake to Little Trout lake is made up of the numbers 681, 683 is [in] downward order, with the thickness stated below (dip 20° S. E.):
No. 681 (seen twenty feet; may have more above). A very fine, black rock, approaching aphanitic slate.
No. 682 (thirty-five feet). Porphyry, both with red and with gray feldspar crystals. This is a part of the rmation lying below the cupriferous, already mentioned, and is in beds of an inch, where weathered, or ' layers of five or six feet. The groundmass seems to be the rock No. 678. The red color seems to come athering, the original color being gray. This is shown in one of the small samples. It has free quartz.
No. 683 (twenty feet; there is a talus below of fifty feet in which the rock is unknown). A fine-grained, ark rock, apparently consisting of triclinic feldspar and diallage, with a little uralite and magnetite.
No. 684. Further north is a layer of four feet of a fine black rock, evidently crystalline, somewhat like or 683, included between some of the beds of the foregoing porphyry, near the bottom of the same."
hese rock samples are from near the centre of S. ½ sec. 5, T. 63-1 W.
ef. Annual Report, x, pages 77, 78.

Meg. A very fine-grained, compact, brownish-gray rock, evidently breaking shale.

Mic. The section is quite fine grained and is more than half composed of a aggregate of somewhat reddened plagioclases, some of which assume a lath-l form. In addition to the plagioclase there are *magnetite*, *chlorite*, fibrous lende and a finely granular strongly doubly refracting mineral, which appears *epidote.* It is possible that some of the latter substance is augite in small . It seems quite probable that the rock was originally holocrystalline.

)ne section examined.

Age. Cabotian. U. S. G.

No. 682. Porphyryte. *(Diabase.)*

ame locality as No. 681.
ef. Annual Report, x, pages 77, 78.

Meg. There are two hand samples of this number. One is a dark brown, rather ained rock, with numerous porphyritic gray plagioclases, the largest of which ut an inch in length. On one side of the sample closely welded to it is a small nt of dense black aphanitic rock, looking like the rapidly cooled edge of a se dike or flow. The other sample is similar to the first, except that most of ldspar, both of the phenocrysts and of the groundmass, is brownish red in making the sample appear much redder than the first.

Mic. Sections from the darker hand sample show porphyritic plagioclases (near *'orite*) embedded in a considerably altered groundmass, which consists of more ; reddened *feldspar*, *augite*, *magnetite*, *chlorite*, *quartz*, *apatite* and confused alter-

American Geologist, vol. xviii, pp. 211-213, October, 1896.

ation products. The feldspar is in part at least plagioclase, although the alteration has in most places gone so far as to obscure its original nature. The feldspar frequently has a tendency to an idiomorphic form and the augite has an ophitic relation to it. The augite is largely altered to a confused gray mass containing much magnetite. The quartz is most probably secondary.

One section shows on one side a narrow band, about one-sixteenth of an inch in width, of a black opaque substance. In it are a few minute, elongated feldspars and some small transparent areas which are now filled mostly with chlorite. This black band undoubtedly represents part of the dense black rock which is attached to one side of the darker hand sample. This dense black rock is evidently later than the diabase porphyryte to which it is attached, and the narrow band in this slide is a small mass of the latter rock, which was chilled very rapidly and solidified at the contact practically as a glass, filling a crack in the other.

A section of the red hand sample is similar to that just described. The feldspar, both of the phenocrysts and of the groundmass, is much reddened and the whole rock is more highly altered than the first mentioned sample. No fresh augite is present, and epidote is common. There is in the slide one apparently pseudo-amygdaloidal area filled largely with epidote and a clear, transparent, isotropic substance whose exact nature was not determined.

Three sections examined.

Age. Cabotian. U. S. G.

No. 683. DIABASE *(with olivine)*.

Same locality as No. 681.
Ref. Annual Report, x, page 77; Bulletin ii, page 107.

Meg. A medium-grained, very dark-gray diabase.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"A gray crystalline rock containing lath-shaped *plagioclase* crystals and in the section it is seen to be composed of lath-shaped plagioclases with a few tabular feldspars forming diverging angles with each other and cutting the yellowish-brown *augite*, which approaches *diallage* in its cleavage. Some greenish altered olivine pseudomorphs of *serpentine*, carrying *magnetite*, occur, while the augite is in part replaced by *hornblende*, *chlorite*, and viridite, which alteration products occupy much of the mass of the section, whose structure otherwise is ophitic."

Among the alteration products is fibrous *hornblende;* a little *biotite* also occurs.

One section examined.

Age. Cabotian. U. S. G.

**Bulletin ii*, p. 107.

No. 684. Diabase. *(Altered.)*

Same locality as No. 681, which see.
Ref. Annual Report, x, pages 76, 77, 84, 96.

Meg. A fine-grained very dark-gray diabase.

Mic. The section shows numerous lath-shaped *labradorites* in a groundmass which is now completely altered to a confused greenish-gray mass in which magnetite is abundant.

One section examined.

Age. Cabotian. U. S. G.

No. 685. Apotrachyte *(with augite)*.

Near the south line of sec. 32, T. 64-1 W., on the portage from Little Trout lake to Misquah lake.
Ref. Annual Report, x, pages 75, 77, 78.

Meg. A compact, very fine-grained, reddish-brown rock, containing porphyritic crystals of red feldspar and smaller black porphyritic crystals apparently of augite.

Mic. The groundmass of the section is composed of a very fine-grained aggregate of *quartz* and reddened *feldspar*, and in places the quartz is in larger areas, so that under crossed nicols there is an approach to the "patchy" areas so frequently seen in the devitrified groundmass of acid rocks. The groundmass of this specimen may be regarded as a product of devitrification. *Magnetite* is common. Some clouded and reddened porphyritic feldspars occur, and some of these appear to be near oligoclase. A few small porphyritic grains of dark green *augite* are seen, and there are also much smaller green areas in the groundmass; some of these are now *chlorite* and others seem to be somewhat altered augites.

One section examined.

Age. Cabotian. U. S. G.

No. 686. Granophyre. *(Keratophyre?)*

From the east side of Misquah lake; sec. 32, T. 64-1 W.
Ref. Annual Report, x, page 78.

Meg. This rock is medium grained, brick red, basaltified and massive, forming mountain-like hills several hundred feet in hight. The main structure dips at a high angle toward the east.

Mic. The reddened substance has an incipiently radiated arrangement, appearing like spheruliths, the centres of which are less reddened, but this structure only appertains to the coloring matter, since each of the spheruliths has a feldspathic background, which extinguishes regularly over the whole radiated mass. There are other feldspars which are not thus reddened, and others in which the reddened (feldspathic?) substance is distributed in the manner of a micro-pegmatyte. Within such a crystal, whose idiomorphic outlines are distinct, are a great many minute idiomorphic feldspathic remnants, whose orientations are the same, and the same as that of the large crystal in which they lie. Even their forms are distinct and parallel with those of the large enclosing crystal. The perimeter of the large crystal excluded the reddened substance, and forms a continuous feldspathic band about as wide as the enclosed remnants. It appears, therefore, that a porphyritic triclinic crystal has been almost wholly removed by the entrance of the reddened substance in the manner of a micro-pegmatyte (or more properly in the manner of a micro-perthite), the original crystal only remaining in the remnants. These remnants are frequently so grouped and shaped that they are plainly outlined by the cleavages of the original feldspar. Some of these feldspars are striated distinctly, and have a nearly parallel extinction, indicating oligoclase, and others do not show any striation.

Quartz is not abundant, indeed is rare, but is seen in a few isolated small grains. And there is still less of magnetite and of chlorite. The rock is essentially coarsely crystalline, but poorly differentiated, almost quartzless, one of the forms of the "red rock" of the state. Small grains that seem to be *augite* (or *diopside*), more or less chloritized, are grouped so as to appear to be originally parts of a larger crystal which pierces the reddened substance idiomorphically.

Age. Cabotian.

Remark. This rock appears to have been the result of a profound alteration of some earlier rock (perhaps a basic one) by the entrance of the reddened element and some quartz. If quartz had been more abundant in this invading element it is quite probable that much micro-graphic structure would have resulted, and if iron had been less abundant the reddened substance would have been some distinct secondary feldspar and would have constituted, with the remnants of the original feldspar, a micro-perthite. As a whole the rock is similar to the "intermediate rocks" of Bayley along the gabbro contact. N. H. W.

No. 687. Apotrachyte. *(Spherulitic.)*

Same locality as No. 686.
Ref. Annual Report, x, page 78.

Meg. A very fine-grained, reddish-brown rock, somewhat porous in texture and earthy in appearance.

Mic. A few highly altered porphyritic feldspars are seen in a reddish groundmass in which *magnetite* and *hematite* are abundant. The groundmass is considerably reddened and consists of numerous circular areas which have a more or less distinct radial structure. Typically each area is composed of (1) A central deeply reddened mass, (2) A zone of lighter color, and (3) A zone like the centre. The radiating structure passes through all three zones but is more marked in that of lighter color. This radiating structure is made by indistinct fibres with approximately parallel extinction and a negative elongation. They are regarded as feldspar and may be orthoclase elongated in the direction of the inclined axis (a). In places there are areas between these spherulitic masses which are filled in with a reddened substance (feldspar), the *iron ores*, *quartz* in distinguishable grains, and *chlorite*.

Scattered all through the section are yellowish-green needle-like bodies which have little or no effect on polarized light. At times they assume a feather-like form. They are thought to represent original crystalliths, possibly of augite.

Two sections examined.

Age. Cabotian.

Remarks. Compare Nos. 658 and 686. U. S. G.

No. 688. Gabbro.

Cross lake; from the outcrop first seen on the right when coming from the portage between Misquah and Cross lakes; N. W. ¼ sec. 32, T. 64–1 W.

Ref. Annual Report, x, pages 78, 82; Bulletin ii, pages 88, 89.

Meg. A gray, rather coarse-grained rock consisting of grayish and pinkish feldspar, pyroxene and magnetite. On the weathered surface most of the feldspar is white.

Mic. M. E. Wadsworth's description of this section is as follows:*

"Under the microscope this rock is seen to have its *diallage* much altered, principally to a uralitic product. The *plagioclase*, in places, exhibits its twinning only at the point of extinction, as was shown by the writer to be the case with the plagioclase of the Bishopville meteorite.†

"The feldspar is also much altered and the section in places shows the structure of graphic granite or the eozoön character occurring in the granites and felsites of Keweenaw point. In No. 688 this structure is evidently produced by the aggregation of the silica in the midst of the feldspar through the medium of the percolating waters, while the remaining feldspar itself is much changed and stained by ferruginous material. Much *apatite* occurs in the section."

One section examined.

Age. Cabotian. U. S. G.

No. 689. Gabbro.

This rock makes the shore and islands of Cross lake. Probably from sec. 29, T. 64–1 W.

Ref. Annual Report, x, pages 78, 79; Bulletin ii, page 75.

Meg. A light-gray, rather coarse-grained rock composed of white and a little pinkish feldspar, augite and magnetite.

Mic. M. E. Wadsworth's description of this rock is as follows:‡

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*Bulletin ii, pp. 88, 89.

†American Journal of Science, 1883 (3), xxvi, 34; *Lithological Studies*, 1884, p. 200.

‡Bulletin ii, p. 75.

"Is a gray crystalline rock with its *feldspar* turned chiefly to a gray or pink color. Under the microscope the feldspar is seen to be in lath-shaped crystals, with triangular interspaces containing *magnetite, viridite, etc.* The feldspar is much altered and filled with kaolin and micaceous scales; but in places it is clear, showing the polysynthetic twinning of plagioclase. Some secondary *quartz* and feldspar occur, and the pyroxenic constituent is replaced by viridite."

One section examined.

Age. Cabotian. U. S. G.

No. 690. Diabase.

Near a small lake at the north end of the portage from Caribou lake. This small lake is called Little lake (or Straight lake) and lies in the N. W. ¼ sec. 18 and S. W. ¼ sec. 7, T. 64–1 W.

Ref. Annual Report, x, page 79.

Meg. A fine-grained, very dark-gray, compact diabase.

Mic. The section is composed of lath-shaped *plagioclases*, *augite* in ophitic grains, *magnetite* and confused grayish, greenish and yellowish alteration products. Some of the secondary materials clearly were derived from the augite, and it seems most probable that the rock was originally a holocrystalline aggregate of the three minerals mentioned above.

One section examined.

Age. Cabotian. U. S. G.

No. 691. Gabbro (*with olivine*).

Same locality as No. 690. "This is a sample of the usual 'trap' of the country. It weathers light, and is in that way in marked contrast with the last, though that difference seems to be due solely to the greater proportionate amount of feldspar in this, and of augite in that. This occurs in patches on and in the last, and especially on the north side. It also seems to cross and cut it in vanishing veins."

Ref. Annual Report, x, page 79; Bulletin ii, pages 92, 93, plate XII, figure 2.

Meg. Hand specimen not found.

Mic. M. E. Wadsworth's description of this slide is as follows:*

"The section is composed of *feldspar*, *diallage*, *magnetite* and *olivine*, and is similar to No. 692. The olivine is largely altered to a yellowish-green fibrous serpentine. This alteration has proceeded in a peculiar manner. In some of the olivine grains are bands of black and brown plates and needles, which for the most part are arranged parallel to the axis of the greatest elasticity, although a few are at right angles to it. The olivine also has two well-marked cleavages parallel to these directions, along which lines the serpentinous alteration extends. But as the alteration is the greatest at right angles to the line of greatest elasticity, the more highly altered olivines present an alternate series of parallel bands of *serpentine* and partially altered olivine. In some places the planes of greatest alteration coincide with the line of greatest elasticity, while in some of the entirely changed olivines the serpen-

Bulletin ii, pp. 92, 93, plate XII, figure 2.

tine is arranged in fine fibrous parallel bands occupying the entire surface. The diallage contains much magnetite dust and grains arranged mostly along the cleavage lines, as a product of alteration.

"Plate XII, figure 2, shows the structure of some of the less altered olivines."

One section examined.

Age. Cabotian. U. S. G.

NO. 692. GABBRO *(with hypersthene)*.

Forms a series of low hills and bluffs along the south side of Little lake. The rock resembles that of No. 691; extends also round the shores of Poplar lake.

Ref. Annual Report, x, page 79; Bulletin ii, pages 59, 91, 92, plate II, figure 2.

Meg. Medium grained, with gabbro aspect.

Mic. The rock consists almost wholly of feldspar, *hypersthene* and *augite*, the last usually in the form of *diallage.*

The rock is fresh, and the relation of the *hypersthene* to the other minerals is interesting, as it forms large crystals which extend more than across the whole field of the microscope when a moderately low power is used (objective No. 3, of Nachet), embracing in a poikilitic manner several crystals of each of the other minerals. It was, therefore, the last mineral to be formed. The hypersthene is dichroic, having a faint green color when the crystallographic axis $\dot{c}$ is brought into approximate parallelism with the vertical spider line, and a brownish pink tint when perpendicular to it. As the outlines of the earlier-formed minerals are rounded, apparently by resorption, the forms of the hypersthene are irregular and serpentine, surrounding and entering the curvilinear angles, embayments and interspaces that remained to be occupied.

Olivine in small rounded grains is sparsely sprinkled in the diallage.

Three sections.

Age. Cabotian.

Remark. This rock is illustrated by Wadsworth, from one of the sections examined above (Bulletin ii, pages 91, 92, plate II, figure 2), but by him the included mineral was considered enstatite, and the including mineral diallage. A section of the hypersthene cut so as to present the axis n_g, showing the prismatic and pinacoidal cleavages, also shows, by the quick disappearance of the hyperbolas on rotation, and their tardy nature, that this orthorhombic pyroxene has the greater angle of the optic axes toward the basal pinacoid, a fact which distinguishes it from enstatite.

The diallage is fresh and original, not due to weathering nor decay, having its diallagic lamellation perpendicular to the optic plane, *i. e.*, parallel to 100. (Compare No. 300.)

It is hard to explain the remarkable freshness of this and other similar rocks, already noted, since they consist of some of the most easily destructible rock-forming minerals, such as are frequently seen much altered. It cannot be due to greater surface abrasion by the glacial epoch, exposing the fresher masses, since where such abrasion certainly occurred, these rocks [*i. e.*, the Keweenawan] are often seen to be still greatly altered. It is left to infer that by far the greatest amount of such alteration is not due to weathering, but to some cause in the original environment of the rocks themselves. N. H. W.

No. 693. Forellenstein.

West end of Poplar lake, at the portage to Duck lake; N. W. ¼ S. E. ¼ sec. 2, T. 64-2 W.
Ref. Annual Report, x, pages 79, 80, 84; Bulletin ii, page 91.

Meg. A gray rock, rusty in appearance; is of granitoid texture and rather coarse grained; composed of plagioclase, magnetite and olivine.

Mic. The section is composed essentially of *plagioclase*, in small part kaolinized, *magnetite* in abundance, and *olivine*. The plagioclase, as well as the olivine, is considerably fissured and the fissures are frequently filled with a yellowish stain. On the peripheries of some of the magnetite grains are small *biotite* scales; and a very small amount of *augite* is present.

One section examined.

Age. Cabotian. U. S. G.

No. 694. Gabbro *(with olivine)*.

South shore of Iron lake, a little east of the west line of sec. 33, T. 65-2 W.
Ref. Annual Report, x, pages 80, 84; Bulletin ii, page 89.

Meg. A dark-gray granitoid rock, composed of gray feldspar and a large amount of black material which seems to be mostly magnetite.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"The section is composed of *plagioclase*, some possible *orthoclase, diallage, olivine* and *magnetite*. The latter is partially surrounded by well marked *biotite* borders, while it contains inclusions of the same. One of the olivines, which is apparently a unit in common light, its form and fracture lines indicating this, is seen in polarized light to be made up of four individuals. A little biotite occurs, but it is not attached to the magnetite."

One section.

Age. Cabotian. U. S. G.

No. 695. Cumberlandyte.

North shore of Mayhew lake; E. ½ S. E. ¼ sec. 36, T. 65-3 W.
Ref. Annual Report, x, pages 48, 80, 81; Bulletin ii, page 109.†

Meg. The rock is a rather coarse-grained aggregate made up very largely of titaniferous magnetite. Numerous olivine grains can be seen, and also a few feldspars.

**Bulletin ii*, p. 89.
†The section described on page 109 of *Bulletin ii* was not made from the hand specimen of this number.

Mic. The section shows that the minerals other than the *magnetite* are more abundant than would be supposed by an examination of the hand specimen. This mineral acts as a sponge inclosing the others. Its outlines are not sharply angular, but are usually curved. The mineral next in abundance is *olivine*, which occurs in more or less rounded grains. It has altered some to a greenish-yellow *serpentine*, and at times there is a narrow, green, serpentine band where the olivine borders on the feldspar. The feldspar is apparently a basic plagioclase, although its species was not determined; it crystallized at a later date than the magnetite and olivine. One large grain of *augite* is seen, including rounded olivines. The augite contains numerous dark, plate-like inclusions.

Biotite is common in small flakes associated with magnetite, and it is almost exclusively confined to areas of magnetite bordered by plagioclase. The biotite sometimes, but not always, is arranged in plates radiating out from the magnetite. Some of the magnetite areas are bordered by a very narrow, continuous, brightly polarizing band which appears to be biotite.

Associated with the magnetite are a few small areas of an opaque mineral which has a metallic yellow color in reflected light. It is more yellow than ordinary pyrite, and is perhaps chalcopyrite. One section examined.

Age. Cabotian.

Remarks. This specimen represents the titaniferous magnetite of the great gabbro mass of northeastern Minnesota.

An analysis by Prof. J. A. Dodge is as follows:

SiO_2	20.90
TiO_2	2.23
Al_2O_3	1.75
Fe_3O_4	70.29
FeO	2.01
CaO	trace
MgO	2.63
P	none
	99.81
Metallic iron	52.46

In the above analysis the amount of FeO required to form $FeO\text{-}TiO_2$ is computed and the rest of the iron is given as Fe_3O_4.

The following rock samples are from this same locality (or near it) and they are all very similar to No. 695: Nos. 1288, 1291, 1292, 791W, 792W, 796W, 442H, 177G, 179G.

A determination of nickel in No. 177G, by Mr. F. F. Sharpless, gave .41 of one per cent. U. S. G.

No. 696. Gabbro.

Same locality as No. 695. Embraced as nodules in No. 695.
Ref. Annual Report, x, pages 81, 82; Bulletin ii, pages 69–71; Bulletin vi, page 135.

Meg. A light-gray rock of coarse grain, composed largely of gray to flesh-colored feldspar and some magnetite.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"Under the microscope it is seen to be composed principally of *plagioclase, diallage* and *titaniferous magnetite.* A little unstriated feldspar was observed. The diallage is of a brownish color and somewhat altered, in places passing into viridite. A very little *biotite* of secondary origin was seen in association with the diallage and magnetite. The feldspar is somewhat altered to the common grayish-white product of its change (kaolin?), but still retains its plagioclastic character, strongly marked by its broad polarization bands."

One section examined.

Age. Cabotian. U. S. G.

No. 697. Gabbro *(with olivine).*

Same locality as No. 695. Embraced as nodules in No. 695.
Ref. Annual Report, x, page 81; Bulletin ii, page 96; Bulletin vi, page 136.

Meg. A dark-gray rock of medium grain, somewhat rusty in appearance. It is composed of feldspar and much black material, part of which is biotite.

Mic. M. E. Wadsworth's description of this rock is as follows:†

"The sections of this rock are composed of *olivine, diallage, feldspar, magnetite* and secondary *serpentine, hornblende, biotite, chlorite,* etc. In its general appearance it is closely allied to wherlyte and picryte, but although its feldspar is subordinate to the other minerals yet it contains sufficient to carry it under gabbro. The olivine, in part, is clear, fissured, and traversed along the fissures by bordering serpentine or ferruginous staining. Other olivines are nearly or entirely replaced by the greenish serpentine. The diallage contains some of the black needle-like inclusions, etc., but for the most part it has been changed to a brown, felty, cleavable mass, or to chloritic and amphibole products. The feldspar in part is much altered. The biotite varies from a deep reddish-brown to a brownish-yellow color—colors to which its dichroism corresponds. The biotite is largely associated with the magnetite, often surrounding the grains of the latter."

The rock varies considerably as regards alteration. Some areas of the slides show all the original minerals in a comparatively fresh state, while in immediately adjoining areas these minerals (except the magnetite) have been completely altered. The feldspar is commonly twinned according to the albite law and its extinction angles show it to be near *labradorite.* The augite is of later date than the feldspar and olivine, and the latter mineral is later than at least some of the feldspar.

Among the secondary minerals in one of the slides are stout needle-like forms of an almost colorless mineral with a marked cleavage, high index of refraction and a strong double refraction. The extinction is parallel or nearly so and the optic

*Bulletin ii, p. 70.
†Bulletin ii, p. 96.

plane is at right angles to the elongation and the cleavage. The mineral thus agrees with *epidote*, although colorless epidote with such a marked elongation has not been noticed in the other rocks of this region.

Two sections examined.

Age. Cabotian. U. S. G.

No. 698. Gabbro. (*Granulitic.*)

Same locality as No. 695. "This is distributed through No. 695 in rounded lumps like some masses of No. 696. Some masses of No. 698 are very large, where they occur on the north side of the swamp."

Ref. Annual Report, x, page 81; Bulletin ii, pages 93, 94; Bulletin vi, page 136.

Meg. A fine-grained, granular, yellowish-gray rock, looking somewhat like a gray sandstone. It appears to be composed of feldspar and a dark mineral.

Mic. The section shows a fine-grained, almost completely granular, aggregate of plagioclase and pyroxene with some magnetite. Small flakes of biotite, usually in connection with the magnetite, are seen, and there are some indistinct greenish and yellowish alteration products. The pyroxene frequently shows somewhat rounded outlines and part of it is clearly earlier than the feldspar.

The feldspar is sometimes twinned according to the albite law, but is frequently untwinned. The twinned and untwinned grains appear to be of the same species. One section cut nearly normal to a gave an extinction angle of 65°, while another almost exactly normal to this axis gave 60°. In sections cut normal to 010 equal extinction angles as high as 32° occur. A cleavage fragment parallel to 010 gave an extinction angle of 19.° All these determinations point to a plagioclase near acid *labradorite.* The feldspar is commonly fresh, but shows a little alteration to *kaolinite.*

There appear to be two species of pyroxene present in the section, although their separation is not always certain. One is of a very light cinnamon color and closely resembles in habit and color the ordinary *augite* of the associated rocks. It frequently has the dark plate-like inclusions so common in augite. Very fine polysynthetic twinning is rather common, and a typical cross section was found showing the prismatic cleavages and the parting parallel to 100 and also parallel to 010. This section in converged polarized light gave an eye, and the optic plane was determined as normal to 100. This section showed fine polysynthetic twinning parallel to 100. The mineral is augite with the *diallagic* parting common to the augite of the gabbros.

The other pyroxene appears to be orthorhombic. It has a fine columnar structure (or twinning) parallel to the vertical axis, and some sections show a very slight pleochroism, changing from a very faint greenish to a weak tint of pinkish. This mineral is probably enstatite, or perhaps hypersthene. Some of its sections show bands crossing the columnar structure. These bands are sometimes of a slightly different color from the rest of the mineral and also of somewhat higher index of refraction. They may represent bands of augite intergrown with the orthorhombic pyroxene.

One section examined.

Age. Cabotian.

Remarks. This specimen represents one variety of the rocks to which the name "muscovado" was applied in the Fifteenth and Sixteenth Annual Reports of this survey. This variety of "muscovado" is clearly a fine-grained gabbro. Rocks of similar nature are developed along the northern edge of the great gabbro mass and in general are of somewhat older date than the gabbro itself. (See description of the Akeley Lake plate, vol. iv.) Dr. Wadsworth regarded the present mineralogical composition and texture of this rock as secondary rather than primary,* but we see no good reasons for considering the minerals and the texture of the rock as anything but original. U. S. G.

No. 699. Gabbro. *(Altered.)*

North shore of Mayhew lake, associated with the titanic magnetite of that locality.
Ref. Annual Report, x, pages 81, 82; Bulletin ii, page 93, plate III, figure 2; Bulletin vi, pages 136, 421.

Meg. Gray, coarse, with reflecting surfaces of magnetite and some mica.

Mic. The feldspar in a section 010, gives extinction on cleavage at 32°. It is somewhat shattered and alteration has begun cotemporary with the entrance of calcite, quartz and mica. Some of it appears to have been orthoclase.

Pyroxene is changed entirely and lost. In one section it is preserved in the form of *diallage.*

Olivine is converted into an isotropic but translucent substance, the seams in which are filled with *hematite.*

Calcite is rather abundant, forming a cement for the other minerals.

Mica, probably biotite, is visible, as occasional hexagonal crystals, and as minute scales distributed through the altered plagioclase. It is largely converted to

Pennine, which, in transmitted light, is light green. Between crossed nicols it is isotropic when parallel to the leaves, and blue when oblique or perpendicular to them. The fibres extinguish parallel with their elongation, and are always positive in elongation. This mineral is rather abundant. It presents the characteristic aureoles, and constitutes here the first instance yet discovered in which the polarization color is distinctly blue in a section whose thickness is less than .03 millimeter. This blue color, however, according to Michel Lévy (Minéraux des Roches, page 168), is not due to the polarization proper of the mineral, but to the fact that sub-microscopic lamellæ, crossing each other, imperfectly compensate themselves, reducing the resultant to a violet lilac, or gray of the first order.

**Bulletin ii*, p. 94.

Zoisite fibres and clusters are in a similar manner disseminated (though more frequently isolated) throughout the altered plagioclases. They are distinguishable from the biotite by their low birefringence and their usually less marked fibration. They appear grayish, or blue, in a normal thin section.

Leucoxene has resulted from the change of the ilmenite. It is strongly cleaved, its lamellæ being separated by films of hematite, which also is more or less disseminated through the whole mass of the mineral. By its increasing abundance, in the direction toward the original grain of ilmenite, the transparency of the leucoxene is lost by degrees, and it apparently blends with the original ilmenite. The coarse cleavage visible is probably due to the original zoned structure of the ilmenite.

Two sections.

Age. Cabotian. N. H. W.

No. 700. Gabbro *(with olivine)*.

Same locality as No. 695. The ore (No. 695) lies on this rock, which seems to have furnished the rounded masses of No. 698 inclosed in the ore.

Ref. Annual Report, x, pages 81, 83; Bulletin ii, page 93, plate III, figure 2; Bulletin vi, page 136.

Meg. A rather fine-grained, dark-gray, granular rock, composed of feldspar and a dark mineral or minerals.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"Is a compact, dark-grayish, crystalline rock, composed of *diallage*, *olivine feldspar* and *magnetite*. Considerable of the secondary *biotite* is found associated with the magnetite and diallage. This section has its minerals somewhat altered, the magnetite dust and grains being quite abundant in the diallage, while a chlorite-like vein traverses the section.

"Plate III, figure 2, shows the general structure of the rock with its brownish diallage, yellowish altered olivines, black magnetite, reddish-brown biotite in the diallage and bordering the magnetite, and colorless feldspar."

The olivine is frequently in somewhat rounded grains and is in general earlier than the augite (diallage) and feldspar. Some of the augite is later than some of the feldspar, which in places has a tendency to a lath-shaped development. The augite sometimes shows twin lamellæ parallel to 100. The feldspar is commonly twinned according to the albite law. Equal extinction angles in sections normal to 010 run up to 32°, and a cleavage chip parallel to 010 gives an extinction angle of 22°. The feldspar is therefore *labradorite*. One section examined.

Age. Cabotian. U. S. G.

No. 701. Gabbro.

Near the centre of S. ½ sec. 36, T. 65-2 W.; north shore of Mayhew lake.

Ref. Annual Report, x, pages 78, 82, 84; Bulletin ii, page 72.

**Bulletin ii*, p. 93.

Meg. A medium-grained, gray, granitoid rock, composed of plagioclase, bioti titaniferous magnetite and other black material. A small amount of a bright yell mineral (probably chalcopyrite) is present.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"In the thin section the *pyroxene* appears to have been principally altered t fine matted mass of *actinolite* fibres and to *biotite;* but the plagioclase has suffe less change than would naturally be supposed from the amount of alteration the pyroxene. Considerable biotite of a secondary origin is to be seen fringing t magnetite grains. The usual needles and inclusions common in the feldspar gabbros occur here in a manner that indicates that they are the result of the co mencement of the plagioclastic alteration rather than original forms."

The rock is clearly a gabbro. The *hornblende, chlorite* and part of the magnet and biotite are evidently secondary minerals from the original augite, none of whi remains. The feldspar is near *labradorite,* as is shown by its extinction angles sections normal to 010 and in cleavage fragments.

One section examined.

Age. Cabotian. U. S. G

No. 702. Gabbro.

Same locality as No. 701. "No. 702 is embraced in pockets and lumps in No. 701. It is the same rock with much coarser crystals and a larger percentage of diallage (see No. 688 and No. 1D)."

Ref. Annual Report, x, pages 78, 82, 84; Bulletin ii, pages 70, 71.

Meg. A coarse-grained granitoid rock, composed of whitish feldspar, magnet and augite, the last mineral being in large masses and especially abundant.

Mic. This rock affords an illustration of very coarse *diallage* associated w *plagioclase* and *magnetite,* all in large grains, the first especially being in large mass The diallage appears to have formed not much later than the feldspars, and has m or less curving outlines, yet embraces occasionally small portions of the plagiocla *Brown* ("basaltic") *hornblende,* much resembling biotite, is closely associated w the magnetite about its borders. There is also a small amount of *biotite, comn hornblende* and *chlorite.*

One section.

Age. Cabotian. N. H. W

No. 703. Cumberlandyte.

Iron ore, at the east end of Pewabic island, in Mayhew lake.

Ref. Annual Report, x, page 82; Bulletin ii, pages 89, 90, plate IV, figure 1.

Meg. Titanic iron ore, mingled largely with pyroxene.

Mic. The *feldspar* has extinction on n_g at 22° and on 010 at 25.° It is entir surrounded sometimes by the *magnetite,* and is separated from it by a border of bro

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**Bulletin ii*, p. 72.

hornblende. It is less abundant than the pyroxene. It is likely to be flecked by decay, the colored polarization indicating the formation of mica scales, amongst which *zoisite* is occasionally found.

The *pyroxene* is usually in the form of *diallage*. It is not separated usually from the magnetite by any rim of hornblende, but it has an abrupt and clear contact with it. Yet in one place in the section such a rim separates the diallage from the magnetite. The *magnetite*, judging from the lack of leucoxene, is but little titaniferous.

That which is here called *bowlingite* is the same that Wadsworth (Bulletin iii, Minnesota Geological Survey) stated is "a substance of unknown character." It was named by Hannay (Mineralogical Magazine, i, 154, 1877), and has been further elucidated by Lacroix in his last work (Minéralogie de France, vol. i, page 442, 1895). It is always a product of decay of olivine rich in iron. In the section examined there are left traces of the olivine in the rims surrounding the feldspars embraced in the magnetite, which are sometimes so intimately associated with this mineral that the transition from olivine to it is evident.

In several of the gabbros already described the fact that olivine forms a narrow rim surrounding the magnetite grains has been noted (see No. 512). Its partial replacement, in such position, by brown hornblende is also common. The general transition from olivine to bowlingite is the cause of the bowlingite rims about the feldspars in this rock, this transition being simply one of natural decay of the olivine.

In general, bowlingite takes a wide range in color. According to Lacroix it is dark brown, or reddish brown, with little or no visible cleavage or micro-structure, or it is lighter colored (yet still brown), but laminated as if by cleavage. Other forms are yellowish and greenish, passing even to nearly translucent, though yet greenish, either laminated (similar to pennine) or finely fibrous. It is frequently pleochroic, but not in all cases. Its double refraction is strong, giving colors in red and yellow even in sections less than .03 millimeter in thickness.

In the section examined this rim is light-yellow in natural light, rarely greenish, becoming translucent as it is replaced by unchanged olivine.

In one section (that examined by Wadsworth) is much *olivine*. This is sometimes in the form of large grains and sometimes as rims separating the magnetite from the feldspar, giving place occasionally to the rim of bowlingite.

Besides the bowlingite rim, Prof. Lacroix has kindly called attention to the characters of the brown rims, which are frequently taken for biotite. They have a uniform extinction embracing sometimes the whole border, or a part of a border of a single grain or even the borders of contiguous grains. They do not remain dark on rotation, as biotite would if lying flat in that manner, and parallel to the cleavage.

They are sometimes cleaved in two directions, and extinction is parallel to one of these cleavages. Biréfringence is low—*i. e.*, too low for a mica. The maximum of pleochroism, which is extreme, is parallel to n_g and with the direction of extinction. A grain cut perpendicular (nearly) to an optic axis does not show a black cross in convergent light, but the figure of a biaxial mineral. These characters exclude it from the mica series, and especially from biotite.

There are occasional clusters of *biotite* scales, strongly pleochroic.

Two sections examined.

Age. Cabotian. N. H. W.

No. 704. Gabbro.

Mayhew lake, south from the little island crossed by the east and west town line.
Ref. Annual Report, x, page 82; Bulletin ii, page 89.

Meg. A heavy, rusty, magnetited gabbro.

Mic. The *feldspar* has extinction on 010 at 28°—indicating *labradorite.* It followed the olivine in crystallization.

The pyroxene is partly *diallage* and partly *augite.* Besides the characteristic inclusions arranged in lines, it embraces many others that are scattered helter-skelter, and which sometimes have orientation and polarization of their own.

Bowlingite(?) the green and yellowish decomposition product from the olivine, is also seen in this rock, but not so often as rims between the magnetite and the feldspar.

Biotite, pennine, olivine, brown hornblende, magnetite, make up the rest of this rock, the last in great amount, and the second only as isolated scales in the altered feldspar. The olivine is in large grains, frequently surrounding the magnetite.

Two sections examined.

Age. Cabotian. N. H. W.

No. 705. Noryte. *(Muscovadyte.)*

"Appears like a metamorphic rock, bedded and dipping north about 45° at a point a little back (north) from the shore, a short distance west from Mayhew's location, which underlies the iron-bearing rock, and the iron ore, and has been styled changed quartzyte." Near the north shore of Mayhew lake and probably near the west line of sec. 31, T. 65-2 W.
Ref. Annual Report, x, pages 82, 83; Bulletin ii, page 94.

Meg. A rather fine-grained, gray, granitoid rock, composed of feldspar, pyroxene and a little biotite.

Mic. M. E. Wadsworth's description of this section is as follows:*

"Its thin section under the microscope shows an irregular aggregation of short crystals, with rounded or irregular outlines, as seen in Nos. 777 and 698, which marks many rocks whose present structure is due in part or whole to the recrystallization of its constituents under the influence of water action. The pyroxenic constituents,

*Bulletin ii, p. 94.

which may be the remains of original crystals, are in short, irregular, ragged crystals and grains considerably altered and belonging to *enstatite.* The feldspar is in part *plagioclase* and in part *orthoclase,* while *magnetite,* in part secondary, and secondary *biotite* and *quartz* are quite common. The rock is metamorphic, but in all probability a metamorphosed eruptive instead of a sedimentary one."

The texture of the rock resembles that usually seen in granites in the fact that the constituent grains vary considerably in size, there being many minute ones. These are, however, not due to dynamic action after the crystallization of the rock. The associated gabbros almost always have the constituent grains of approximately uniform size throughout a given section. The feldspar is both untwinned and twinned according to the albite law. Extinction angles show that the mineral is in most part near *andesine* and *labradorite.* The untwinned grains appear to be of the same species as the twinned; an untwinned grain cut almost normal to $\mathfrak{c}$, gave an extinction angle of 28°, indicating rather basic *labradorite.* Feldspar more acid than andesine may be present, but it was not determined. The feldspar is in places altering to *kaolinite* and *chlorite.* A careful search failed to reveal any quartz, although it is possible that some of the smaller grains are of this mineral.

The pyroxene is clearly orthorhombic. The section is about .04 millimeter in thickness, and this mineral is noticeably, although not markedly, pleochroic, $\mathfrak{a}$ being very pale yellowish, $\mathfrak{b}$ pale reddish, and $\mathfrak{c}$ pale greenish. From its pleochroism and its double refraction, which is considerably higher than the feldspar, it may perhaps be referred to *hypersthene* rather than to enstatite. It alters to a gray, finely fibrous, brightly polarizing aggregate.

Considerable *pyrite* is present in the slide. One section examined.

Age. Cabotian. U. S. G.

No. 706. Granite. *(Fine grained.)*

"Through the iron-rock at the location No. 705 run seams, three to six inches in thickness, of pinkish rock consisting of quartz, orthoclase and hornblende, in rather fine grains. These seams and veins are parallel with the basaltic jointage of the rock No. 705. Sometimes a pinkish shade of color runs into the trap, accompanied by quartz."

Ref. Annual Report, x, page 83; Bulletin ii, page 70.

Meg. A fine-grained, granitoid, light-gray rock, of a pinkish shade on weathered surfaces. The minerals are quartz, white feldspar and a small amount of black micaceous substance.

Mic. The section shows a granitoid aggregate of *quartz, feldspar* and a little *chlorite* which in places appears to be an alteration product of biotite. The feldspar is much clouded and altered and some of it is nearly opaque. It is probably largely *orthoclase,* but some grains which still show polysynthetic albite twinnings appear to be *oligoclase.* One section examined.

Age. Cabotian. U. S. G.

Remark. "These pinkish beds and seams, which simulate planes of bedding, are probably due to near contact with the underlying formation and infusion from it." There are two rocks represented by this number, although doubtless from the same place and closely related; one is the above fine-grained granite, which may be a recomposed acid debris (or graywacke), and the other is a coarser phase of the "intermediate" or contact rocks, a basic irruptive permeated by acid elements, showing granophyric structure, though mainly still of basic character. (Compare, also, rock No. 707.) N. H. W.

No. 707. Gabbro. *(Altered.)*

"In some places in the trap, where one of these red seams (No. 706) passes through it, the hornblende, which accompanies the red rock, greatly preponderates, or is very coarse and sometimes is fibrous and radiating, coating the walls of the seam. In such places mica also can be seen, and also, mixed with the fibrous hornblende, occasionally a crystal of quartz."

Ref. Annual Report, x, page 83; Bulletin ii, page 87.

Meg. A medium-grained, granitoid rock of a dark greenish-gray color. The rock is composed of gray feldspar and considerable quantities of dark minerals, among which can be recognized biotite, magnetite and fibrous hornblende.

Mic. The section shows a gabbro which has been considerably altered. The minerals are *plagioclase, augite, magnetite, hornblende, chlorite, quartz, biotite, kaolinite* and *apatite*. The plagioclase, augite, apatite and part of the magnetite appear as original minerals, and the others as secondary. The augite shows the diallagic parting well developed and it has largely altered to fibrous hornblende and chlorite. The apatite is in grains of considerable size.

One section examined.

Age. Cabotian. U. S. G.

No. 708. Dioryte *(with quartz).*

Portage between Mayhew and Loon lakes; near the centre of the S. W. ¼ sec. 36, T. 65-3 W.

Ref. Annual Report, x, pages 83, 86; Bulletin ii, page 118.

Meg. A rather fine-grained rock, greenish-gray in color and composed of white to pinkish feldspar and considerable hornblende. Reflections can be obtained from areas of small size, thus giving a lustre-mottled appearance to the rock.

Mic. The section is composed mainly of *feldspar* and *hornblende*. The former mineral is rather weakly polarizing and is considerably altered, *kaolinite, muscovite* and *chlorite* being developed in it. It is mostly untwinned, but a few grains show albite twinning. The uniformly low extinction in the twinned sections, as well as in cleavage fragments, indicates that the feldspar is mainly *oligoclase* or *oligoclase-andesine*, although this determination is not as certain as might be desired. This mineral occurs in rather large irregular grains making up the background of the rock and including the other minerals in a somewhat poikilitic manner.

The hornblende is in large amount and is colorless to green, usually the latter. A few brownish grains also occur. The hornblende is quite frequently fibrous, is in irregular areas of various sizes and does not show crystal boundaries. It is clearly a secondary or metamorphic mineral.

The section also contains *magnetite*, *sphene* and numerous small prisms of *apatite*, which are most frequently short but occasionally are much elongated. These apatites penetrate indiscriminately both the feldspar and the hornblende. A little *quartz* is present.

One section examined.

Age. Cabotian.

Remark. This rock seems to be a metamorphosed one, but what its original nature was is uncertain. It might have been a gabbro or a diabase, and in this connection we wish to suggest the possibility that this rock represents one of the diabase sills, in the adjoining Animikie strata, which was somewhat altered and then metamorphosed by the gabbro contact. If this be true the diabase sills are of earlier date than the gabbro, a conclusion which has some facts in its favor. (See remarks under No. 709.) U. S. G.

No. 709. Diabase. *(Altered.)*

From the top of the hill near the base of the long point on the south shore of Loon lake; probably from S. W. ¼ N. W. ¼ sec. 35, T. 65-3 W.

Ref. Annual Report, x, pages 83, 84, 86; Bulletin ii, page 118.

Meg. This rock in general is similar to No. 708. The minerals are white to brownish feldspar and hornblende.

Mic. The section is composed of feldspar, *green hornblende*, *chlorite*, *magnetite*, *biotite*, *quartz*, *augite* and *apatite*. The feldspar is partly kaolinized, but is usually fresh and shows abundant albite twin lamellæ, as well as some pericline twinning. Equal extinction angles in sections normal to 010 are as high as 27°, showing a feldspar as basic as *andesine*. The hornblende is often fibrous. This mineral, the chlorite, biotite, quartz and part of the magnetite, are regarded as secondary. Only a small amount of augite remains.

One small section examined.

Age. Cabotian.

Remark. This rock is undoubtedly from one of the diabase sills of the Animikie. The metamorphism of such an altered diabase as this might readily, so it seems, make a dioryte like No. 708. U. S. G.

No. 710. Dioryte.

This rock underlies No. 709 in the same hill, is five to ten feet in thickness and is in beds six to ten inches thick.

Ref. Annual Report, x, page 84.

Meg. A fine-grained, compact black rock, appearing like a diabase.

Mic. The section shows *feldspar*, *green hornblende*, *magnetite*, *biotite*, *chlorite*, a possibly a few small grains of *quartz*. The feldspar is usually in elongated grai and is, in large part at least, plagioclase apparently near *andesine*. The hornblen and magnetite are frequently in elongated grains, and sometimes there is an ind tinct radial arrangement of these grains.

One section examined.

Age. Cabotian.

Remark. This rock represents the finer grained lower portion of the diaba sill, of which No. 709 represents the main part. It is impossible to tell whether N 710 was originally holocrystalline, and thus whether the secondary minerals m represent original augite or original unindividualized matter. U. S. G.

No. 711. GRAYWACKE. (*Slate.*)

Nos. 711 and 712 make up the lower part of the hill in which Nos. 709 and 710 occur. There is 100 to feet in thickness of Nos. 711 and 712; they are slaty, and dip towards the south at angles of 10° to 15°. Ab nine-tenths of this slaty rock is made up of No. 711.
Ref. Annual Report, x, page 84.

Meg. A very fine-grained graywacke slate, showing small glistening flakes of some mineral with a marked cleavage.

Mic. The section shows a fine-grained slate, composed of *quartz*, possibly so *feldspar*, *biotite*, *muscovite chlorite*, *magnetite* and *pyrite*. The biotite is quite abunda There are a few irregular shaped areas of some transparent mineral which is much larger grains than the other constituents of this rock. This mineral evidently the same as that mentioned so abundant in No. 712.

One section examined.

Age. Animikie. U. S. G

No. 712. GRAYWACKE. (*Slate.*)

Same locality as No. 709. See under No. 711.
Ref. Annual Report, x, page 84.

Meg. A fine-grained, slaty rock, in general resembling No. 711.

Mic. The most noticeable feature of the section under a low power, or wh examined with a hand lens, is the apparent sponge-like texture of the rock, th being lighter areas enclosed in a general background of darker color. The secti shows a banding due to the abundance of the iron ores in certain lines. The da background of the section consists of a very fine-grained aggregate of *quartz*, possil some *feldspar*, *biotite* in abundance, *chlorite*, *muscovite*, *pyrite* in abundance, *magne* and *hematite*. These minerals, except the quartz, are also scattered through t lighter areas in the section, but not in large amount, the dark color of the backgrou being due to the great abundance of biotite and the iron ores.

The lighter areas in the section are of irregular and not sharply defined outlines, and each area is not always of one grain. The mineral is somewhat cloudy, and not completely transparent; this appearance may be due entirely to the numbers of inclusions it contains. It has approximately the index of refraction and the double refraction of quartz. No cleavage is to be seen. The interference figures obtained were very indistinct. A few were seen which are of a uniaxial, or closely uniaxial mineral, and the character of the double refraction is negative. This mineral may be *cordierite*.

One section examined.

Age. Animikie. U. S. G.

No. 713. GABBRO *(with olivine)*.

North shore of Tucker lake. This lake lies in secs. 2, 3 and 4, T. 64-3 W. This embraces also masses of rock like No. 702.

Ref. Annual Report, x, page 84; Bulletin ii, page 71, plate I, figure 2.

Meg. A coarse-grained gray rock, composed of feldspar, augite, magnetite, biotite, hornblende and olivine.

Mic. The section shows a considerably altered olivine gabbro. The original minerals are *plagioclase, augite, olivine* and *magnetite*. Contrary to the usual order of alteration, this section shows the plagioclase and the augite frequently very highly altered while the olivine is usually comparatively fresh. The plagioclase has changed largely to "saussurite" which in this case consists of *chlorite, zoisite* and colorless micaceous minerals. The zoisite commonly shows the blue interference color which is so frequently given by this mineral. The augite has in many places changed to a mass of green fibrous *hornblende, chlorite,* magnetite, *biotite* and a little *brown hornblende*.

One section examined.

Age. Cabotian. U. S. G.

No. 714. GABBRO *(with olivine)*.

From the hill range south of Tucker lake, in the north part of sec. 10, T. 64-3 W.

Ref. Annual Report, x, page 84; Bulletin ii, page 93.

Meg. A medium-grained, granular, dark-gray rock, composed almost entirely of plagioclase and augite.

Mic. The section shows a gabbro of finer grain than the main mass of the gabbro of northeastern Minnesota. The minerals are *plagioclase, augite, magnetite,* a little *olivine,* a few small flakes of *biotite,* and alteration products.

One section examined.

Age. Cabotian. U. S. G.

NO. 715. GABBRO *(with enstatite and olivine).*

"From an island in Poplar lake, near the portage coming from Little lake. The usual rock about Poplar lake." Probably near the centre of the west side of sec. 7, T. 64–1 W.
Ref. Annual Report, x, page 85; Bulletin ii, page 91.

Meg. The rock is closely similar to No. 714, except that this specimen (No. 715) is a little coarser grained than the other.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"Is a grayish granular rock, composed of plagioclase, some *olivine* and *pyroxene*, part of which has the cleavage and optical characters of *enstatite* and part that of *diallage*."

No section found.

Age. Cabotian. U. S. G.

NO. 716. DIABASE *(with orthoclase, quartz and hornblende).*

From the top of Stair portage, between Mud and Duncan's lakes; N. W. ¼ sec. 27, T. 65–1 W.
Ref. Annual Report, x, page 85; Bulletin ii, pages 115, 117.

Meg. A medium-grained, greenish-gray rock, composed of white feldspar, hornblende and magnetite.

Mic. M. E. Wadsworth's description of this rock is as follows:†

"A greenish-gray crystalline rock, somewhat altered, macroscopically, while the section shows that it is miscroscopically a much altered specimen. Some of the *augite* is distinguishable, but most of it is nearly or entirely altered to *viridite* and *green hornblende,* part of which, however, is stained brown. The feldspar is also much changed to the common dirty white kaolin-like substance, while its clear spaces are replaced by secondary *quartz, orthoclase,* and *plagioclase.* Considerable *apatite, biotite* and magnetite occur."

The texture of the section is markedly diabasic, the augite having an ophitic relation to the feldspar.

One section examined.

Age. Cabotian. U. S. G.

NO. 717. DIABASE *(with quartz and hornblende).*

North side of South lake opposite the east line of sec. 24, T. 65–2 W.
Ref. Annual Report, x, page 85; Bulletin ii, pages 114–116.

Meg. A very dark-gray rock, rather fine grained and composed largely of feldspar, augite and hornblende.

Mic. M. E. Wadsworth's description of this section is as follows:‡

"The section shows that the rock has been much altered. Part of the original *feldspar, augite* and *magnetite* remain intact, but much of the augite has been replaced

**Bulletin ii*, p. 91.
†*Bulletin ii*, p. 117.
‡*Bulletin ii*, pp. 114, 115.

by *brownish hornblende*, particularly along the borders and ends of the crystal. Some of this hornblende shows the well-marked prismatic amphibole cleavage. The feldspar and augite are also both altered to *viridite*, while secondary *quartz*, replacing the feldspar, is abundant. In this rock we have a diabase showing a stage approaching near to the formation of a quartz dioryte by alteration."

One section examined.

Age. Cabotian. U. S. G.

NO. 718. DIABASE *(with quartz.)*

"Fine trap-rock, south side of Gunflint river, a little east of the location of No. 305 last year. This runs obliquely down to the river, and under the water, in angular basaltic blocks like trap, presenting a face (back in the woods) toward the north much the same as the highest bluffs of the country." Probably from near the centre of the W. ½ sec. 16, T. 65-2 W.

Ref. Annual Report, x, pages 85, 86.

Meg. A very dark-gray, fine-grained, diabasic rock, holding a few small porphyritic feldspars.

Mic. The section is in general similar to that of No. 717, except that this rock (No. 718) is finer grained and the augite has almost entirely disappeared. Greenish and grayish alteration products, the latter largely in the feldspar, are common. There is one apparently pseudamygdaloidal area in which there are numerous small flakes of *chlorite* in a background of *calcite*, which mineral also appears to make up a large part of the grayish alteration products in the feldspar.

One section examined.

Age. Cabotian. U. S. G.

NO. 719. DIABASE *(with quartz.)*

From the eastern of the two points which enclose the little bay, on the south side of Gunflint lake, from which there is a portage to Loon lake. Near the centre of the western side of the S. W. ¼ sec. 24, T. 65-3 W.

Ref. Annual Report, x, page 86; Bulletin ii, pages 115, 116.

Meg. A very dark-gray, almost black rock, of medium grain, composed of feldspar and much black material among which is *magnetite*, *augite* and *hornblende*.

Mic. M. E. Wadsworth's description of this section is as follows:*

"The section is similar to that of the preceding (No. 717) but contains secondary *biotite* from the alteration of the augite. The secondary *quartz* is abundant, and, together with the other secondary minerals, is traversed by numerous *actinolite* and *apatite* needles."

One section examined.

Age. Cabotian. U. S. G.

NO. 720. DIABASE *(with quartz)*.

From the western of the two points which enclose the little bay, on the south side of Gunflint lake, from which there is a portage to Loon lake; S. E. ¼ S. E. ¼ sec. 23, T. 65-3 W.

Ref. Annual Report, x, pages 86, 87.

**Bulletin ii*, p. 115.

Meg. A very dark-gray diabasic rock, of rather fine grain.

Mic. The section shows a somewhat altered diabase, quite similar to some of the preceding (Nos. 717 and 719). Secondary quartz is common.

One section examined.

Age. Cabotian. U. S. G.

No. 721. Diabase (*with quartz and hornblende*).

A north and south section was taken of the steep, northward facing hill 250 feet in hight, which is crossed by the portage between Gunflint and Loon lakes. The section was made a little east of the portage trail and was thus near the eastern sides of secs. 23 and 26, T. 65-3 W. Rocks Nos. 721-727 come from this hill. No. 721 forms the top of the hill and is seventy-five feet thick.

Ref. Annual Report, ix, page 81; Annual Report, x, pages 86, 87; Bulletin ii, page 75.

Meg. A dark-gray rock, of medium grain, and thus somewhat coarser than the preceding diabases. It is composed of gray feldspar and black minerals, among which are magnetite and hornblende. The feldspar has a tendency to a flattening and elongation in one plane, giving a semblance of a platy texture to the rock.

Mic. M. E. Wadsworth's description of this section is as follows:*

"A dark-green section, composed of partially altered *augite*, *diallage*, *feldspar*, *magnetite*, and secondary *quartz*, *biotite*, *hornblende*, *viridite*, and *apatite*. The section is stained in places yellowish from ferric oxide. The pyroxene is altered along its edges and even often throughout its interior to viridite, biotite and hornblende (both green and brown). The alteration extends generally along the cleavage planes, which in the diallage appear to be produced from a change in the common augite. The feldspar is kaolinized and contains quartz and other secondary minerals. The rock, mineralogically, could well be pronounced a hornblende-biotite-granite bearing accessory pyroxene, although it is evidently an altered basalt of the gabbro or diabase type."

One section examined.

Age. Cabotian. U. S. G.

No. 722. Diabase (*with quartz and hornblende*).

From about half way down the perpendicular portion of the bluff. Same locality as No. 721.

Ref. Annual Report, ix, page 81; Annual Report, x, page 86; Bulletin ii, pages, 115, 116.

Meg. A dark-gray rock of fine grain, composed of feldspar and black minerals. Pyrite is quite common.

Mic. M. E. Wadsworth's description of this section is as follows:†

"The section is similar to those of Nos. 716 and 719, and it still shows in polarized light its original structure of divergent feldspars with the interstitial portions of pyroxene, etc. But the section is now largely composed of secondary minerals, such as *chlorite*, *viridite*, *biotite*, *quartz*, *magnetite*, *hornblende*, etc., with

*Bulletin ii, p. 75.

†Bulletin ii, p. 115.

kaolinized feldspar and some *augite*. In places it shows aggregations of secondary magnetite, with their interstitial portions filled with biotite, which is also an alteration product. These forms simulate closely the appearance of a mineral partially destroyed by the molten magma, instead of being what it actually is—a mineral (biotite, holding magnetite) in the process of formation. The augite, when altered, leaves dirty gray cloudy grains and masses resembling *leucoxene*, while in the midst of some of the quartz, chlorite, viridite, etc., are to be seen dark orange red and yellow secondary granules resembling *titanite*. They are translucent and anisotropic. *Actinolite* and apatite needles are not uncommon."

One section examined.

Age. Cabotian. U. S. G.

No. 723. Diabase *(with quartz and hornblende)*.

From near the bottom of the perpendicular part of the bluff. Same locality as No. 721.
Ref. Annual Report, ix, page 81; Annual Report, x, page 86.

Meg. A fine-grained, dark, greenish-gray diabase, showing some pyrite and chalcopyrite.

Mic. The section shows a diabase more altered and finer grained than Nos. 721 and 722, but still of the same general type and from the same rock mass.

One section examined.

Age. Cabotian. U. S. G.

No. 724. Diabase.

One foot lower in the bluff than No. 723. Same locality as No. 721.
Ref. Annual Report, ix, page 81; Annual Report, x, page 87.

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

Mic. The section shows a rock similar to, but much more altered than, No. 723. *Magnetite* is abundant, and is in rods, feather-like and grating-like forms. *Pyrite* is common.

One section examined.

Age. Cabotian. U. S. G.

No. 725. Diabase.

Six inches lower than No. 724. Same locality as No. 721.
Ref. Annual Report, ix, page 81; Annual Report, x, page 87.

Meg. Similar to, but finer grained than, No. 724.

Mic. Another fine-grained, much altered diabase, in general similar to No. 724.

One section examined.

Age. Cabotian.

Remark. This rock represents the finer grained lower part of the large diabase sill which forms the ridge between Gunflint and Loon lakes, and of which Nos. 721

to 725 are samples. These sills, as far as examined, always show a much finer and usually more altered lower side, and in the field there is some difficulty in distinguishing this lower portion of a sill from the immediately underlying, almost black, slaty rocks which have been somewhat altered by the diabase contact. There is, however, no "transition" between the diabase and the slate, as is seen by an examination of the thin sections, and usually one who is accustomed to these rocks can distinguish the two within an inch of the contact; and frequently the exact contact line can be determined.

Quite a number of specimens from the diabase sills (Logan sills) of the Animikie in Cook county have been collected. Among these are the following from the vicinity of Gunflint lake: Nos. 308, 709, 710, 717 to 725. U. S. G.

No. 726. Slate.

A foot lower than No. 725. Same locality as No. 721.
Ref. Annual Report, ix, page 81; Annual Report, x, page 87.

Meg. A fine-grained, earthy, yellowish-gray slate. A little pyrite is present.

Mic. The most noticeable feature of the section under a low power is the presence of numbers of dark spots which are of rather irregular, though approximately circular, outline. They are fairly uniform in size and average a little less than .1 millimeter in diameter. Under a high power these spots are seen to be more irregular in outline, and they are not very sharply marked off from the rest of the rock. The section is composed of a very fine-grained aggregate of *quartz*, possibly some *feldspar*, *muscovite*, *chlorite*, *pyrite*, *magnetite*, and probably some carbonaceous material. The iron ores are the largest grains in the rock. The dark spots are seen to be aggregations of the opaque minerals of the rock and chlorite, quartz and muscovite being in small amount or lacking entirely. Much of each spot is made up of minute black specks which are quite probably of carbonaceous material.

One section examined.

Age. Animikie. U. S. G.

No. 727. Slate.

Four feet lower than No. 726. Same locality as No. 721.
Ref. Annual Report, ix, pages 81, 82; Annual Report, x, page 87.

Meg. A slate similar to No. 726, but darker colored.

Mic. The section is very similar to No. 726, but is even finer grained and does not show as much *muscovite*. Some yellow grains which appear to be *epidote* are present. The black spots are numerous, but average fully twice the size of those in the section of No. 726.

One section examined.

Age. Animikie.

Remark. These two rocks (Nos. 726 and 727) are parts of the black slate member of the Animikie. Their spottedness is probably due to the metamorphosing action of the great diabase sill above them. U. S. G.

No. 728. Granite *(with hornblende).*

From the island in Saganaga lake which is nearest the entrance of the international boundary stream. Near the centre of the E. ½ sec. 4, T. 66-4 W.

Ref. Annual Report, x, page 88.

Meg. A coarse-grained, light-gray, granitic rock, composed of white to pinkish feldspar, quartz and hornblende. Some of the white feldspar is plagioclase. A little biotite is present.

Mic. The section shows the hypidimorphic-granular texture, the plagioclase feldspar and the *hornblende* having a tendency to assume crystal outlines. The minerals are feldspar and *quartz* in large amount, hornblende in smaller amount; also small quantities of *chlorite, epidote, magnetite, apatite, sphene* and brownish alteration product which is perhaps *limonite* derived from *pyrite.*

The feldspar frequently shows considerable alteration to a gray, almost opaque, kaolin-like substance. Frequently the centres of the crystals are more altered than the edges. Some of the feldspar presents the aspect of *orthoclase,* and some of it is finely twinned according to the albite law. The uniformly low extinction angles in these twinned grains indicate a feldspar near *anorthoclase* or *oligoclase.* The quartz is frequently in areas of considerable size, but under crossed nicols these areas break up into several interlocking grains. The hornblende is of the usual green variety, and chlorite and epidote are frequent secondary products from this mineral. The latter mineral (epidote) is also developed in small amount in the feldspar. There is one grain which appears like biotite altering to chlorite. No part of the grain is fresh characteristic biotite, and it is uncertain whether it represents original biotite or an alteration product from hornblende.

One section examined.

Age. Archean, probably of date between the Lower and Upper Keewatin.

U. S. G.

No. 729. Granite *(with chlorite).*

From "Caribou narrows" in Saganaga lake, N. E. ¼ N. E. ¼ sec. 19, T. 66-4 W.

Ref. Annual Report, x, page 88.

Meg. A medium-grained, reddish granite, composed of feldspar, which is gray to reddish (usually the latter), quartz, chlorite and a little epidote.

Mic. The section shows a granite in general similar to No. 728, but *quartz* is not so abundant. The feldspar is rather uniformly clouded and altered, but a considerable part of the feldspar is seen to be *plagioclase.* The original ferromagnesian mineral, which was probably *hornblende*, is completely replaced by *chlorite*, *calcite* and a little *epidote*.

One section examined.

Age. Archean, probably of date between the Lower and Upper Keewatin.

No. 730. GRANITE *(with chlorite)*.

From the rapids between West Sea Gull and Sea Gull lakes. Near the centre of N. E. ¼ sec. 9, T. 65-5 W. *Ref.* Annual Report, x, pages 88, 89.

Meg. Similar to No. 729, but with more quartz.

Mic. The section is similar to the last two (Nos. 728 and 729), and orthoclase and plagioclase are both present. The original ferromagnesian constituent, which, judging from areas with outlines of hornblende cross sections, was *hornblende*, is altered to *chlorite* and *calcite* with some *epidote*. The chlorite is not as green nor as abundant as in No. 729.

One section examined.

Age. Archean, probably of date between the Lower and Upper Keewatin.

Remark. These three samples (Nos. 728, 729 and 730) are good representatives of the mass of the Saganaga granite, which is a coarse-grained hornblende granite.

An analysis* of a characteristic epecimen of the Saganaga granite—No. 686G—from Saganaga lake (S. W. ¼ N. E. ¼ sec. 22, T. 66-5 W.) is as follows:

SiO_2	69.34
Al_2O_3	17.25
Fe_2O_3 and FeO	2.46
CaO	3.43
MgO	1.18
K_2O	.71
Na_2O	4.33
H_2O	1.17
Total	99.87

This shows that the amount of K_2O is quite small, and the rock is thus more properly called a quartz dioryte, or perhaps a soda granite, for it is evidently from the alteration products of the hornblende that a large amount of the lime is contained in this mineral, thus leaving a smaller amount than would be thought from the analysis alone, of the anorthite molecule in the feldspar. U. S. G.

No. 731. AMPHIBOLYTE.

South side of West Sea Gull lake, near the stream which flows from Frog Rock lake. Near the centre of the N. ½ sec. 17, T. 65-5 W.
Ref. Annual Report, x, pages 88-90, 93-96.

Meg. A fine-grained, greenish-gray rock, rather soft, and having a few veinlets in which is some calcite. The samples are quite small and do not show any marked schistosity.

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*Made by Mr. A. D. Meeds, gas inspector of Minneapolis. *Twenty-first Annual Report*, p. 43.

Mic. The section shows a mass of numerous, small, green *hornblende* flakes, which interlace with each other. They run in every direction through the section, but there is still a roughly parallel arrangement of a number of them, giving an indistinct schistose structure to the section. Under a higher power some of these hornblendes are seen to have fine twin lamellæ, which run parallel with the elongation and cleavage of the hornblende flakes. With the hornblende is some *chlorite*, and both of these minerals are set in a background of interlocking, completely allotriomorphic grains of *feldspar*, and possibly a few grains of *quartz*. The last named mineral was not determined with certainty, and perhaps does not exist in the slide. The hornblendes are included in the feldspars frequently and also pass through one feldspar grain into another. The feldspar is rarely twinned, shows almost no cleavage and is somewhat cloudy; its species was not determined. A few grains show indistinct fine albite twinning lamellæ, which are usually not visible except near the point of extinction, and which have a closely parallel extinction.

Running through the section, in general parallel to the more usual elongation of the hornblende, are some irregular, discontinuous, roughly lens-shaped areas which contain a little *calcite* and much of another mineral. These areas are evidently smaller forms of the veinlets seen in the hand specimens. The mineral which makes up most of these areas was not determined. It is gray or colorless and has a finely granular appearance, although under crossed nicols it breaks up into irregular areas of considerable size. The granular appearance reminds one of granular epidote, but this mineral has not the high index of refraction nor the strong double refraction of epidote. Its index of refraction is higher than the feldspar of the rock and its double refraction is more marked; the feldspar polarizes in grays of the first order, while this mineral is usually yellow or red and sometimes reaches blue of the second order. This mineral is clearly biaxial.

One section examined.

Age. Archean, Lower Keewatin or older.

Remark. This rock, and also Nos. 733, 734, 735 and 736, are parts of the "greenstone" terrane which extends along the south side of the Saganaga granite mass from Frog Rock lake eastward to within nearly two miles of Gunflint lake, where it disappears under the Animikie strata. (Compare the map and report on the Akeley Lake plate.) This terrane is of earlier date than the Saganaga granite, which cuts it, and is thus as old as the Lower Keewatin. There are also some facts which tend to show that this "greenstone" terrane along the southern side of this granite mass may be older than the Lower Keewatin, and thus belong to a pre-clastic series, *i. e.*, to the "Archean" or Basement Complex, as these terms are used by the U. S. Geol. Survey. U. S. G.

Remark. In vol. iv, and elsewhere, all the greenstone older than the Ogishke conglomerate is classed in the Lower Keewatin, the oldest (and lowest) portion being considered as igneous. The granite of Saganaga lake cuts a greenstone, but it is not known whether it is the igneous, pre-clastic, portion, or the fragmental portion in which are found in general the jaspilyte masses of northeastern Minnesota. So far as known there is no rock in the state of older date than the igneous portion of the Lower Keewatin. In the case of this amphibolyte it is probable that it is derived from some portion of the Lower Keewatin, a metamorphic rock due to the granitic revolution which centred in the region of the Saganaga lake granite. (Compare Part I of this volume.) N. H. W.

No. 732. Aplyte.

Found in vein-like forms in No. 731.
Ref. Annual Report, *x*, page 89.

Meg. A fine-grained, light, pinkish-gray, granitoid rock composed of quartz and feldspar. No section.

Remarks. This rock is from one of the aplyte dikes which cut both the "greenstone" terrane (see remarks under No. 731) and the Saganaga granite. It is similar to No. 650G, which is from this same locality. U. S. G.

No. 733. Andesyte (?)

Frog Rock lake. Exact locality not given, but quite probably from near the portage to West Sea Gull lake (sec. 17, T. 65-5 W.).
Ref. Annual Report, x, page 89; Bulletin ii, page 119.

Meg. A fine-grained, very dark, greenish-gray rock cut by veinlets which are composed mainly of epidote.

Mic. The section shows a fine-grained, somewhat confused aggregate of *feldspar* and green *hornblende*, with some *epidote* and *chlorite*. The feldspar is sometimes in elongated, irregularly outlined grains and also in non-elongated grains. In places the elongated forms give the section a resemblance to a diabase in texture. The feldspar is much clouded and kaolinized and fine grains of epidote have developed in it. It has no cleavage, and is very rarely polysynthetically twinned, though there are a few simple twins. The species was not determined, but a test of the rock powder with hydrofluosilicic acid showed that an abundance of sodium was present, considerable calcium and very little potassium. The hornblende is green and in small plates and fibres. The plates themselves show no well defined crystal outlines, and are usually fibrous around the edges. The rock perhaps represents an original andesyte. The minerals, except possibly the feldspar, are secondary, and it may be that this mineral and the whole texture of the rock are secondary also.

One section examined.

Age. Archean, Lower Keewatin or older. U. S. G.

No. 734. Andesyte *(with hornblende).*

Near the same place as No. 733.
Ref. Annual Report, x, page 89; Bulletin ii, page 127, plate XI, figure 2.

Meg. A fine-grained, greenish-gray rock, containing a few porphyritic crystals of white feldspar and of hornblende.

Mic. The section is quite similar to the preceding (No. 733), but that section is not porphyritic. The porphyritic *feldspars* are considerably altered, but are clearly plagioclase. The porphyritic *hornblendes* are sometimes fibrous and sometimes compact, but do not have sharp crystal boundaries. Some of these hornblendes are brownish in color, and there are narrow green rims around some of them. Zonal structure, aside from the rims, is also seen, and the ends of even the compact grains are more or less fibrous. An area of *calcite* was seen.

Two sections examined.

Age. Archean, Lower Keewatin or older. U. S. G.

No. 735. Gabbro. *(Altered.)*

Falls at the outlet of Frog Rock lake, near the centre of sec. 17, T. 65-5 W.
Ref. Annual Report, x, page 89; Bulletin ii, page 120.

Meg. A medium-grained, gray rock, looking like a dioryte. The minerals are white feldspar, a greenish-black mineral and a little pyrite.

Mic. M. E. Wadsworth's description of this slide is as follows:*

"The section is gray and of a granitic structure. It is composed of gray, granular, altered feldspars, with crystals of partially altered *augite.*

"The augite is partly replaced by *uralite*, *chlorite*, etc. Some *quartz*, *epidote* and colorless *mica* plates were seen."

One section examined.

Age. Archean, Lower Keewatin or older. U. S. G.

No. 736. Andesyte *(with hornblende).*

From an island in Frog Rock lake, about half a mile southwest from its outlet; N. W. ¼ S. W. sec. 17, T. 65-5 W.
Ref. Annual Report, x, page 89; Bulletin ii, pages 125, 126, plate XI, figure 1.

Meg. A fine-grained, greenish-gray rock, with small porphyritic hornblende crystals.

Mic. M. E. Wadsworth's description of this section is as follows:†

"The section has a greenish groundmass holding yellowish-green and greenish pseudomorphs after pyroxene and perhaps hornblende. The pseudomorphs are composed chiefly of *hornblende*, *biotite* and *epidote*. One twinned crystal, apparently

**Bulletin ii*, p. 120.
†*Bulletin ii*, p. 126.

originally of rhombic and monoclinic pyroxene, has been altered to yellowish hornblende with the dichroism varying from pale yellow to yellowish green. This shows the cleavage of hornblende while the prismatic planes are those of pyroxene. See plate XI, figure 1.

"The pseudomorphs show, as a rule, regular forms, but the chlorite, hornblende, and epidote also occur in irregular masses scattered through the groundmass and are formed from the molecular aggregation of their material from the groundmass and not from any direct pseudomorphic process.

"The epidote is abundant, and the groundmass of this section is composed of tabular altered feldspar (largely plagioclase) in a firmer groundmass of felty material, colorless mica and chlorite scales, epidote, microliths and grayish altered magnetite. The feldspars are mainly changed to chlorite and colorless mica scales, while the mica, in quite large plates, is associated with the epidote.

"The original condition of this rock was apparently that of an andesyte of the augite-andesyte type, and in its altered condition it is now best classified as a porphyryte, or, if preferable, a horneblende porphyryte or even a dioryte.

"The analysis given below, made by professors Dodge and Sidener, of this rock, shows that chemically it is the same as an altered basalt, and hence it may be that my reading of the microscopic physical characters is incorrect, if one was to be governed by the chemical composition alone in deciding."

SiO_2	49.65
Al_2O_3	16.36
Fe_2O_3	4.39
FeO	7.19
CaO	9.18
MgO	8.00
Na_2O	2.49
K_2O	1.17
H_2O	2.39
Total	100.82

One section examined.

Age. Archean, Lower Keewatin or older. U. S. G.

No. 737. Conglomerate.

"A talcose or chloritic rock, having a coarse perpendicular schistose structure, from the rapids between Frog Rock and Town Line lakes, northwest from Frog Rock lake. This is conglomeritic, some of the pebbles being six inches across, and like the gray amphibolyte (No. 731). There is in it also considerable pyrite. The pebbles are rounded, and are intimately connected with the matrix. There may be thirty feet of this here visible, including that below the water and above. There seems to be a south dip of about 10° to 15°. The aspect of the country changes at once on entering on this conglomerate. There are no bald rock hills to be seen around the Town Line lake, but the trees grow all over the rock and down to the water." N. W. ¼ S. W. ¼ sec. 18, T. 65-5 W.

Ref. Annual Report, x, pages 89-91, 95; Bulletin ii, pages 121, 122.

Meg. The few pebbles seen in the hand sample are of "greenstone;" the matrix varies in color from green to pinkish gray, is rather soft, fine grained, and somewhat schistose.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"The section is grayish green and composed of fragments of old basaltic rocks (melaphyr) with some probable andesyte fragments, and a few of other rocks. The basic eruptive material retains its structural characters but has its base and groundmass altered to a confused fibrous and scaly plexus of green *chlorite* and colorless micaceous minerals with magnetite dust. The porphyritically inclosed feldspars in the melaphyr and andesyte fragments are largely altered to colorless micaceous scales, but still retain their plagioclastic characters, distinguishable in polarized light. Chlorite, in plates, is also common. Considerable *quartz* was observed in the rock mass and in larger grains, but it is doubtful if any of the grains are original, but are rather formed by the secretion of silica during the process of the rock alteration. Much *pyrite* of secondary origin and a small fragment of jasper were seen. There occurs, as an alteration product, in the section, some microliths and radiating small bluish or brownish crystals. They are generally associated with quartz or pyrite as the nucleus for radiation, and are uniaxial, negative, varying in dichroism from a greenish blue to a brownish yellow. They are here referred to *tourmaline*. This mineral is not given in Prof. Winchell's list of minerals found in Minnesota, published in the annual report for 1882, and no mention is made of it in the index to Irving's Copper-Bearing Rocks." Two sections examined.

Age. Keewatin; quite probably Upper Keewatin. U. S. G.

Remark. It is, of course, almost impossible to decide from the hand sample and the sections whether the matrix of this rock is a volcanic tuff or whether it is fragmental material derived by erosion and decay from the terrane of "greenstone" immediately adjoining (see remarks under No. 731). Either origin is possible, but from the fact that only a short distance to the northeast (West Sea Gull lake) and also to the southwest (Ogishke Muncie lake) a true conglomerate is found, which is clearly younger than this "greenstone" terrane, this rock is here called a conglomerate. We see no reason why some of the quartz grains in the rock may not be fragmental grains, dating from the deposition of the rock.

Tourmaline has since been found at other localities in the state, as in the granite at Koochiching falls on the northern border of Itasca county (No. 1030G);† also in Nos. 773, 1525A, 2162. U. S. G.

No. 738. Conglomerate.

Near the northeast end of Ogishke Muncie lake; probably in N. W. ¼ S. E. ¼ sec. 13, T. 65–6 W.
Ref. Annual Report, x, pages 90, 91, 95; Bulletin ii, pages 122, 123.

Meg. A light-gray rock, containing much quartz and feldspar and also small fragments of different rocks.

**Bulletin ii*, pp. 121, 122.
†A. N. Winchell: *American Geologist*, vol. xx, p. 296.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"A gray, fragmental, much indurated rock, containing *quartz* grains and many small pebbles. It resembles a consolidated sandstone. This belongs more properly with the schists and sandstones, but is described here on account of its connection with No. 739. The section is apparently a transition specimen between one composed of basaltic material and one composed of granitic and felsitic (quartz-porphyry) debris. The major part of the section is made up of quartz and feldspar fragments, with rounded masses of felsyte (quartz-porphyry) and some fragments of argillyte and melaphyr. *Pyrite* is common. The same alterations have taken place in melaphyr and feldspar as before described, while the felsyte groundmass is diversified into a confused granular mixture of quartz, feldspar, micaceous and chlorite scales. The quartz and feldspar fragments are apparently from a granite."

One section examined.

Age. Ogishke conglomerate, at the base of the Upper Keewatin. U. S. G.

NO. 739. TUFF. *(Volcanic.)*

Ogishke Muncie lake; probably in N. W. ¼ sec. 24, T. 65–6 W.
Ref. Annual Report, x, page 90; Bulletin ii, pages 122, 123.

Meg. "A dark, greenish, compact, feldspathic groundmass, with greenish material scattered irregularly through this groundmass. A few lath-shaped feldspars also occur in the groundmass."

Mic. M. E. Wadsworth's description of this section is as follows:†

"The section is composed of rounded and irregular rock fragments with their cementing debris. So far as the character of these fragments can now be ascertained, they appear to be basaltic (melaphyr) with some probably more acidic ones. The *pyroxene* has been entirely altered to *chlorite*, and the feldspar largely to chlorite and colorless micaceous scales, but the triclinic character of many of the crystals is still distinct in polarized light. Much *pyrite* in grains is to be seen, while the groundmass is changed to chlorite and colorless micaceous scales with quartz."

There is also a considerable amount of a carbonate, which shows at times a quite noticeable absorption—*siderite*, probably.

One section examined.

Age. Keewatin. U. S. G.

NO. 740. SLATE.

North shore of Ogishke Muncie lake; probably in N. W ¼ sec. 24, T. 65–6 W.
Ref. Annual Report, x, pages 91, 93, 94.

Meg. A fine-grained, dark-gray, clay slate.

**Bulletin ii*, pp. 122, 123.
†*Bulletin ii*, p. 122.

Mic. A very fine-grained aggregate of *quartz*, probably some *feldspar*, *chlorite*, *muscovite*, *epidote*, *pyrite* and other opaque grains. Scattered through the section are angular quartz grains of considerably larger size than the main mass of the minerals.

One section examined.

Age. Keewatin; probably Upper Keewatin. U. S. G.

No. 741. Grit.

Same locality as No. 740.
Ref. Annual Report, x, pages 91, 93, 94.

Meg. A fine-grained, gray grit made up largely of quartz and feldspar.

Mic. The section is composed largely of *quartz* and *feldspar* grains. The quartz is in sharply outlined, angular, sub-angular and sub-rounded grains; those which show rounding are, however, not common. The feldspar grains are less distinct than those of quartz, and are much clouded and altered to a kaolinic mass, which material, also at times, extends between the different grains of the rock. *Calcite* is common; *chlorite* and *pyrite* also occur, and there are a few small rock fragments probably of quartz-porphyry.

One section examined.

Age. Keewatin; probably Upper Keewatin. U. S. G.

No. 742. Diabase.

A dike cutting the conglomerate of Ogishke Muncie lake; N. W. ¼ N. E. ¼ sec. 26, T. 65-6 W. This dike is ten feet wide, and it strikes 10° south and east.
Ref. Annual Report, x, pages 91, 93.

Meg. A fine-grained, dark, greenish-gray diabase.

Mic. In texture the section approaches a gabbro, but is still to be referred to diabase. The chief minerals are *plagioclase*, *augite* and *magnetite*. In general the first mineral is decidedly kaolinized, although in places it is quite fresh. Equal extinction angles in sections normal to 010 are as high as 29°. The augite is altering to *uralite* and *chlorite*, and in these alteration areas is a little secondary *quartz*. *Apatite* needles occur and are especially common in some of the alteration areas. A little *pyrite* is present.

One section examined.

Age. Probably Keweenawan.

No. 743. Schist. (*Calcareous.*)

N. E. ¼ N. E. ¼ sec. 26, T. 65-6 W; near Ogishke Muncie lake.
Ref. Annual Report, x, pages 91, 95.

Meg. A roughly schistose, rusty weathering, soft rock which effervesces rather readily with cold hydrochloric acid. It is fine grained, but in places is distinctly crystalline like marble.

Mic. The section is composed essentially of a carbonate which is much clouded and semi-opaque. In places it shows absorption. On treatment with hydrofluosilicic acid numerous crystals of the silicic fluoride of calcium appeared, together with quite a number which are characteristic of either magnesium or iron compounds. The rock is composed largely of *calcite*, with considerable $FeCO_3$ and also, very probably, some $MgCO_3$. In the section is an irregular vein of irregularly interlocking grains of *quartz*, which is somewhat clouded. On the sides of the vein the quartz is much finer grained, and it commonly shows undulatory extinction. The vein thus appears to have been crushed.

One section examined.

Age. Keewatin. U. S. G.

No. 744. Conglomerate. *(Matrix.)*

Campers' island in Ogishke Muncie lake. This island is just west of the narrows of the lake in sec. 23, T. 65-6 W., and is near the centre of S. ½ S. ½ of this section.

Ref. Annual Report, x, pages 91, 92, 95; Annual Report, xvii, pages 194, 205; Bulletin ii, pages 128, 129.

Meg. There are two varieties of specimens with this number. The first was collected in 1879 and there may have been some mistake in numbering the specimens, for they do not represent the main characters of the matrix of the conglomerate on Campers island. M. E. Wadsworth examined these specimens and slides, calling the rock porodyte; his description is as follows:*

"A fine-grained, greenish rock of a compact structure and conchoidal fracture. Contains some pyrites. The sections are grayish green and composed of altered andesitic fragments. This andesyte was originally made up of tabular plagioclastic *feldspars* in a fine felty groundmass. The feldspars and groundmass have now been altered to an aggregation of *chlorite* and colorless *mica* scales, secondary *feldspar*, *magnetite* and *pyrite*. The feldspars retain their forms and sometimes traces of twinning. The colorless mica is, in this section, in larger scales than those before seen, and it possesses the cleavage and optical characters of *muscovite*, to which mineral it is here referred."

The other specimens were collected several years later and they represent the main mass of the matrix of the conglomerate of the island. These were taken from the north side of the blunt point at the southwestern corner of the island, where there are extensive exposures. These specimens show a rather coarse-grained, gritty, gray rock which is plainly fragmental. Some of the component grains are well rounded, and this is usually the case with larger pebbles contained in the matrix. The most noticeable grains of the rock are quartz and feldspars, and small flinty fragments are common.

**Bulletin ii*, pp. 128, 129.

Mic. The section is composed of fragments, both of minerals and rocks, of various kinds. The fragments are sharply angular, but more commonly sub-angular, and some are partly rounded. The well rounded grains so common in ordinary sandstones do not occur. Of the minerals *quartz* and *feldspar* are abundant. The former is the usual granitic quartz and the latter is considerably clouded and kaolinized. Much of the feldspar is *plagioclase,* which is commonly acid rather than basic. The following minerals are also present: *calcite, muscovite, epidote, sphene, zoisite, chlorite* and almost colorless, fibrous *amphibole.* Among the rock fragments may be recognized those of andesyte, apparently devitrified rhyolyte, graywacke, jaspilyte and possibly carbonaceous slate.

Three sections examined.

Age. Ogishke conglomerate at the base of the Upper Keewatin. U. S. G.

NO. 745. SLATE. *(Siliceous.)*

N. E. ¼ sec. 26, T. 65-6 W.; near Ogishke Muncie lake.
Ref. Annual Report, x, page 92.

Meg. The hand specimen is a slate which shows a number of bands of finer and coarser grained material. The rock is hard and very dark gray in color, but weathers much lighter. Some of the bands contain quartz grains large enough to be seen by the unaided eye. In addition to an imperfect slaty cleavage parallel to the bedding, the rock shows much fracturing and some minute faults.

Mic. The slide shows a fine banding, due to the concentration of the darker particles of the rock into bands which are not very sharply defined. The rock is made up of a very fine-grained aggregate of *quartz,* possibly some *feldspar, chlorite,* opaque substances, *calcite* and *muscovite.* A little *epidote* is present. The opaque substances appear to be *magnetite, hematite* and other material which is gray in reflected light. A few *quartz* grains, much larger than the usual grains of the rock, are seen.

One section examined.

Age. Keewatin; probably Lower Keewatin.

Remark. From the field notes it seems quite probable that this rock is part of the Lower Keewatin lying unconformably below the Ogishke conglomerate. The reasons for this inference are the presence of the conglomerate, the abrupt change in strike, and the non-slaty and non-fractured condition of the conglomerate when compared with the slate. The field notes are as follows:*

"There is a sudden change in the direction of the strike of the rock of the country, in N. E. ¼ sec. 26, from nearly east and west to north and south. At the shore on the peninsula, in section 23, it is the same as the slates generally seen in

**Tenth Annual Report,* p. 92.

the Huronian in this part of the state, but after passing the valley in which are the calcareous schist and the marble, it is north and south. That the change is somewhat sudden is shown by the fact that the beds running north and south are seen to cease abruptly, and to be replaced by the conglomerate in a number of places. The conglomerate in these cases is, so far as seen, rather finer than the average."

U. S. G.

No. 746. Limestone. *(Siliceous.)*

Associated with No. 743.

Ref. Annual Report, x, pages 91, 97; Annual Report, xv, page 371; Annual Report, xvi, page 95; Bulletin vi, page 17.

Meg. A very fine-grained, gray marble. It has been considerably fissured and cemented, largely by quartz, and from the hardness of the rock one would think that fine-grained quartz was disseminated all through it.

Mic. The main part of the rock is composed of very fine-grained, gray *calcite* with a little *quartz* also in minute grains. Larger grains of calcite are, however, also present. The rock appears to have been crushed, and the fine grain of the calcite is probably due to the crushing. There are also numerous fissures in the section. The smaller fissures are filled in with calcite, which is more transparent than that of the main mass of the rock, and the larger fissures are filled by both calcite and quartz.

Two sections examined.

Age. Keewatin. U. S. G.

No. 747. Flint.

S. W. ¼ S. E. ¼ sec. 26, T. 65-6 W.; east shore of Ogishke Muncie lake.

Ref. Annual Report, x, pages 92, 94.

Meg. A black, very hard, aphanitic rock.

Mic. The most noticeable feature of the section is the presence of numerous, small, irregularly outlined spots which are of darker color than the rest of the rock. These spots at times show a slight absorption, and under crossed nicols they polarized like carbonate. They are probably largely *siderite.* Aside from these spots the section is made up almost entirely of cryptocrystalline silica, with considerable opaque dust-like material.

One section examined.

Age. Keewatin. U. S. G.

No. 748. Slate. *(Calcareous.)*

Portage between Ogishke Muncie and Dyke lakes; N. W. ¼ S. W. ¼ sec. 27, T. 65-6 W.

Ref. Annual Report, x, page 93.

Meg. A fine-grained, slaty rock, greenish-gray to black in color. One side shows a black, apparently carbonaceous layer. With cold hydrochloric acid the rock effervesces rather freely.

Mic. The section shows a very fine aggregate of *quartz*, *chlorite*, *muscovite* and dust-like material. Considerable calcite is present, and this is usually in larger grains than the other minerals. A few *rutile* needles are present.

One section examined.

Age. Keewatin. U. S. G.

NO. 749. DIABASE.

From a dike cutting No. 748. This dike runs north and south and is thirty to forty feet in width.
Ref. Annual Report, x, page 92; Bulletin ii, page 117.

Meg. A medium-grained, dark-greenish rock evidently containing much hornblende.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"The section shows the usual structure of altered diabases, and is composed of divergent, quite largely altered *feldspars (plagioclase)*, with the interstitial altered *augite*, *magnetite* and secondary *viridite*, *chlorite*, *biotite*, *hornblende*, etc. The magnetite is associated with *leucoxene* and yields on measurement the same angles as that seen in No. 758."

One section examined.

Age. Probably Keweenawan. U. S. G.

NO. 750. CONGLOMERATE.

North side of Dyke lake; N. E. ¼ S. E. ¼ sec. 28, T. 65–6 W.
Ref. Annual Report, x, pages 92, 95; Bulletin ii, page 122.

Meg. A gritty, greenish rock, resembling No. 744. Two rounded pebbles of considerable size, one of "greenstone" and the other of white flint, or jaspilyte, are present.

Mic. M. E. Wadsworth's description of this rock, which he included under the term porodyte, is as follows:†

"The sections are composed of fragments of diabase, melaphyr and *quartz*, with interstitial material composed originally of their debris. One of the melaphyr fragments, evidently, was nearly in a glassy state in its original condition. The non-quartzose material retains its structure largely, but beyond this it has been altered to *chlorite* and colorless micaceous scales. The feldspars retain their outlines, but are entirely filled with the colorless *mica* scales, and show aggregate polarization. *Pyrite*, in striated cubes, is very abundant as a secondary constituent of the rock. The quartz probably came from some granitoid rock."

Two sections examined.

Age. Ogishke conglomerate at the base of the Upper Keewatin. U. S. G.

**Bulletin ii*, p. 117.
†*Bulletin ii*, p. 122.

No. 751. Porphyryte. *(Hornblende.)*

Mallmann's peak; S. E. ¼ sec. 30, T. 65-6 W. (See "Remark" below.)
Ref. Annual Report, x, pages 92, 93; Bulletin ii, pages 124, 125, plate X, figures 1 and 2; Annual Report, xv, page 367; Annual Report, xvi, page 107; Annual Report, xvii, pages 194, 196; Annual Report, xviii, page 53; Annual Report, xxi, pages 15, 55-58.

Meg. A very fine-grained, compact, purple rock, showing numerous small, porphyritic crystals of hornblende sometimes associated with chlorite.

Mic. M. E. Wadsworth's description of this section is as follows:*

"A greenish-gray, porphyritic rock, having a compact, greenish-gray or brown base, holding porphyritic inclusions of hornblende and augite.

"The section has a greenish-gray groundmass, holding yellowish-brown crystals of hornblende, *epidote* and greenish pseudomorphs of *chlorite.* The *hornblende* is of the usual foreign character in the andesitic rocks, having been attacked by the molten magma, which has torn and eaten into the hornblende, that has its edges blackened and rendered magnetic by the heating and corroding effects. Some of the hornblendes here have been broken and faulted and blackened on the broken sides, others retain only a small portion of hornblende in the interior, while others are reduced to a heap of *opacite* or *magnetite* grains. The chloritic pseudomorphs are composed of plates and scales of *chlorite* with some *epidote*, but whether they are pseudomorphs after hornblende or *augite*, the writer cannot determine. The epidote is in small crystals and crystal aggregations of pale yellowish color, with pleochroism varying from colorless to pale yellow and to a deeper yellow. The epidote is here an alteration product, and is commonly associated with the chlorite. The groundmass is altered and is now composed of chlorite scales, partially altered augite microliths and granules, magnetite grains (disseminated throughout the entire groundmass), feldspar, microliths, fibrous material, etc., all replacing the usual felty base of the andesytes with its enclosed minerals. Here the augite, feldspar and magnetite are original, and the rest secondary.

"So far as the writer is aware, no other rocks belonging to the andesytes have been heretofore recognized in Minnesota, or, indeed, about lake Superior, except one described by the writer in 1880,† as none of the diabase-porphyrytes or quartzless-porphyries of Irving appear to belong to the andesytes, so far as can be told from his description, unless it be that from Stannard's rock.

"Prof. N. H. Winchell has indeed observed the peculiar character of this rock, stating in the annual report for 1881: 'This rock is a peculiar porphyry. The groundmass is amorphous, and the disseminated crystals are hornblende. It is unlike anything before seen.' (Page 93.)

"The rock itself is an altered and old andesyte of the variety known as porphyryte or hornblende-porphyryte amongst lithologists. This andesyte, in its original

Bulletin ii, pp. 124, 125.
†Geology of the Copper and Iron districts of lake Superior, 1880.

condition, would be called by most lithologists a hornblende andesyte. Plate X, figures 1 and 2, show the general characters of this rock with its porphyritic structure. The hornblende grains on the left in figure 1 have been faulted by the action of the magma and partially corroded. This is shown by the cleavage lines and in the upper form by a twinned band seen in polarized light. In figure 2 the corrosion of the hornblende by the magma is shown, while the line of magnetite grains in the upper hornblende shows the original outline. The lower hornblende has an interior core of the groundmass. This is not owing to the inclusion of the groundmass during the crystallization of the hornblende, but is due to the interpenetration of one of the gnawing, dissolving tongues of groundmass that had penetrated the hornblende, and which has been cut off during the grinding of the section, leaving it as an apparent inclusion."

One section examined.

Age. Keewatin.

Remark. We have been unable to find any porphyryte in place on Mallmann's peak, although search was made for it. This specimen (No. 751) was brought to Prof. N. H. Winchell in 1879, by one of his guides, and the former did not visit this place personally. It is, however, quite possible that areas of this porphyryte may be found in the vicinity of Mallmann's peak, as the district has not been examined carefully. Still, this specimen is exactly similar to the porphyryte found near the southwest end of Epsilon lake, and it seems very probable that this came from that locality. This idea is strengthened by the fact that at the Epsilon lake locality a large diabase dike, similar to the next specimen (No. 752), is seen cutting the porphyryte.

The porphyryte is known definitely from only one locality in this vicinity, and is confined to a belt of not more than a quarter of a mile in width which curves around the southwestern end of Epsilon lake. (See plate II of the Twenty-First Annual Report.) The surface covered by this rock is about one-fourth of a square mile in extent; it is confined, with the exception of a few acres in the S. W. $\frac{1}{4}$ S. E. $\frac{1}{4}$ sec. 20, T. 65-6 W., to the N. $\frac{1}{2}$ sec. 29. This area has been studied somewhat carefully and a number of specimens of the porphyryte have been collected.* These specimens are Nos. 927W, 928W, 929W, 932W and 933W; also Nos. 792G, 793G, 793aG, 794G, 794aG, 796G and 797G. A general description of this porphyryte has already been published† and is here given as it bears directly on the rock under consideration (No. 751).

The single section, which was accessible to Dr. Wadsworth when his description was written, is more or less altered, and does not clearly show the original nature of

*A. Winchell: *Sixteenth Annual Report*, pp. 321-327.

†*Twenty-first Annual Report*, pp. 55-58.

the groundmass. Other sections of the less altered rock show that the groundmass is composed of interlocking laths of feldspar, sometimes the feldspar has a tendency towards a granular development, as stated below.

Macroscopically the porphyryte is seen to have an aphanitic groundmass, which varies in color from a reddish purple to a dull olive green; the freshest and more abundant phases show the purple color. In this groundmass are sharply outlined shining black crystals of hornblende and also irregular greenish areas, in and around which are frequently small bright yellow spots and small white spots. Under the microscope the groundmass is seen to be made up entirely of small, short interlacing laths of feldspar. In some sections the groundmass becomes coarser and there is a decided tendency towards a granular development of the feldspar. Although polysynthetic twinning is common, still some of the feldspar does not show it and seems to be monoclinic in character; that there is considerable orthoclase in the rock is also indicated by the percentage of potash in the analysis.* The feldspar is undergoing alteration and is filled with small inclusions and minute fibres which sometimes appear to be *sericite.* The rock is crowded with dust-like particles, to which, perhaps, is due its purple color. There seems to have been but one period of crystallization for the feldspar, phenocrysts of this mineral being entirely absent. In all the slides examined there is no unindividualized glassy matter to be seen.

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

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

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

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

An analysis of a typical specimen of this porphyryte (No. 797G) is as follows:

SiO_2	60.32
Al_2O_3	15.80
Fe_2O_3	5.42
FeO	.89
CaO	4.65
MgO	5.08
K_2O	1.82
Na_2O	4.09
P_2O_5	.12
H_2O	1.67
Total,	99.86

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

No. 752. Diabase.

Same locality as No. 751.
Ref. Annual Report, x, pages 92, 93; Bulletin ii, page 100.

Meg. A coarse-grained, dark, greenish-gray diabase, in which much of the augite has altered to hornblende. From a dike forty feet wide, cutting rock No. 751.

Mic. M. E. Wadsworth's description of this section is as follows:*

"In the thin section the feldspars are mostly cloudy and kaolinized, although the triclinic character of some is observable in polarized light. The augite is *brown* and largely altered to *viridite,* which mineral substance replaces part of the *feldspar.* Some green pseudomorphs, apparently after olivine, were observed, while more or less *actinolite, biotite* and *chlorite* were seen associated with the viridite and formed from it. Considerable secondary *quartz* was noticed associated with the feldspar, while microliths are common both in the quartz and augite. Some *apatite* crystals were seen, as well as '*leucoxene*' and *pyrite.*"

One section examined.

Age. Probably Cabotian or Manitou. U. S. G.

No. 753. Porodyte.

S. W. ¼ sec. 14, T. 65-6 W. Hill north of the narrows of Ogishke Muncie lake.
Ref. Annual Report, x, pages 47, 94, 95; Bulletin ii, page 128, plate XII, figure 1.†

Meg. A very fine-grained, compact, greenish rock containing small hornblende crystals.

**Bulletin ii*, p. 100.

†In the *Tenth Annual Report*, p. 94, and also in *Bulletin ii*, the locality is by a typographical error given as T. 65-4 W., instead of T. 65-6 W.; and in *Bulletin ii* the description is placed under No. 153 instead of No. 753.

Mic. M. E. Wadsworth's description of the sections of this rock is as follows:*

"The sections are green and composed of fragments of andesyte, andesitic *augites*, destroyed and blackened *hornblendes*, and a mineral which is pleochroic varying from yellow to yellowish brown and yellowish green. Most of its sections extinguish parallel to a nicol diagonal, but not all, and it appears to answer in a great measure to the rhombic *pyroxene* of the andesytes partially altered to hornblende. The extinction of the clear, pale-yellow augite is oblique, and this is altered only to a greenish *chlorite*. The feldspars are altered to the usual chloritic and micaceous scales. Some *epidote* and *quartz* fragments were seen. The andesitic base is changed to a fibrous or granular material but is not altered as much as in the preceding described andesytes. This rock apparently was once an andesitic tuff or volcanic ash, as it closely resembles the modern andesitic tuffs of California.

"Plate XII, figure 1, shows in some measure the characters of this rock, and exhibits, a little to the left of the centre, one of the partially destroyed hornblendes so common in andesitic rocks."

Two sections examined.

Age. Keewatin. U. S. G.

No. 754. Conglomerate.

"One mile north of the central narrows of Ogishke Muncie lake;" probably near the south line of sec. 14, T. 65–6 W.

Ref. Annual Report, x, pages 94, 95.

Meg. The hand specimen in general resembles the other conglomerate samples already described (Nos. 738 and 744), but it is darker colored and is more indurate or metamorphosed. A number of pebbles, most of them well rounded, are present. These pebbles are of red jaspilyte, quartz, "greenstone," granite and hard, siliceous, gray and black, flinty rocks.

Mic. Under the microscope the rock does not differ markedly from Nos. 738 and 744 except that many of the fragments, especially the *quartz* grains, are well rounded. Considerable *calcite*, acting as a cement, is present.

Two sections examined.

Age. Ogishke conglomerate at the base of the Upper Keewatin. U. S. G.

No. 755. Diabase.

South of Ogishke Muncie lake, probably near the centre of sec. 35, T. 65–6 W. Rock of one of the subordinate hills, near the summit.

Ref. Annual Report, x, pages 96, 97; Bulletin ii, pages 118, 119.

Meg. A rather fine-grained, dark, greenish-gray diabase, evidently with its augite altered to hornblende.

**Bulletin ii*, p. 128.

Mic. The section is that of an altered diabase. There are numerous lath-shaped *plagioclases*, usually much altered, in a confused background composed of green *hornblende*, *chlorite* and *magnetite*.

One section examined.

Age. Keewatin. U. S. G.

NO. 756. DIORYTE. (*Gabbroid.*)

From a ridge south of No. 755.
Ref. Annual Report, x, pages 96, 97; Bulletin ii, page 83.

Meg. A rather coarse-grained, granitoid rock, composed essentially of hornblende and altered feldspar.

Mic. The section shows a rock which consists of secondary *hornblende* and *chlorite*, highly altered *feldspar*, and iron ore. The last frequently shows the opaque gray alteration products common to *ilmenite*.

One section examined.

Age. Keewatin. U. S. G.

NO. 757. DIABASE (*with olivine.*)

From a dike six feet wide, running northwest and southeast and cutting No. 756.
Ref. Annual Report, x, page 96.

Meg. A rather fresh diabase of medium grain.

Mic. The section shows long lath-shaped *plagioclases*, *augite*, *olivine* and *magnetite*. The section is very noticeably less altered than those of the last two numbers. A peculiar feature is that the olivine has crystallized at the same time with and in part later than the feldspar. The areas of olivine are penetrated through and through by feldspar, and frequently the intergrowth of these two minerals is pegmatitic rather than poikilitic.

Two sections examined.

Age. Probably Keweenawan.

Remarks. Compare Nos. 1275 and 1842, in which the olivine is also younger than the feldspar. U. S. G.

NO. 758. DIABASE.

From the top of the mountain and south of No. 757. This specimen is probably from the top of mount Northrop, in N. W. ¼ sec. 2, T. 64-6 W.
Ref. Annual Report, x, pages 96, 97; Bulletin ii, pages 116, 117.

Meg. A dark greenish-gray diabase, of medium grain.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"A grayish-green crystalline rock. In the section this diabase is seen to be much altered. Its structure is ophitic, and the *augite* remains in places in distinct cores, surrounded by green *hornblende*. *Quartz*, *viridite*, *chlorite*, *biotite*, *actinolite*, *titanite*

**Bulletin ii*, pp. 116, 117.

grains, etc., occur with the hornblende as secondary products. *Leucoxene* occurs with the iron ore, which is arranged in dash-like bars. These bars form rectangles and rhombs with one another—one perfect rhomb measuring for its inside angles, approximately, 70° 30′ and 109° 30′. Several other imperfect rhombs yielded on measurement about the same angle." One section examined.

Age. Keewatin. U. S. G.

No. 759. Dioryte. (*Gabbroid.*)

"Occurs in patches in No. 758, and is like No. 756, but contains so much magnetite as to appreciably increase its weight."

Ref. Annual Report, x, page 97; Bulletin ii, pages 77, 78.

Meg. A coarse-grained, granitoid rock, dark greenish-gray in color and composed of hornblende, feldspar and some magnetite.

Mic. The section, which appears to have been originally a gabbro or coarse diabase, is composed essentially of secondary green *hornblende*, *chlorite*, considerably altered *plagioclase*, *magnetite* and secondary *quartz*. No augite remains.

One section examined.

Age. Keewatin. U. S. G.

No. 760. Limestone. (*Siliceous.*)

Specimens Nos. 760-765 were obtained on a trip taken to Twin peaks from Ogishke Muncie lake. The trip was probably made from the west end of this lake in S. W. ¼ sec. 27, T. 65-6 W., through W. ½ sec. 34, T. 65-6 W., to the summit of East Twin peaks, which is probably in N. E. ¼ sec. 4, T. 64-6 W. The following notes were taken on the specimens collected on this trip:*

"In passing from Ogishke Muncie lake directly to Twin peaks, the following observations were made by Mr. Mallmann. After a space of conglomerate, perhaps one-half a mile, there is a gorge in which a creek runs S. 30° W., the rock over which it passes being:

"No. 760. A light siliceous marble, or calcareous quartzyte, undistinguishable from the marble, No. 746. On either side of the gorge is a wall of rock. On the west is conglomerate, and on the east is

"No. 761, which is a pyritiferous, dark, aphanitic rock, one of the conditions of the slate of the slaty conglomerate.

"No. 762. Is from a trap dike cutting the conglomerate, about one-fourth mile from the lake.

"South from the gorge is more conglomerate and quartzyte, then a ridge, or a succession of benches rapidly ascending. The first bench, twenty feet high, has a regular bedding, and dip toward the south, but no basaltic structure. It consists of

"No. 763. Which is apparently closely allied to No. 755.

"No. 764. In a higher ridge is this rock, which is the same as No. 763.

"No. 765. The top of the Twin peak (East Twin) is a fine-grained variety of the same rock. This peak, and the general average of the mountain range, may be 500 feet higher than Ogishke Muncie lake. The Twin peaks are conspicuous because they stand isolated, further north than the rest of the high land, not because they are higher."

Ref. Annual Report, x, page 97.

Meg. A gray siliceous limestone very similar to No. 746.

Mic. The section is in general similar to that of No. 746, but contains more cryptocrystalline *quartz*. *Chlorite* and some opaque gray material are present. There are also angular fragments of *quartz* and *feldspar*, and in some parts of the section there is a resemblance to a crushed and altered quartz-porphyry.

One section examined.

**Tenth Annual Report*, p. 97.

Age. Keewatin.

Remark. In connection with Nos. 760–765 compare Nos. 1386–1395 which were collected between the southwest corner of Ogishke Muncie lake and the summit of East Twin peak; also Nos. 1756–1764 which were collected on a trip from Kekequabic lake to the summit of West Twin peak. U. S. G.

No. 761. "GREENSTONE."

See under No. 760.
Ref. Annual Report, x, page 97; Bulletin ii, page 121.

Meg. A compact, fine-grained, greenish rock, showing considerable pyrite.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"The sections show an entirely altered rock, composed of greenish *chlorite* scales, colorless *micaceous* plates, and numerous granules of *pyrite* and *magnetite.* Although no absolute proof can be obtained from these sections to show the original status of the rock, yet from what the writer has seen from other localities, he considers this to be a highly altered diabase, now forming a chloritic rock or compact chlorite schist."

Two sections examined.

Age. Keewatin. U. S. G.

No. 762. DIABASE.

See under No. 760.
Ref. Annual Report, x, page 97.

Meg. A fine-grained, black diabase.

Mic. The section shows rather fresh, lath-shaped plagioclases in a dark background, composed of *augite*, *magnetite*, alteration products of *augite*, and possibly some unindividualized base.

One section examined.

Age. Probably Cabotian or Manitou. U. S. G.

No. 763. DIABASE.

See under No. 760.
Ref. Annual Report, x, page 97.

Meg. A fine-grained, compact, dark greenish rock.

Mic. The section shows small, altered, much elongated, lath-shaped *plagioclases* in an altered, fine-grained background, which is composed essentially of fibrous *hornblende*, *chlorite* scales and *magnetite.*

One section examined.

Age. Keewatin. U. S. G.

**Bulletin ii*, p. 121.

No. 764. Diabase.

See under No. 760.
Ref. Annual Report, x, page 97.

Meg. A medium-grained, dark, greenish-gray, diabase-like rock.

Mic. The section is essentially similar to that of No. 763 except for a coarser grain and the fact that the *hornblende* fibres sometimes have a radial arrangement.

One section examined.

Age. Keewatin. U. S. G.

No. 765. "Greenstone."

See under No. 760. Top of East Twin peak.
Ref. Annual Report, x, page 97.

Meg. A compact, fine-grained, green rock.

Mic. This section shows a fine-grained, confused aggregate in which green *hornblende*, altered *feldspar* and *quartz* are the chief minerals. *Magnetite, chlorite, muscovite, calcite* and opaque gray material are also present. The original texture of the rock has entirely disappeared.

One section examined.

Age. Keewatin.

Remark. Nos. 761–765, except No. 762, which is a later dike diabase, are part of the extensive "greenstone" terrane that forms the high range of hills south of Ogishke Muncie lake. It is quite evident that Nos. 763 and 764 were originally diabase or closely related rocks. Nos. 761 and 765 are so highly altered that their original nature is not certain, but from their general character, composition and associations it seems quite probable that they also were originally diabases or possibly basic tuffs. U. S. G.

No. 766. Iron Ore. *(Magnetic.)*

From a ferruginous belt in the slates on the portage from Fox lake to Ash lake, near the former lake; S. W. ¼ S. W. ¼ sec. 25, T. 65–6 W.*
Ref. Annual Report, x, page 98.

Meg. A very fine-grained magnetic iron ore.

Mic. The section shows a very fine-grained rock, consisting mainly of *magnetite* with some *quartz* and a yellowish fibrous mineral which appears to be *grünerite*. The section is crossed by a few minute veins which are composed of quartz or quartz

*The locality references for the specimens collected on the trip from Ogishke Muncie lake south to lake Superior, at the mouth of Poplar river (where there is now a postoffice called Lutsen)—specimens Nos. 766 to 796—are in some cases not as accurate as could be desired, and when this is the case the locality is designated as "probably" or "perhaps," the latter word being used when there is considerable uncertainty. When this trip was made by the senior author most all the townships had not been subdivided, and it was thus impossible to locate oneself accurately. Since then these townships have been surveyed, and by reference to the township plats it is possible to locate, with a fair degree of certainty, the points at which the different specimens were collected. The location of these points has been made easier by the facts that, since the townships were surveyed, (1) The junior author has been over the route from Ogishke Muncie lake to and beyond "the last lake in Frog Rock river" (Nos. 766 to 773), and (2) Dr. A. H. Elftman has kindly aided in this matter in that part of the route from Sawbill lake to the mouth of Poplar river (Nos. 788 to 796).

and grünerite. In one of the larger veinlets there are three bands, the inner one being composed of magnetite largely and the outer ones of the two other minerals.

One section examined.

Age. Keewatin. U. S. G.

NO. 767. GABBRO. *(Granulitic.)*

South shore of Gabemichigama lake; perhaps in sec. 1, T. 64-6 W.
Ref. Annual Report, x, page 98; Annual Report, xv, page 379.

Meg. A fine-grained, yellowish-gray, crystalline rock,—part of the so-called "muscovado."

Mic. The section is composed of *feldspar*, *pyroxene* and *hornblende*, with a little *magnetite*, *pyrite* and *biotite*. The feldspar is in elongated crystals, which usually show albite twinning, and also in irregular grains varying much in size and quite commonly showing no twinning. There are, however, all gradations between the two forms of feldspars, and they appear to be of practically the same species. In parts of the section the elongated feldspars are numerous and give a decidedly diabasic texture to the rock. At times the outlines of the feldspars are very irregular or serrate. The feldspar, as well as the pyroxene and hornblende, frequently contains numerous small cavities and dark dust-like inclusions. The grains which show albite twinning have extinction angles running up to 34,° indicating *labradorite*.

The pyroxene is in small rounded grains and in larger plates which are very irregular in outline, often having a lobe-like border, and include poikilitically small grains of feldspar. The pyroxene when in the plates is usually fissured, and the section has in places a decidedly "granular" aspect. Some of the pyroxene shows a weak pleochroism and an orthorhombic character, though much of it is monoclinic. A few grains show fine polysynthetic twinnings or possibly intergrowths of orthorhombic and monoclinic pyroxene.

The hornblende occurs in the same manner as pyroxene and seems to have been derived from that mineral.

One section examined.

Age. Probably Cabotian. U. S. G.

NO. 768. QUARTZYTE *(with pyroxene.)*

South side of Gabemichigama lake; probably near east line of sec. 1, T. 64-6 W.
Ref. Annual Report, x, page 98; Annual Report, xv, page 379.

Meg. A rock, which varies considerably in grain, composed of quartz, pyroxene and magnetite.

Mic. The section is composed essentially of *hypersthene*, *quartz*, and *magnetite;* the last mineral is in comparatively small amount. The quartz is in grains of more or less rounded outline included in the hypersthene, which is commonly in large plates. More complete descriptions of this type of rock are given under some of the following numbers: 960, 962, 1041, 1336, 1338, 1349, 1340, 1343, 1362.

One poor section examined.

Age. Iron-bearing member of the Animikie(?) U. S. G.

Remark. It has been found later that this ferruginous quartzyte, and a number of other localities of the same kind further southward, formerly referred to the Animikie, probably are portions of the Keewatin, affected by the gabbro. N. H. W.

No. 769. Gabbro.

Northwest end of Little Saganaga lake; perhaps from S. E. ¼ S. E. ¼ sec. 6, T. 64-5 W.
Ref. Annual Report, x, page 98; Bulletin ii, page 72.

Meg. A medium-grained, gray, granitoid rock, composed of plagioclase, augite, hornblende and magnetite, with a little biotite and apparently some olivine, although this mineral is not seen in the section. A part of the great gabbro mass.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"Is a brownish-gray coarsely crystalline rock, like the preceding. In the thin section the rock is seen to be somewhat altered, while it has its *plagioclase* filled with the brownish needles and globuliths so commonly seen in the feldspars of gabbros. These, as usual, are arranged along cleavage planes, one well marked arrangement being parallel to the polysynthetic twinning planes, although one crystal was observed in which no microliths were seen, whose position corresponded to the striation lines, but all cut these lines at a small angle."

One poor section examined.

Age. Cabotian. U. S. G.

No. 770. Anorthosyte.

South side of Little Saganaga lake; N. W. ¼ sec. 16, T. 64-5 W.
Ref. Annual Report, x, page 98.

Meg. A medium-grained, gray rock, composed almost entirely of plagioclase, weathering nearly white.

Mic. The section is a granitoid aggregate of *plagioclase.* With the possible exception of a few small grains of *magnetite* the section shows no evidence of any original mineral other than the plagioclase, which is in places kaolinized. A few small *chlorite* scales are present. The plagioclase is commonly twinned according to the albite law. Approximately equal extinctions run up to 30.° Two grains cut approximately normal to the least axis of elasticity gave extinction angles of 40° and 44°; sections parallel to 001 gave 16° and 17°; and sections parallel to 010 gave 30° and 31.° The plagioclase thus appears to be *bytownite.* One section examined.

Age. Cabotian. U. S. G.

*Bulletin ii, p. 72.

No. 771. Granite *(with biotite)*.

Near the west end of East-and-West lake, on the south shore; probably in S. E. ¼ S. W. ¼ sec. 15, T. 64–5 W. From a vein twenty inches wide and dipping 75° towards the east, cutting the gabbro.
Ref. Annual Report, x, pages 98, 99.

Meg. A medium-grained reddish granite, composed of colorless to red feldspar, quartz, a little biotite and also apparently a little hornblende.

Mic. The section shows *feldspar*, *quartz*, *biotite* and a little *chlorite* and *magnetite*. The feldspar is in general some clouded and in places is much reddened. It seems to be largely *orthoclase*, but there are some grains which show very minute twinning lamellæ, which are usually visible only near the point of extinction,—probably *anorthoclase*.

One section examined.

Age. Cabotian. U. S. G.

No. 772. Gabbro *(with hornblende and biotite)*.

Lake in Frog Rock river. This lake is probably the one at the northwest corner of sec. 26, T. 64–5 W. From a vein one foot wide.
Ref. Annual Report, x, page 99; Bulletin ii, pages 75, 76.

Meg. A coarse-grained, granitoid rock, composed of feldspar, hornblende, biotite, and magnetite.

Mic. M. E. Wadsworth's description of this section is as follows:*

"The section shows a partially altered *plagioclase*, *biotite*, *quartz*, *viridite* and *magnetite*. Of these the quartz, biotite and viridite are secondary or alteration products. Another section shows some *diallage*, with green and brown hornblende and biotite as associated alteration products of the diallage. The section contains secondary quartz and *titanite*, and much of the rock is a typical quartz-dioryte formed by the alteration of a gabbro."

Two sections examined.

Age. Cabotian. U. S. G.

No. 773. Gabbro.

Last lake in Frog Rock river; probably in S. E. ¼ sec. 27, T. 64–5 W.
Ref. Annual Report, x, pages 99–101, 103; Bulletin ii, page 71, plate IV, figure 2.

Meg. A coarse-grained, granitoid rock, composed largely of feldspar, with some augite and magnetite.

Mic. M. E. Wadsworth's description of this section is as follows:†

"Its pyroxene constituent is seen under the microscope to be altered to *viridite* and a greenish and brownish *biotite*. The plagioclase is somewhat changed and contains secondary *orthoclase*, *quartz*, *mica* scales, etc.

**Bulletin ii*, pp. 75, 76.
†*Bulletin ii*, p. 71.

"In one portion a pyroxene, in a triangular mass, is seen remaining as pyroxene in one part and altered to a greenish-brown biotite carrying *magnetite* in another portion of the same mass.

"A radiated group of *epidote* crystals was observed in the section.

"Plate IV, figure 2, shows the relation of the biotite formed from the alteration of the diallage. It extends along the cleavage and fissure lines with portions of the unchanged pyroxene between. The whole is surrounded by somewhat kaolinized feldspars bearing biotite."

The radiating group of crystals mentioned above—at least only one such group was seen in the section—has the characters of *tourmaline* rather than of epidote. *Calcite* also occurs. One section examined.

Age. Cabotian. U. S. G.

No. 774. Granite (*with augite*).

At or near Duck lake. This lake is in sec. 3, T. 63-5 W.

"This comes in apparently *through* No. 773 at first, but afterward it lies on No. 773, and in rude, lenticular and broken bedding dips to the south. It forms a range of hills about 100 to 150 feet high next west and south of Mesabi and Duck lakes. It has been molten, as evidently as No. 773, and in that sense it is an igneous rock, but it differs from it in its mineral composition. It is a reddish syenyte, but seems to contain mica, as well as some plagioclase. In passing along Duck lake considerable confusion prevails in the relative positions of Nos. 773 and 774. Along the south side of the point that separates the lake into northeast and southwest parts, No. 774 plainly lies on parts of No. 773; but on the east side of the lake, there is considerable mixing, the two changing places suddenly, and either one being in patches in the other—particularly No. 774 embracing masses of No. 773, and suddenly cutting No. 773 like dike-rock."

Ref. Annual Report, x, pages 99-101; Bulletin ii, page 103.

Meg. A rather fine-grained, granitoid rock, pinkish gray in color, composed of feldspar, quartz and black minerals. A little pyrite is seen both in the hand samples and in the section.

Mic. M. E. Wadsworth's description of this section is as follows:*

"The section is largely composed of *feldspar* and *quartz* arranged in graphic or eozoön form. Besides these minerals much *magnetite*, *augite*, a little *diallage*, *hornblende*, some *biotite*, yellowish pseudomonphs after olivine or augite, and microliths occur. The augite in places is altered into *uralite* and at others into *brown hornblende*, which exhibits the characteristic cleavage. The brown hornblende occupies part of the original augite areas, is contiguous with the augite mass and was formed from its alteration. The biotite is mainly associated with the magnetite. Although the pyroxene is abundant here, this rock answers to the augite syenyte of Irving, but has been formed from the further alteration of a basaltic diabase."

Two sections examined.

Age. Cabotian.

Remarks. This rock is similar to others of the augite granites and its composition and field relations place it with the granites or "red rocks" of the Cabotian rather than with the gabbro. U. S. G.

* *Bulletin ii*, p. 103.

No. 775. Granite *(with hornblende and biotite)*.

Southeast end of Duck lake; S. W. ¼ S. W. ¼ sec. 2, T. 63-5 W. "At the southeast end of Duck lake No. 773 lies on No. 775, which is the well-known and so-called 'red granite.' This lies in even and regular beds of four to eight inches (or in beds of three to four feet), dipping south, amounting in all to about twenty feet, the rock No. 773 being unconformable on it, but intimately cemented to it, as at Rice point. Over both of these, further toward the southeast, No. 774 comes in again."

Ref. Annual Report, x, pages 100, 101.

Meg. A fine-grained, pink, granitoid rock, composed of pinkish feldspar, quartz, biotite, hornblende. There are a few larger feldspars which give a sub-porphyritic aspect to the rock.

Mic. The section shows a fine-grained granite. The minerals are *feldspar*, *quartz*, *biotite*, *hornblende* and *magnetite*. The feldspar is somewhat reddened and much clouded; it is probably largely *orthoclase*.

One section examined.

Age. Cabotian. U. S. G.

No. 776. Granite *(with augite)*.

Portage between Duck and L lakes; probably in S. W. ¼ S. W. ¼ sec. 2, T. 63-5 W.

Ref. Annual Report, x, pages 100, 101; Bulletin ii, pages 96, 97.

Meg. A medium-grained, brownish-gray, granitoid rock, composed of feldspar, quartz, biotite, hornblende and probably augite.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"Has its section composed of partially altered *diallage*, *feldspar*, *magnetite*, and secondary *quartz*, *hornblende*, *biotite*, etc. The diallage is filled with the usual black needles and grains, which also occur abundantly in the feldspar. Part of the feldspar appears to be of a secondary origin, while numerous *amphibole* microliths of secondary origin extend through the quartz and feldspar. Fluid cavities occur in the quartz. The hand specimen is a brownish-gray, granitoid or dioritic rock, with tabular pinkish feldspar. It shows surface weathering."

No section found.

Age. Cabotian. U. S. G.

No. 777. Gabbro. *(Granulitic; porphyritic.)*

L lake, probably just at the east of the portage to Wind lake; probably near the centre of N. W. ¼ sec. 11, T. 63-5 W. "At the point where the portage leaves L lake is a bluff at the left, made up of the following (Nos. 777-780):

"No. 777. A characteristic gabbro, seamed by red syenyte, and weathering nearly white, porphyritically, so as to appear much like No. 773. This passes downward into—

"No. 778, which was obtained about thirty-five feet below the top of No. 777 and near the next. This is apparently a form of the gabbro, when in closer contiguity with the sedimentaries, and has been penetrated by minerals from them. It is finer grained than No. 777, and darker, but also seems to have orthoclase and mica. These together make a thickness of about forty-five feet, from the top of the bluff downward. They are one in structure, dip and general characters. They dip south in heavy layers at an angle of about 30°.

"No. 779. Red syenyte, unconformable under No. 778, showing about fifteen feet. What appears like bedding in No. 779 may be coarse jointage, as there are two sets of planes, one set being perpendicular to the bedding of the gabbro overlying, and the other crossing it so as to have a dip south of about 70°.

* *Bulletin ii*, p. 96.

"No. 780 is a form of the rock in the same bluff about twenty feet below the top; evidently a part of the igneous rock, but affected by proximity to the underlying rock so as to appear like a dioryte.

"There is a striking contrast in the appearance, form and color of the rocks Nos. 777 and 779."

Ref. Annual Report, x, pages 100, 101; Bulletin ii, pages 91, 92, 94, plate IV, figure 1.

Meg. A fine-grained, dark-gray crystalline rock, which contains a number of porphyritic plagioclases. These porphyritic crystals, on account of a color similar to that of the mass of the rock, are not very evident in the hand sample.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"Is grayish brown, porphyritic, resembling that found in Gloucester, Mass., and belongs to the gabbros. The section is composed of large plagioclase crystals, lying in a crystalline granular groundmass of *diallage, augite, biotite, uralite, magnetite, plagioclase, orthoclase,* and some *quartz.* All are in more or less rounded grains, and the general structure of the groundmass is that of one which has been formed by the recrystallization of its materials, *i. e.,* the augite and diallage are the remnants of larger crystals, while much of the feldspar and all of the quartz, biotite and uralite are the results of alteration. The biotite and uralite are formed from the pyroxene. The larger plagioclase crystals are filled with elongated dark needle-like shapes which are arranged parallel to the twinning, clinopinacoid, and other crystal planes. These needles polarize with a bright, yellowish-brown color, like thin biotite plates. On further examination some sections are found cut obliquely to these needles, when they are found to be elongated, oval, yellowish-brown plates of biotite. These plates are evidently an alteration product of the feldspar itself.

"Plate IV, figure 1, shows the granular structure of this rock with the brown biotite on the right and greenish hornblende at the bottom of the figure. The section in places shows the characters of a dioryte or hornblende schist."

The texture of the groundmass of this rock is very similar to that of No. 698; but in No. 777 the grain is a little finer and the plagioclase has more of a tendency to a lath-shaped development, giving the rock a diabase-like appearance, and thus the rock might be called a diabase porphyryte.

The porphyritic feldspars have equal extinction angles in sections cut normal to 010 as high as 33°, and a cleavage flake parallel to 010 gave an extinction of 20°. Both indicate *labradorite* with approximately the composition $Ab_1\ An_1$. The feldspar of the groundmass was not determined carefully, but it appears to be labradorite.

Two sections examined.

Age. Cabotian. U. S. G.

No. 778. SYENYTE(?) *(with augite).*

Same locality as No. 777.

Ref. Annual Report, x, pages 100, 101; Bulletin ii, page 120.

Bulletin ii, pp. 91, 92.

Meg. A rather fine-grained, crystalline, dark, brownish-gray rock, composed of feldspar, biotite, hornblende, probably augite and a little quartz.

Mic. M. E. Wadsworth's description of this section is as follows:*

"The section is composed of feldspar (largely *plagioclase), augite* cores, and secondary *quartz, biotite, hornblende, magnetite,* and microliths. The augite cores are surrounded by and pass into both biotite and uralite. The rock is now a quartz-biotite-dioryte, but the writer has no doubt that it is simply an altered diabase to which its augite and feldspar ally it."

Two sections examined.

Age. Cabotian. U. S. G.

No. 779. Granite *(with biotite and hornblende).*

Same locality as No. 777.
Ref. Annual Report, x, pages 100, 101.

Meg. A rather fine-grained, reddish, granitoid rock, composed of feldspar, quartz, hornblende and biotite.

Mic. The section shows a fine-grained granite composed essentially of *feldspar,* which is much clouded and frequently reddened, *quartz, hornblende* and *biotite.*

One section examined.

Age. Cabotian. U. S. G.

No. 780. Syenyte(?) *(with augite).*

Same locality as No. 777.
Ref. Annual Report, x, pages 100, 101; Bulletin ii, page 85.

Meg. A medium-grained granitoid rock, composed of feldspar, a little quartz and black minerals. Similar to No. 776.

Mic. M. E. Wadsworth's description of this rock is as follows:†

"It is a yellowish-gray granitoid rock, composed of *feldspar, magnetite, biotite* and *hornblende.* It is so altered that the transition is complete, except in the case of a few pyroxene grains, so as to form a quartz-dioryte, although it contains much *orthoclase* and some biotite and might thus be styled a granite. The orthoclase, *quartz,* biotite and hornblende all appear to be secondary, as are probably the numerous microliths by which they are traversed." One poor section examined.

Age. Cabotian. U. S. G.

No. 781. Gabbro(?) *(with quartz).*

Portage between L and Wind lakes; probably in E. ½ sec. 11, T. 63-5 W.
Ref. Annual Report, x, page 101; Bulletin ii, page 97.

Meg. A medium-grained, gray, granitoid rock, composed of feldspar, augite, biotite and a little quartz.

**Bulletin ii*, p. 120.
†*Bulletin ii*, p. 85.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"A gray crystalline granitoid rock, composed of gray *feldspar*, *biotite*, *hornblende*, etc. Its section is similar to the preceding No. 776, but it has few microliths. The diallage *has* fewer inclusions than that of No. 776, and is largely altered to hornblende and biotite. The quartz is quite abundant, and the biotite is largely associated with and surrounds the magnetite. The analysis by professors Dodge and Sidener gave the following result:"

SiO_2	53.43
Al_2O_3	13.81
Fe_2O_3	5.08
FeO_2	9.86
MnO	trace
CaO	8.25
MgO	4.64
Na_2O	2.51
K_2O	1.12
H_2O	0.27
Total	98.97

Two poor sections examined.

Age. Cabotian. U. S. G.

Remark. "Along the north side of Wind lake, these formations, the red and the gray, are somewhat interbedded, and so brecciated and mixed that the bluffs are spotted promiscuously with the two colors. Sometimes, also, they seem to have been fused and blended into a rock that is neither red nor gray." N. H. W.

No. 782. Granite *(with biotite)*.

Southeast side of Wind lake; perhaps in S. E. ¼ sec. 15, T. 63–5 W.
Ref. Annual Report, x, page 101.

Meg. A fine-grained, granitoid rock, pinkish-gray in color, composed of feldspar, quartz and biotite.

Mic. The section shows a fine-grained granite, composed of *quartz*, *feldspar*, *biotite*, *magnetite* and a little *chlorite*. Most of the feldspar is considerably clouded and appears to be *orthoclase;* some of the least clouded grains have the characters of a plagioclase near *oligoclase*. One section examined.

Age. Cabotian. U. S. G.

No. 783. Quartz-Porphyry(?)

Southeast side of Wind lake; perhaps in S. E. ¼ sec. 15, T. 63–5 W. "This is one of the metamorphosed sandstones of the Cupriferous."
Ref. Annual Report, x, pages 101, 121.

Meg. A very fine-grained, granular rock of a flesh color. The minerals appear to be quartz, feldspar and biotite. The rock looks much like a fine-grained feldspathic quartzyte.

**Bulletin ii*, p. 97.

Mic. The section is composed of a very fine-grained granitic mosaic of *quartz, feldspar, biotite* and *magnetite.* The feldspar is much clouded and often considerably reddened; its species was not determined carefully, but it appears to be *orthoclase* largely. Scattered through the section are a few considerably larger grains of quartz and of highly altered feldspar. These grains, which have the appearance of porphyritic crystals, do not have crystal outlines, but have serrate borders into which fit the smaller grains of the groundmass. The section resembles some of the metamorphosed quartzytes of Pigeon point, but has no distinctly fragmental characters. It also resembles a quartz-porphyry with a micro-granitic groundmass. No definite statement can be made from the section alone as to whether this is an acid igneous rock or a recrystallized sedimentary. One section examined.

Age. Cabotian. U. S. G.

NO. 784. QUARTZ-PORPHYRY.

"At the place where the portage trail leaves Wind lake is a bluff which, in form, is a duplicate of the red quartzyte bluffs at New Ulm, and in Rock and Pipestone counties.

"No. 784 is from this bluff, and constitutes the most of it. It is a hard, red, fine, sub-granitized quartzyte, somewhat sprinkled with darker specks, that may be chloritic or micaceous, or graphite, and having rarely a distinct crystalline grain of orthoclase. It is in distinct sedimentary layers that dip south at an angle of 20° to 25°." Perhaps near the centre of the S. E. ¼ sec. 15, T. 63–5 W.

Ref. Annual Report, x, pages 101, 102.

Meg. A very fine-grained, granular rock, of a flesh color, and resembling No. 783. Small porphyritic crystals of quartz and feldspar are present.

Mic. The section shows a quartz-porphyry with a microgranitic groundmass, and is quite similar to No. 783. The porphyritic crystals are more marked than in No. 783, and some of the quartzes show bipyramidal outlines.

Two sections examined.

Age. Cabotian. U. S. G.

Remark. The feldspar "phenocrysts" embrace the fine quartzes of the groundmass poikilitically. This is an instructive section, which, taken with No. 783 and similar changed quartzytes of Pigeon point, illustrates the manner of genesis of this rock. N. H. W.

NO. 785. DIABASE.

This rock occurs in irregular patches and areas, apparently in No. 784; showing on the face of the bare bluff rounded off by glaciation.

Ref. Annual Report, x, pages 101, 121.

Meg. A very dark, greenish-gray, fine-grained diabase.

Mic. The section shows rather fresh, small, lath-shaped *plagioclases* in a considerably altered fine-grained background, which consists of a little unaltered *augite, hornblende, chlorite, magnetite, biotite* and a little *pyrite.*

One section examined.

Age. Cabotian. U. S. G.

No. 786. Gabbro. *(Granulitic.)*

Portage between Spotted Rock and South Side lakes, but north of the summit crossed by this portage; perhaps in N. E. ¼ sec. 23, T. 63-5 W.
Ref. Annual Report, x, page 103; Bulletin ii, page 91.

Meg. A fine-grained, brownish, granular rock.

Mic. The section shows a fine-grained, granular aggregate composed essentially of *plagioclase*, *pyroxene* and *magnetite*. The pyroxene is both orthorhombic and monoclinic. *Biotite*, sometimes in large plates, is also present.

Two sections examined.

Age. Cabotian.

Remarks. This rock closely resembles No. 698. U. S. G.

No. 787. Gabbro *(with olivine)*.

On same portage as No. 786, but south of the summit.
Ref. Annual Report, x, page 103; Bulletin ii, pages 59, 90, 91, plate III, figure 1.

Meg. A medium-grained, gray, granitic rock, composed of feldspar, pyroxene, olivine and magnetite.

Mic. M. E. Wadsworth's description of this section is as follows:*

" A grayish medium-grained rock, composed principally of a clear, glassy feldspar holding brownish *olivine*, *diallage* and *magnetite*. The section is composed of clear feldspar, holding yellowish-brown olivine, darker brown *enstatite*, and *magnetite*.

" The feldspar shows a clear brilliant polarization, while the polysynthetic twinning according to the albite-pericline law is marked even in common light. The fibrous alteration has begun to appear along the cleavage planes and fissures giving it, in places, the common cloudy appearance seen in feldspars of considerable age. The olivine stands next in abundance to the feldspar and is much fissured with a yellowish ferruginous staining along the fissures, and sometimes even extending through the entire mass of the mineral. It contains some magnetite, part of which is secondary, while the olivine itself appears to be foreign.

" The *enstatite* is mostly built out upon the olivine grains as an apparent continuation of them but only rarely do they correspond in optical orientation. The enstatite shows the beginning of alteration, indicated by a brownish color, and the development of fine smoky ferruginous bands parallel to the principal cleavage It also has an irregular cross fracture. The magnetite is often bordered by forming fibrous biotite.†

"This rock answers to the olivine-noryte of Rosenbusch, and in its structure it somewhat macroscopically resembles some of the basaltic meteorites. Figure 1, plate III, shows the structure of the rock." One section examined.

Bulletin ii, pp. 90, 91.
†Irving: *Copper-Bearing Rocks*, 1888, p. 51; Hawes: *Lithology of New Hampshire*, 1878, p. 205; Wadsworth: *Lithological Studies*, 1884, p. 77.

Age. Cabotian.

Remark. The section studied by Wadsworth was a very unfavorable one. Having later had a better section prepared by Marchand, several features of this rock are distinctly presented. (1) The olivine is in somewhat spreading masses with smooth outlines, and somewhat embraces occasionally the labradorites whose outlines are also rounded, thus resembling the olivine of rock No. 258. (2) The few magnetite grains are surrounded by brown hornblende, rather than by biotite.* (3) The border of pyroxene that surrounds the olivines is augite, with occasional close twinning with some other pyroxene, and but rarely presents the lamellation characteristic of diallage. Sometimes two growths appear in the same grain, the older being corroded and surrounded by the later, and of different orientation. N. H. W.

No. 788. Gabbro.

East side of Burntwood lake; perhaps in N. E. ¼ sec. 9, T. 62-4 W. The country rock.
Ref. Annual Report, x, page 104; Bulletin ii, page 101.

Meg. A medium-grained, rusty, granitoid rock, composed of feldspar and black minerals.

Mic. M. E. Wadsworth's description of this rock is as follows:†

"The section is composed of *feldspar*, *augite*, *hornblende*, *biotite*, *quartz*, *apatite*, *magnetite*, etc. The feldspar is altered and kaolinized in part, and is both *orthoclase* and *plagioclase.* The augite is of a brownish color, and along its borders, and sometimes throughout much of its mass, has been altered to a greenish fibrous and scaly or leafy substance. This, in places, possesses the characters of green hornblende, and in others those of biotite. The apatite and quartz are clearly secondary, both occurring in the secondary hornblende. The augite and part of the magnetite and feldspar are the only original minerals left."

One section examined.

Age. Cabotian. U. S. G.

No. 789. Gabbro.

Portage from Burntwood lake (probably) to Temperance River lake (called Descent lake on the map, plate I of the Tenth Annual Report); perhaps in W.½ sec. 10, T. 62-4 W.
Ref. Annual Report, x, page 104; Bulletin ii, page 87.

Meg. Very similar to No. 788.

Mic. The section shows an altered gabbro, the augite being largely replaced by *hornblende* and the feldspar being much kaolinized. *Quartz* and *apatite* needles also occur.

One section examined.

Age. Cabotian. U. S. G.

* Brown hornblende, having its maximum extinction angle sometimes as low as one degree, and being highly pleochroic in the same colors, is easily mistaken for biotite.

† *Bulletin ii*, p. 101.

No. 790. Basalt. *(Amygdaloidal.)*

Portage from a small lake (in secs. 23 and 24, T. 62–4 W.) to Poplar River lake (otherwise called Pine lake); the sample is from near the Poplar River lake end of the portage, and probably from N. W. ¼ N. E. ¼ sec. 25, T. 62–4 W.

Ref. Annual Report, x, page 104.

Meg. A very fine-grained, dark-gray rock, indistinctly blotched with small areas of lighter color than the main mass of the rock.

Mic. The most noticeable feature of the section, when examined without the microscope, is the presence of numerous small, white blotches, which have the appearance of amygdaloidal (possibly pseudamygdaloidal) cavities filled with white material. The background of the section is much darker colored than are these white areas. Some of these areas have a border darker than, and passing gradually into, the main mass of the section. In a few cases a white area is composed of a light colored outer rim, then a dark band, and within this dark band a lighter area of about the same color as the main mass of the section. These white areas frequently have a brownish stain.

Under a low power and crossed nicols the background of the section reminds one of a glassy rock which has devitrified to a very finely crystalline aggregate in which are some original, minute, plagioclase laths. Under a high power the background of the rock is seen to consist of minute laths of *plagioclase* feldspar, in irregular grains, and many minute and more or less rounded grains of *magnetite* and a nearly colorless mineral; and the resemblance to a devitrified rock is not so noticeable as under a low power. The nearly colorless mineral has a higher index of refraction than the feldspar and also a stronger double refraction, commonly polarizing in yellows or reds of the first order, while the feldspar shows grays. This mineral is perhaps *augite.*

The lighter colored amygdaloidal areas are composed of *quartz*, *feldspar* and large amounts of a granular mineral, whose index of refraction is higher than quartz and whose double refraction is stronger, but apparently not so strong as that of the augite-like mineral of the main mass of the rock which it resembles. This granular mineral appears like *epidote*, but its double refraction is not marked enough for epidote. In these lighter colored areas magnetite is in only small quantities. The lighter and darker color of different parts of the section is due mainly to the scarcity or abundance of these magnetite grains.

One section examined.

Age. Cabotian. U. S. G.

No. 791. Basalt.

West shore of Poplar River lake; probably in the E. ½ sec. 25, T. 62–4 W.

Ref. Annual Report, x, page 104.

Meg. A very fine-grained, very dark, greenish-gray rock, compact and resembling a fine-grained diabase.

Mic. The section is composed of small, much kaolinized *plagioclase* laths, arranged by flowage, *augite* and much *magnetite.* The augite is thickly set with minute grains of magnetite and has altered in places to a confused mass, rich in magnetite. It is possible that some of these apparent altered augite areas represent an original unindividualized base.

One section examined.

Age. Cabotian. U. S. G.

No. 792. Diabase.

Poplar river; N. E. ¼ sec. 20, T. 60-3 W. From the foot of a precipitous hill facing north; part of the Sawteeth mountains. This sample is probably from the place known locally as "the rock pile." Compare No. 455E.

Ref. Annual Report, x, page 105.

Meg. A medium-grained, dark, yellowish-gray diabase.

Mic. The section shows chiefly *plagioclase* laths and *augite*, the latter later than the former and commonly in ophitic plates of considerable size. There is much secondary, green, chloritic material, also some *magnetite.* A few yellowish-brown areas (bowlingite?) are present; these are probably the results of alteration of olivine or original augite.

One section.

Age. Cabotian. U. S. G.

No. 793. Diabase.

From the foot of the last hill (nearest lake Superior) on the west side of Poplar river; 600 feet above the lake. Probably in N. E. ¼ sec. 29, T. 60-3 W.

Ref. Annual Report, x, pages 105, 106.

Meg. A rather fine-grained, yellowish-brown diabase.

Mic. The section is considerably altered and has much yellowish and greenish alteration material, also, some secondary *quartz.* There are small laths of *plagioclase* and *augite*, the latter not in ophitic grains, but, in part at least, later than the feldspar. Some *olivine*, or the alteration product of olivine, is present; also *magnetite* and *hematite.* One section.

Age. Cabotian. U. S. G.

No. 794. Diabase.

"From the same hill [as No. 793], one-fourth way up."

Ref. Annual Report, x, page 106.

Meg. Similar to No. 793.

Mic. Similar to No. 793, but not quite so much altered. One section.

Age. Cabotian. U. S. G.

No. 795. DIABASE. *(Porphyryte.)*

"From the same, one-half way up. The same rock [as No. 794] with coarser feldspar crystals."
Ref. Annual Report, x, page 106.

Meg. Similar to No. 796, but the phenocrysts are small and comparatively scarce in No. 795.

Mic. The slide is in general similar to Nos. 793 and 794, but contains one large porphyritic feldspar.

One section.

Age. Cabotian. U. S. G.

No. 796. DIABASE. *(Porphyryte.)*

"From the top of the hill, 1,111 feet above lake Superior." See under No. 793.
Ref. Annual Report, x, page 106. Compare No. 456E.

Meg. The rock is a rather fine-grained, gray diabase, similar to Nos. 793 and 794, but it contains numerous porphyritic plagioclases of a yellowish-gray color. These phenocrysts are mostly from a half inch to an inch across.

Mic. The groundmass of the rock is in general similar to Nos. 793 to 795, *i. e.*, it is composed of lath-shaped *plagioclases*, *augite*, *olivine*, iron ore and alteration products. In addition there is a cloudy gray feldspar in irregular grains, which is of later date than the lath-shaped feldspars, and which seems to have been the last mineral to crystallize. All the feldspar, including that in phenocrysts, is more or less kaolinized.

Two sections.

Age. Cabotian. U. S. G.

No. 797. DIABASE.

Taylor's Falls.
Ref. Annual Report, x, page 106; Bulletin ii, page 114.

Meg. A fine-grained, greenish-black diabase with marked areas of poikilitic augite, which give a "lustre-mottled" character to the rock. One of the specimens has a considerable area of "chaldedonic" quartz.

Mic. The rock and sections are similar to No. 820.

Three sections.

Age. Cabotian. U. S. G.

No. 798. DIABASE. *(Porphyryte.)*

Taylor's Falls.
Ref. Annual Report, x, page 106.

Meg. A medium-grained, yellowish-green diabasic rock with porphyritic crystals of brownish plagioclase. The rock has been considerably altered and has much epidote developed in it. The specimen is crossed by a vein of epidote and "chalcedonic" quartz, the former mineral forming the most of the vein, and, where the quartz occurs, making the sides of the vein, the quartz being in the centre. There are also a few areas, probably pseudamygdules, of quartz.

Mic. The sections show a much altered diabase porphyryte. The minerals are mainly *feldspar*, *hornblende*, *epidote*, *chlorite* and iron ore. The chlorite is frequently developed in the feldspars, which are also kaolinized.

Three sections.

Age. Cabotian. U. S. G.

No. 799. Granite *(with hornblende)*.

"Saganaga lake. The first island on entering the lake from the east." S. ½ N. E. ¼ sec. 4, T. 66–4 W.
Ref. Annual Report, ix, page 84; Annual Report, x, page 106.

Meg. Coarse-grained, gray granite, composed of feldspar (white to pinkish), quartz (in large grain) and hornblende. A typical sample of the Saganaga granite.

Mic. Same rock as No. 316.

Three sections.

Age. Archean (igneous). U. S. G.

No. 800. Granite *(with hornblende)*.

Falls of Gunflint river at the first portage going north from Gunflint lake. N. E. ¼ sec. 13, T. 65–4 W.
Ref. Annual Report, ix, page 83; Annual Report, x, page 106.

Meg. Rock like No. 799, except that No. 800 has the hornblende more altered and more epidote developed.

Mic. Same as No. 315.

One poor section.

Age. Archean (igneous). U. S. G.

No. 801. Granite *(with biotite and hornblende)*.

From S. E. ¼ sec. 17, T. 35–30, about two and a half miles southeast of St. Cloud, on the east side of the Mississippi river.
Ref. Annual Report, x, pages 106, 107; Bulletin ii, pages 85–87.

Meg. A coarse-grained, gray granite composed essentially of feldspar (white to pinkish), quartz, hornblende and biotite.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"A dark-gray, coarsely-crystalline rock, composed of *hornblende*, *biotite*, pinkish and gray feldspar, *quartz* and *magnetite*. Under the microscope it is seen to be composed of the above minerals with *titanite*, *apatite* and microliths. The feldspar is in part *plagioclase* and in part *orthoclase*, but in both cases the feldspar material seems to be of a secondary origin, replacing other feldspars and in part retaining their cloudy kaolinized material and striations. The feldspar also, in places, shows some

**Bulletin ii*, pp. 85–87.

of the common inclusions found in the feldspar of gabbros. The hornblende is green, like that of No. 305, and filled in the same manner, but more abundantly, with apatite. Some of the biotite shows the polarization phenomenon produced by the grinding, as the preceding No. 305, but the bands very irregularly cross one another. The quartz is like that of the preceding. While this rock, in its present stage, makes a good representative of a biotite-hornblende-granite, it is believed to be but a further stage in the alteration process than that shown by No. 305. In both we have the same general characters in their minerals, except that in No. 305 part of the diallage remains, while in No. 801 it has been entirely changed. Macroscopically this rock is like part of the preceding rocks, and this solution of its structure would account for the later origin of the quartz and its impression by the other minerals in all so-called granites having the same origin as this.

"One portion of the rock is darker than the other, and an analysis was made of each portion by professors Dodge and Sidener, with the following results:

	Light Portion.	Dark Portion.
SiO_2	61.19	58.77
Al_2O_3	15.22	13.12
Fe_2O_3	3.20	5.45
FeO	3.55	6.87
MnO	trace	trace
CaO	7.94	5.99
MgO	2.38	4.93
Na_2O	3.17	1.94
K_2O	2.62	2.83
H_2O	0.40	0.45
Total	99.67	100.35

"These results indicate either that during alteration the basic rocks become more acidic by alteration, as the writer showed* was the case for the peridotytes, or else that this rock is from a more acidic group than the basalts, and that the writer has wrongly placed it with the altered gabbros."

Three sections.

Age. Archean (igneous).

Remark. The portions of the rock which are darker colored are simply areas in which the hornblende and biotite are concentrated. The writer would put this rock with the original granites, or the quartz diorytes, rather than with the altered gabbros as does Dr. Wadsworth. U. S. G.

No. 802. Diabase.

From a dike four feet wide, running southwest and northeast, and cutting No. 801.
Ref. Annual Report, x, page 107.

Meg. A fine-grained, heavy, black, diabasic rock. One side of the specimen, which is finer grained than the rest of the specimen, evidently represents the side of

*Lithological Studies, 1884, pp. 186–189.

the dike and has along it a small amount of the granite. Cleavage faces of feldspar are scattered thickly through the rock and are very evident, owing to the finer grained state of the other minerals, on the contact side of the specimen.

Mic. The section shows plagioclase, augite, magnetite, hornblende, chlorite and calcite.

The *plagioclase* occurs in numerous, small, lath-shaped crystals, and also in larger grains of irregular outline. These larger grains are of later date than most of the lath-shaped crystals, but there is not a very sharp distinction to be made between the two forms of feldspar, all gradations from the laths to the irregular grains being seen. Albite twinning, especially in the laths, is common, and pericline twinning is rare. Equal extinction angles on either side of the albite twinning line in sections cut normal to 010 run up to 30° in the lath-shaped crystals, indicating acid *labradorite.* The irregularly outlined feldspars are apparently a little more acid than the lath-shaped crystals and are probably *andesine.*

The *augite* is later than at least the lath-shaped feldspar and occurs usually in small grains, but sometimes larger areas are found which assume an ophitic relation to the feldspar. The irregular feldspars appear about cotemporaneous with the augite, although this relation is not very marked. The augite is of a light cinnamon color and is slightly pleochroic. It has altered in quite a large measure to green fibrous *hornblende* and *chlorite*, with some *calcite.*

Magnetite is abundant in small grains and is often enclosed in the augites.

One section.

Age. Dike, perhaps of Keweenawan age, in Archean granite. U. S. G.

No. 803. Granite *(with hornblende).*

From an old quarry of Breen and Young, East St. Cloud.
Ref. Annual Report, x, pages 107, 121; Final Report, vol. i, pages 144, 145, 196–199 (No. 6), plate A, figure 5.

Meg. A coarse-grained, reddish granite, composed of reddish feldspar in abundance, and quartz and hornblende in smaller amounts. Some of the feldspar is in larger grains than the average mass of the rock, and thus a sub-porphyritic aspect is given to the hand specimen.

Mic. The main part of the section is composed of large grains of *feldspar* and also of *quartz*, which, however, do not show crystal outlines. These larger grains interlock with each other and also with smaller grains of feldspar, quartz and hornblende, which smaller grains form a groundmass, but of small quantity, for the rock. The feldspar is considerably clouded, but appears to consist of *orthoclase, microperthite, microcline* and *oligoclase.* The *hornblende* is in small amount, and is greenish to brownish in color. It is strongly absorptive, the ray which vibrates approximately parallel to the vertical axis being almost entirely absorbed.

A partial chemical analysis of this rock gave the following results:

SiO_2	74.43
Al_2O_3	12.68
Fe_2O_3 and FeO	3.82
CaO	1.28
MgO	0.25
Na_2O	1.91
K_2O	2.25
Total	96.62

One section.

Age. Archean (igneous). U. S. G.

No. 804. Gneiss *(with biotite).*

Granite City, Morrison county.
Ref. Annual Report, x, page 107.

Meg. A medium to coarse-grained granitic rock, composed of white feldspar, quartz and much biotite, the plates of the last mineral giving a gneissic structure to the rock.

Mic. The section is composed largely of feldspar. This is mainly *microcline* and *orthoclase.* All the feldspar is more or less clouded, and there are some small rounded grains of this mineral embraced in larger grains of the same. These smaller grains are so much altered as to be almost opaque. *Quartz* and *biotite* are also present. There is a little *chlorite,* apparently an alteration product from biotite, and in one small area are many *muscovite* scales.

One poor section.

Age. Archean. U. S. G.

No. 805. Granite *(with biotite and hornblende).*

Watab, Benton county.
Ref. Annual Report, x, page 107.

Meg. A coarse-grained, pinkish granite composed of pinkish feldspar, quartz, biotite and hornblende.

Mic. The sections show much feldspar—apparently *orthoclase, microperthite*—abundantly twinned plagioclase near *oligoclase,* and *microcline.* There are also some *quartz, biotite, hornblende* and a few *apatite* needles. The biotite is sometimes in small, irregular areas and shreds, surrounded by areas of minute flakes of the same mineral. Such areas are regarded as secondary. There is a little micropegmatyte of quartz and feldspar.

Two sections.

Age. Archean. U. S. G.

No. 806. Granite *(with hornblende and biotite).*

Watab, Benton county.
Ref. Annual Report, x, page 107; Final Report, vol. i, pages 144, 145, 196–199 (No. 10).

Meg. A coarse-grained, gray granite composed of white feldspar, quartz, biotite and hornblende.

Mic. Feldspar, *quartz, hornblende, biotite, chlorite,* as an alteration product of hornblende and biotite, and *magnetite. Sphene* is common, and there is a little *epidote.* The feldspar is *orthoclase, microperthite* and *plagioclase.* The last is in great quantity, and is abundantly twinned, in some cases the twinning being exceedingly minute. This plagioclase is probably both *oligoclase* and *anorthoclase.*

A chemical analysis of this rock gave the following results:

SiO_2	78.12
Al_2O_3	11.14
Fe_2O_3 and FeO	2.68
CaO	0.62
MgO	trace
Na_2O	3.33
K_2O	4.48
H_2O	0.43
Total	100.80

Two sections.

Age. Archean. U. S. G.

No. 807. Quartzyte.

Duluth.
Ref. Annual Report, x, pages 107, 108. Compare rocks Nos. 44, 1966 and 1967.

Meg. A compact, very fine-grained, dark-gray to black, reddish-weathering, almost flint rock. This rock underlies the diabase No. 43, and in the field appears to be a part of No. 42. It overlies No. 808.

Mic. The section consists of small, irregular grains of quartz, and a red, cloudy feldspathic substance which acts almost as a cement to the quartz grains. A little chlorite and magnetite are present.

One section.

Age. Animikie.

Remarks. This rock resembles some of the very fine-grained, metamorphosed quartzytes or quartz slates of the Animikie at Pigeon point. U. S. G.

No. 808. Granite.

Newson's old quarry, Duluth. Underlies No. 807.
Ref. Annual Report, x, pages 108, 109.

Meg. A medium-grained, reddish, granitic rock, composed mainly of reddish feldspar and quartz.

Mic. The section shows one of the usual "red rocks." There is much quartz and clouded and reddened feldspar, the red color being due to the presence of much finely divided hematite. Chlorite is present, also a little epidote. One section.

Age. Cabotian. U. S. G.

NO. 809. SHALE. *(Red.)*

Boyle's quarry, on the railroad above Fond du Lac.
Ref. Annual Report, x, page 109; Annual Report, xiii, pages 100, 103 (No. 166).

Meg. Soft, fine-grained, red shale, with a few small, gray, circular areas, which, aside from the color, do not appear particularly different from the rest of the rock.

A chemical analysis of this rock gave the following results:

SiO_2	48.92
Al_2O_3	18.45
Fe_2O_3	16.88
FeO	0.57
CaO	0.70
MgO	3.68
Na_2O	0.48
K_2O	1.32
H_2O	7.14
Total	98.14

No section.

Age. Upper Cambrian. U. S. G.

NO. 810. ANORTHOSYTE.

Two and a half or three miles below Beaver bay.
Ref. Annual Report, x, pages 109, 110; Bulletin vi, pages 126, 421.

Meg. An extremely coarse-grained mass of plagioclase feldspar, frequently showing albite twinning. Compare No. 814, which is coarsely laminated as a rock.

Mic. The section, except for small impurities or products of alteration, is of *plagioclase*, commonly showing broad albite twinning lamellæ. There are some small earthy areas which may represent the alteration products of augite inclusions. *Kaolin* and *chlorite* are present as alteration products, also a little of a brownish mineral in cracks. Cleavage chips of the feldspar parallel to 001 gave extinction angles of 22° and 23°, and those parallel to 010 gave angles of 30° and 32°. These angles indicate *bytownite*.

One section.

Age. Cabotian. U. S. G.

NO. 811. GRANITE.

"From the large red granite island, three or four miles below Beaver bay, which is arched on the lakeward side."
Ref. Annual Report, x, page 110.

Meg. A medium-grained, dark-red granite, composed of red feldspar, quartz and some dark material.

Mic. The section shows one of the usual "red rocks." The minerals are *feldspar*, altered and much reddened, *quartz*, *hematite* and *magnetite*. The quartz and feldspar in places are intergrown in a pegmatitic manner.

One section.

Age. Cabotian. U. S. G.

No. 812. Apobsidian.

Two miles west of the palisades, north shore of lake Superior; S. E. ¼ sec. 32, T. 56–7 W.
Ref. Annual Report, x, page 110.

Meg. A very fine-grained, reddish-gray, homogeneous rock, except for a few small areas, which appear to be feldspars, and some linings which are brought out by weathering. These linings are probably due to some flowage phenomena in the original rock.

Mic. The section is composed essentially of fine-grained *quartz* and *feldspar*. The latter is much altered and the former exists in small, irregularly outlined, poikilitic areas. This rock is undoubtedly a devitrified glass. There are throughout the slide specks of iron ore and of a gray opaque substance.

Age. Cabotian. U. S. G.

No. 813. Aporhyolyte.

Great Palisades, north shore of lake Superior; sec. 22, T. 56–7 W.
Ref. Annual Report, x, page 110.

Meg. This rock is almost identical with No. 140(7).

Two sections.

Age. Cabotian. U. S. G.

No. 814. Anorthosyte.

Two and a half or three miles east of Beaver bay, north shore of lake Superior. Compare No. 694.

"There is one place two and a half or three miles east of Beaver bay, where the 'feldspar rock' is bedded, and dips easterly in all respects like the usual trap of the shore. It here shows also a confused mixture with the trap, in which, in other places, it seems to be (and is) embraced as isolated masses, as at Splitrock point. This bedded condition is very evident in coming from the northeast, as the conspicuous surface slopes in that direction. Narrow dikes of fine-grained, gray doleryte cut the feldspar rock. One dike is six inches wide and one is about nine. They are about parallel, twenty-five feet apart, and run east and west by compass. The feldspar here is very coarsely crystalline, and is represented by No. 810. The alternate beds consist of bands of coarse crystals succeeded by layers of fine crystals, in which are also numerous grains of a more rapidly disintegrating mineral which, by becoming disseminated, stains the whole of a green color. This disintegrating mineral seems to take the place of the augite seen in the gabbro; therefore the 'bedding' is an alternation of gray, coarse feldspar with green, decaying gabbro. No. 814 represents the feldspar stained *with the green-weathering mineral.* The bands of color are from three to six inches, fading into the uncolored, clear feldspar above and below. About twenty feet of this bedded feldspar can be seen here." [N. H. W.]

Ref. Annual Report, x, pages 80, 110, 111, 115; Bulletin ii, page 95; Bulletin vi, pages 126, 421; volume iv, page 302.

Meg. A rock composed of coarse-grained, greenish-gray plagioclase and a much smaller amount of a soft black mineral, probably serpentine.

Mic. The section shows a few large grains of plagioclase abundantly twinned according to the albite law, and with a few pericline twinnings. There is a small amount of greenish and brownish (chlorite and serpentine) alteration products. A cleavage chip of the feldspar parallel to 001 gave an extinction angle of 30°, and one parallel to 010 gave 33°, indicating *bytownite.*

One thick section.

Age. Cabotian. U. S. G.

No. 815. Diabase.

Same place as No. 814. The rock that embraces the anorthosyte masses.
Ref. Annual Report, x, page 111.

Meg. A medium-grained, yellowish-black diabase, showing "lustre-mottling" indistinctly.

Mic. A diabase composed of *plagioclase* laths and augite, the latter frequently in large ophitic areas. There are many greenish-yellow areas (perhaps *bowlingite*) which are thought to represent original olivines; also secondary *chlorite* and some *magnetite*.

One section.

Age. Cabotian. U. S. G.

No. 816. Gabbro.

Beaver Bay. Compare Nos. 532 and 551.
Ref. Annual Report, x, pages 38, 41, 48, 112; Bulletin ii, page 85.*

Meg. There are two hand samples. One is a coarse-grained gabbro composed largely of plagioclase; it is similar to No. 1. The other sample is a medium-grained, almost black rock with a resinous lustre. It is composed of feldspar and olivine more or less altered. These are embraced in the manner of foreign pieces in the trap at Beaver bay.

Mic. The section is made from the second hand sample and shows a *forellenstein*. The rock is composed essentially of *plagioclase* and *olivine*, both minerals being much fissured. The olivine is in general of earlier date than the feldspar, but in places they seem to have crystallized nearly simultaneously. The olivine is altering along the fissures, and in some grains the alteration is complete to a yellow serpentine-like mass. With this alteration of the olivine, considerable magnetite has been developed. The feldspar commonly shows albite twinning, and, aside from the fissuring, has not been altered much. Sections cut approximately normal to 010 show extinction angles up to 31°, and a section nearly normal to $\mathfrak{c}$ gave an extinction angle of 25°. Neither of these determinations was very accurate, as the sections were not cut exactly in the proper directions, but the results would indicate a feldspar near *labradorite*.

One section.

Age. Cabotian. U. S. G.

No. 817. Shale.

Two Harbor bay, north shore of lake Superior.
Ref. Annual Report, x, pages 40, 114, 115. Compare No. 525.

Meg. A gray to pink shale, the pink color being due apparently to laumontite. This rock lies below the Beaver Bay diabase where charged with masses of feldspar.

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*There is some mistake about the description, given on this page, of rock No. 816. We find no section marked 816 to which this description would apply, nor could a section of that nature be made from either of the hand samples marked 816.

Mic. The section shows a rock with a very fine-grained background, which is composed of minute grains of *quartz*, cloudy *feldspar*, *chlorite*, *epidote*, *magnetite* and *hematite*. Throughout the section are larger, more or less angular grains of quartz and feldspar, and also many sub-angular and rounded grains of a colorless mineral. The grains of this mineral are usually stained with hematite along the borders and sometimes the hematite stain and an incipient cloudiness penetrate the grains. This mineral is biaxial, positive, has a double refraction a little weaker than quartz and an index of refraction higher than quartz, although the appearance of a higher index of refraction may be due to the red borders of the grains. The species of this mineral was not determined, but it may be *heulandite*.

One section.

Age. Cabotian. U. S. G.

No. 818. Anorthosyte.

East side of Splitrock point, north shore of lake Superior. One of many pieces embraced in the dark diabase on the east side of the point.

Ref. Annual Report, x, page 115; Bulletin ii, page 95.

Meg. A coarse-grained rock composed almost entirely of plagioclase which is generally gray in color. There are small areas of reddish feldspar and along the weathered surface and joint planes the feldspar is entirely reddened.

Mic. The section shows plagioclase, more or less altered and stained reddish, and some earthy and greenish alteration products.

One poor section.

Age. Cabotian. U. S. G.

No. 819. Diabase *(with olivine)*.

"From the top of the high hill back of Silver creek; the highest hill near the mouth of the creek, yet on the west side, rising 415 feet above the lake, though a mile further back it rises perhaps 150 feet higher."

Ref. Annual Report, x, pages 64, 115, 116; Bulletin ii, page 98.

Meg. A rather coarse-grained diabase of a yellowish-black color.

Mic. M. E. Wadsworth's description of this rock is as follows:*

"Is a grayish-brown rock having a resinous lustre. The section is composed of lath-shaped plagioclases cutting through irregular masses of augite, also olivine grains and magnetite. The *feldspars* are quite clear, but are in places somewhat kaolinized, and contain a viriditic product as well as the remains of inclusions of the globulitic base. Trains of vapor cavities extend in the feldspar and are continued with and through the *augite*. This mineral is quite clear, of a brownish color, and shows its characteristic irregular cleavage.

"The *olivine* is partially inclosed in the augite and is much fissured, with the border of the fissures formed by greenish, yellowish and brownish *serpentine*, which

*Bulletin ii, p. 98.

also borders the grains, and sometimes extends through quite a portion of their mass. The olivine is foreign and possibly the magnetite is the same; but if not, it has been the first mineral to crystallize from the magma followed by the feldspar and lastly by the augite, although the last two were nearly, if not quite, contemporaneous.

"In one portion of the section the twinning of the plagioclase is seen to be dependent upon the pressure exerted by the solidifying augite."

The olivine, in part at least, is of later date than the feldspar. One section.

Age. Cabotian. U. S. G.

Remark. In respect to the comparative dates of the olivine and the other minerals, this rock resembles Nos. 258, 512, 703, 757, 1275 and 1842. The augite is ophitic. N. H. W.

No. 820. Diabase.

From the railroad cut, Taylor's Falls.
Ref. Annual Report, x, pages 106, 116–118; Final Report, vol. i, pages 196–199.

Meg. A tough, heavy, dark-gray rock, with medium grain, not much changed, the weathered surface specked by the weathering out of ophitic pyroxene.

Mic. The rock is considerably altered, but the ophitic relation of the feldspar with the pyroxene is beautifully exhibited. The *feldspars* are in two sizes or dates of origination, the microliths being embraced in the later formed pyroxene. Yet this distinction into two generations is not common. In general the feldspars are of one size, and are considerably altered, giving rise to *calcite*, *muscovite* and *pennine*. Some calcites are large.

The pyroxene grains are so large that, with their included microliths of feldspar, they individually, sometimes, cover the whole field of the microscope (objective No. 3) and embrace from twenty-five to fifty of the small feldspars. In no rock have I seen this structure so well displayed (see photograph figure 12, plate I). The pyroxene is of the form *augite* when not altered to *hornblende.*

The *olivine* grains are small, and doubtless of the first generation, frequently surrounded by magnetite, and so decayed that they have no effect on polarized light, being then greenish.

Leucoxene and *epidote*, with more or less *chlorite*, serve to becloud the section, especially when thick.

Magnetite is quite common, but for the most part is later than the other minerals, prevailing in the neighborhood of the olivine.

Much of the augite, of a date earlier than the large ophitic plages, is surrounded by a faintly yellow border that is apparently due to alteration. It has different orientation from the augite and probably is related to hornblende. Three sections.

Age. Cabotian. N. H. W.

No. 821. Diabase.

Taylor's Falls.
Ref. Annual Report, x, page 116.

Meg. Similar to Nos. 820 and 822, but the ophitic augites have changed to a yellowish-green material. There are also splashes of red color on the specimen.

Mic. Similar to the more altered parts of Nos. 820 and 822. The augite has all disappeared, and the feldspar also is highly altered. One poor section.

Age. Cabotian. U. S. G.

No. 822. Diabase.

Same rock as No. 820, but taken near the surface in order to show the brownish-gray weathered spots which appear on the exposed surface of No. 820.
Ref. Annual Report, x, page 116.

Meg. The rock, No. 820, is flecked with a spotted faint rustiness, the colored spots appearing near the natural surface of the ground, and at the surface. The spots are from a sixteenth to a quarter of an inch in diameter, approximately circular, and appear to be due to the dissemination of iron oxide from some oxidizing mineral having much iron, since at the centres of the spots may be seen frequently a fine powder resembling limonite. At other times the spots are simply a light gray color pervading the grains of the darker gray mass.

Mic. There seems to be no special difference between this rock and No. 820, except that hematite can be seen more abundant in some parts of the slide, and *calcite* is noticeable in large areas.

It is probable that the discoloration, in spots, is due to the action of artificial heat on the surface, for these rocks were formerly covered with a forest which has largely been destroyed by fires. Further, when these spots are near the thin weather-coating, they blend with it, all the minerals acquiring a rustiness. The green spots mentioned in connection with No. 821 are not due to the same cause, but more likely are caused by a deep-seated alteration of some mineral, perhaps pyroxene.

Age. Cabotian. N. H. W.

No. 823. Diabase.

"Pebbles from the conglomerate forming the lower part of the bluff excavated by the railroad where it crosses the highway south of Taylor's Falls."
Ref. Annual Report, x, page 117.

Meg. The pebbles are of the general diabasic rocks of the region; they are considerably decayed and do not show the lustre-mottling common to Nos. 820 to 822, and they are also finer grained than the most of the adjoining rocks.

Mic. The section shows a rock composed of minute irregular laths of *plagioclase* and a mass of alteration products, chief among which are iron ores, *chlorite* and an opaque, gray substance. One section.

Age. Pebbles in the Upper Cambrian. U. S. G.

No. 824. Dolomyte.

Taylor's Falls. The upper portion of the matrix embracing the conglomerate where excavated for the railroad at the highway crossing, southern part of the village.
Ref. Annual Report, x, page 117.

Meg. Completely crystalline, each grain of which is a perfect crystal of rhombohedral habit, containing fossils of Lingulæ and nodules of coarse calcite crystals. Passes upward into regular beds of dolomitic limestone.

Mic. The only substances visible belonging to the rock are the rhombohedral crystals mentioned, of *dolomite* and a few small, scattering, angular grains of *quartz.*

Age. Upper Cambrian. N. H. W.

No. 825. Diabase.

Boulder from the conglomerate. (See Nos. 823 and 824.)
Ref. Annual Report, x, pages 117, 118. Cf., also, C. P. Berkey: "The Geology of the St. Croix Dalles," American Geologist, vol. xx, pages 345–383; vol. xxi, pages 139–155, 270–294. N. H. Winchell: "The Significance of the Fragmental Eruptive Debris at Taylor's Falls, Minnesota," American Geologist, vol. xxii, pages 72–78.

Meg. A considerably altered, rather soft, dark brownish diabasic rock. On one side of the specimen is a coating of impure malachite.

Mic. The section shows a highly altered diabase. The outlines of the lath-shaped *feldspars* can be distinguished in places, but this mineral is highly altered, clouded and kaolinized. Aside from the altered feldspars are iron ore (*magnetite* and *limonite*), *chlorite*, *epidote* and some *quartz.* The whole section is in fact a confused mass of secondary products.

One section.

Age. Boulder in Upper Cambrian. U. S. G.

No. 826. Diabase.

At the top of the hill north from No. 825.
Ref. Annual Report, x, page 118; Bulletin ii, page 119.

Meg. A dark-green, fine-grained, diabasic rock, with considerable epidote.

Mic. M. E. Wadsworth's description of this section is as follows:*

"The section is that of a highly altered diabase, the only portions of its original structure being the remains of the divergent *feldspars* and some apparent opacite pseudomorphs after *olivine.* The rock now is composed of granules and plates of secondary minerals like green *hornblende, chlorite, viridite, epidote, quartz, feldspar,* ferrite, opacite, magnetite, etc. The epidote, in pale yellowish granules, is abundant."

One section.

Age. Cabotian. U. S. G.

**Bulletin ii*, p. 119.

No. 827. Conglomerate.

Taylor's Falls.
Ref. Annual Report, x, page 119.

Meg. A rough, porous conglomerate, gray, yellowish, brownish and greenish in color. It contains pebbles and fragments of decayed diabasic rock, some of which is amygaloidal.

Mic. The section was evidently made from one of the pebbles. It shows a decayed, fine-grained, diabasic rock in general similar to No. 823.

One section.

Age. Upper Cambrian. U. S. G.

No. 828. Conglomerate.

Taylor's Falls.
Ref. Annual Report, x, page 119.

Meg. The matrix of the specimen is porous, is brownish in color, containing considerable iron oxide, and is largely composed of quartz. Pebbles, of all sizes up to an inch across, are common. They are sub-rounded or rounded. They consist of various materials, among which are quartz, fine-grained, diabasic rock, quartzyte and shale.

Mic. The matrix is of rounded and sub-rounded grains of *quartz*, with more or less confused opaque materials. The pebbles are of indefinite character, being mostly masses of nearly opaque materials.

One section.

Age. Upper Cambrian. U. S. G.

No. 829. Conglomerate.

On the St. Croix river, a mile and a half below Franconia.
Ref. Annual Report, x, page 120.

Meg. The specimen shows a coarse conglomerate, the pebbles being greenish-gray in color and apparently formed of much decayed basic Keweenawan igneous rocks. The matrix of the conglomerate is fine grained, brown in color, and holds numerous fragments of *Lingula* shells.

Mic. The section is small and is much stained and impregnated by *hematite*. Besides the hematite it consists largely of what appear to be much altered, nearly isotropic *feldspar* laths. In addition there are some very minute, brightly polarizing grains (epidote?). The section appears to be that of a highly altered diabase.

One section.

Age. Upper Cambrian. U. S. G.

No. 830. Shale. *(Soft.)*

Sioux Falls, South Dakota.
Ref. Annual Report, x, page 120.

Meg. A soft, fine-grained, pinkish to white or brown shale (also said to be at times of a pea-green color). It is easily scratched with the finger nail. It shows numerous small, silver-like, micaceous scales. In a closed tube the rock on heating gives off water.

Mic. The section is composed of three essential parts: (1) A few, usually angular, *quartz* grains; (2) Much very fine, indistinct earthy matter; (3) A fibrous and flaky mineral. This mineral has the general appearance of *muscovite*, but not the double refraction. There is a good cleavage and the extinction is parallel, or nearly so, on this cleavage. Cleavage flakes show a bisectrix nearly perpendicular to the cleavage; optic angle small, but distinctly biaxial; the mineral is optically negative. It occurs also in fan-shaped or almost vermicular forms, and here the fibrous or flaky character is distinct. The elongation is always positive. The double refraction is apparently a little less than that of quartz. The species of the mineral was not determined certainly, but it seems to agree best with *kaolinite.*

One section.

Age. Potsdam. U. S. G.

No. 831. Quartzyte. *(Spotted.)*

Sioux Falls, South Dakota.
Ref. Annual Report, x, pages 120, 121.

Meg. A fine-grained, brown quartzyte, containing somewhat irregularly outlined spots of a flesh color. These spots vary from about one-sixteenth to one-fourth inch across.

Mic. The section is composed essentially of small, sub-angular, closely-packed quartz grains in a sparse cement of red iron oxide. The spots seem to be due to areas in which the red cement is lacking.

One section.

Age. Potsdam. U. S. G.

No. 832. Quartzyte. *(Red.)*

From Redstone, near New Ulm.
Ref. Annual Report, x, page 121.

Meg. A fine-grained, red quartzyte. There are a few small spots of lighter color in the rock.

Mic. The section shows many sub-angular and rounded *quartz* grains and a large amount of red and black iron oxide. There are also a number of grains, probably originally *feldspar*, which are now clouded and stained red or are largely made up of small kaolinic flakes. These small flakes are also quite common between the quartz grains. Some of the quartzes show enlargements. One section.

Age. Potsdam. U. S. G.

No. 833. Shale. *(Red and sandy.)*

The lowest rock seen in the railroad cut at Redstone, near New Ulm.
Ref. Annual Report, x, page 121.

Meg. A fine-grained, red, sandy shale; an impure sandstone.

Mic. The section shows a rock in general similar to No. 832, but with less quartz and a much larger amount of red iron oxide.

One section.

Age. Potsdam. U. S. G.

No. 834. Quartzyte. *(Red.)*

"Slab of red quartzyte from Sioux Falls, showing the finely pitted exterior of the individual sand grains on the removal of the white schist, No. 830."
Ref. Annual Report, x, page 121.

Meg. No hand specimen found.

No section.

Age. Potsdam. U. S. G.

No. 835. Granite. *(Coarse-grained.)*

From the quarries at East St. Cloud.
Ref. Annual Report, x, pages 107, 121, 122; Final Report, vol. i, pages 196–199.

Meg. A coarse-grained, gray to yellowish-gray granite, composed of feldspar, quartz, hornblende and biotite.

Mic. The section shows *feldspar*, *quartz*, dark, brownish-green, almost opaque *hornblende* and *biotite*. The feldspar and quartz, especially the former, are in large and also in small grains, the two interlocking closely, and the large grains do not show their crystal form. The feldspar, while not carefully studied, still appears to be of four varieties: (1) Clouded, untwinned *orthoclase;* (2) *Perthite* in large grains; (3) Very finely twinned *anorthoclase*; (4) *Plagioclase* near *oligoclase*. One section.

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

SiO_2	74.72
Al_2O_3	12.30
Fe_2O_3 and FeO	3.19
CaO	1.51
MgO	.25
K_2O	2.25
Na_2O	1.91
Total	96.13

Age. Archean. U. S. G.

No. 836. Quartzyte. *(Pink.)*

"No. 836, the pink quartzyte known as the 'jasper rock' locally, from Sioux Falls, Dakota. This is a pinkish granular quartzyte, but with a cement that, on disintegration, allows the rock to become a white sand."
Ref. Annual Report, x, page 122.

Meg. A fine-grained, compact, pinkish quartzyte. Along cracks a soft, earthy, white material occurs in small quantity.

Mic. The section is too thick for study. The rock is made up of water-worn quartz grains which frequently are enlarged. Between the grains there is some dust-like red (hematite) and gray material.

One section.

Age. Potsdam. U. S. G.

No. 837. Sandstone. *(Red.)*

Fragments from 205 feet below the surface; from the deep well at the Washburn C mill, Minneapolis.
Ref. Annual Report, xiii, page 39. This is evidently No. 16 of the section given at pages 280, 281, of volume ii of the Final Report.

Meg. A medium-grained, red sandstone.

Mic. The section shows well rounded quartz grains in a rather abundant cement of *calcite* and *red iron oxide.*

One section.

Age. Near the bottom of the St. Peter sandstone. U. S. G.

No. 838. Quartzyte. *(Red.)*

Redstone, near New Ulm.
Ref. Annual Report, xiii, page 39.

Meg. A rock of rather fine grain and brick-red color. Numerous quartz grains occur embedded in a copious red, very fine-grained cement.

Mic. There are rounded and sub-rounded *quartz* grains and some clouded, altered *feldspars* in a matrix which is abundant and is composed of fine flakes of micaceous material. These flakes appear to be both *muscovite* and *kaolinite.* The quartz grains are surrounded by a narrow rim of red iron oxide, and in the matrix are also areas outlined by iron oxide, thus suggesting that some part of that which now seems to act as the matrix of the rock was originally feldspar grains. One section.

Age. Potsdam. U. S. G.

No. 839. Granite *(with augite).*

Sauk Rapids.
Ref. Annual Report, xiii, page 39. Same as Museum No. 4466 (Annual Report, x, page 167).

Meg. A medium-grained gray granite, composed of white to flesh-colored feldspar, quartz, hornblende and biotite.

Mic. The section shows a granitic aggregate, composed essentially of *feldspar, quartz, hornblende* and *biotite.* The feldspar is more or less clouded and consists of orthoclase and a minutely twinned plagioclase. The hornblende is green and seems to be, in part, if not in whole, derived from augite. In the centers of some of the hornblendes a little augite still remains. *Magnetite,* brown *sphene,* which is pleochroic, and *apatite* are also present. One section.

Age. Archean. U. S. G.

No. 840. Granite. (*Hornblendic.*)

East St. Cloud.
Ref. Annual Report, xiii, page 39. Same as Museum No. 2128 (Annual Report, vii, page 51).

Meg. Very similar to No. 839.

Mic. The section, which is quite thick, shows a granite, composed of clouded *feldspar*, *quartz*, green *hornblende* and *biotite*. One section.

Age. Archean. U. S. G.

No. 841. Granite. (*Hornblendic.*)

Near (north of) Motley.
Ref. Annual Report, xiii, page 39. Same as Museum No. 2596.

Meg. A medium-grained, gray granite, composed of quartz, greenish to pinkish feldspar and hornblende.

Mic. The section shows a granite, composed of much clouded *feldspar*, *quartz* and *hornblende*. Some *epidote* and *chlorite* are also present. The sections are much too thick for study. Two sections.

Age. Archean. U. S. G.

No. 842. Epidosyte (?)

From sections 17 and 18, Ashley, Stearns county.
Ref. Annual Report, xiii, page 39. Same as Museum No. 4499 (Annual Report, x, page 168).

Meg. A medium-grained, greenish, granitic rock, composed of feldspar and epidote.

Mic. The section shows a rock of rather coarse grain, composed essentially of *feldspar* and *epidote*. The feldspar is in large allotriomorphic grains which sometimes show polysynthetic twinnings. The mineral is optically positive and a section closely perpendicular to the acute bisectrix gave an extinction angle of 19° to 20°. A test with hydrofluosilicic acid showed the presence of a large amount of soda and practically no potash and lime. The feldspar is thus *albite*. The epidote is yellow and pleochroic; it exists in grains smaller than the feldspars, and frequently minute grains occur in the feldspar. Two sections.

Age. Archean. U. S. G.

No. 843. Diabase.

From a dike in the Motley granite.
Ref. Annual Report, xiii, page 39; Bulletin ii, page 116. Same as Museum No. 2593.

Meg. A rather coarse-grained diabase.

Mic. The section shows an ordinary diabase. The feldspar is *plagioclase* (species not determined) and is in places considerably altered. The *augite* is largely altered to *hornblende*, *chlorite* and dust-like material. Iron ore, probably *ilmenite*, is present, and there is some secondary *quartz*. Two sections.

Age. Dike cutting Archean rocks. U. S. G.

No. 844. Porphyryte.

From a dike in the Motley granite.
Ref. Annual Report, xiii, page 39. Same as Museum No. 2595.

Meg. A fine-grained, green rock, looking like some of the more massive greenstones of the Archean.

Mic. The section is composed largely of fine-grained, green *hornblende* and small *plagioclase* laths. The plagioclase also occurs in laths of a size three or four times that of the general grain of the rock. There are some rounded areas which seem to represent some original ferromagnesian phenocrysts now largely altered to hornblende. This was perhaps hypersthene.

One section.

Age. Dike cutting Archean rocks. U. S. G.

No. 845. Andesyte.

From a dike in the granite at Sauk Rapids.
Ref. Annual Report, xiii, page 39. Same as Museum No. 2122.

Meg. Hand specimen not found.

Mic. The section shows plagioclase laths, small, but of varying sizes, embedded in an almost opaque groundmass. Where the slide is thin this groundmass is of a yellowish color and under a high power and crossed nicols breaks up into an aggregate of minute particles. The nature of these particles is not clear. The groundmass probably was originally glassy and is now devitrified. Scattered through the section are the remains of some old phenocrysts which show embayments of the groundmass. These phenocrysts are now completely altered and their place is filled with an indistinct, fine-grained aggregate consisting largely of flakes of muscovite and chlorite and minute grains of magnetite. One thick section.

Age. Dike cutting Archean rocks. U. S. G.

No. 846. Andesyte (?)

"Amygdaloidal dike rock, Maine Prairie."
Ref. Annual Report, xiii, page 39. Same as Museum No. 2123 (Annual Report, vii, page 51).

Meg. Hand specimen not found.

Mic. The section shows a groundmass which is quite fine grained. It is composed of feldspar, green hornblende and biotite. The feldspar is largely plagioclase in the form of imperfect laths. Throughout the section are a few more or less rounded phenocrysts of plagioclase and of quartz, and there is one large area of considerable size, composed of a number of feldspar grains. The rounded nature of the phenocrysts probably caused the rock to be called an amygdaloid, but the slide does not show conclusively that it is an amygdaloid. One section.

Age. Dike cutting Archean rocks. U. S. G.

No. 847. Slate.

Little Falls.
Ref. Annual Report, xiii, page 39. Same as Museum No. 2681 (Annual Report, vii, page 78).

Meg. A fine-grained, dark gray slate, having the slaty cleavage at a considerable angle with the bedding. Scattered porphyritically through the rock are small glistening flakes of some mineral whose species was not determined.

No section.

Age. Upper Keewatin(?) U. S. G.

Remark. Later a section was made of this rock and the glistening flakes were immediately seen to be biotite. It had been, owing to its manner of occurrence, taken for ottrelite, but it is optically negative. N. H. W.

No. 848. Mica Schist.

Little Falls.
Ref. Annual Report, xiii, page 39. Same as Museum No. 2690 (Annual Report, vii, p. 78).

Meg. A fine-grained mica schist, apparently composed essentially of quartz and biotite.

Mic. The rock is composed of a fine-grained, granular aggregate of *quartz*, *feldspar* and *biotite*, with a little *magnetite*. The rock might be called a granulyte. The feldspar is clear, untwinned, and very rarely shows cleavage. It is easily confounded with quartz, but in converged polarized light its biaxial character is distinct. It is optically positive and has a lower index of refraction than quartz. It is quite likely *albite* or *cordierite*.

Two sections.

Age. Upper Keewatin(?) U. S. G.

No. 849. Mica Schist. *(Staurolitic.)*

Pike Rapids, Morrison county, near the mouth of Swan river.
Ref. Annual Report, xiii, page 39. Same as Museum No. 2689 (Annual Report, vii, page 78).

Meg. A mica schist of medium grain, composed of biotite and quartz and also probably feldspar. There are a number of staurolite crystals, about an inch long, scattered through the rock, and there are also small red garnets not larger than a pin's head.

Mic. The section was evidently made from one of the *staurolite* crystals, and is thickly strewn with small grains of *quartz* (and perhaps also feldspar); it contains also a few grains of *magnetite* and *garnet*. The section is quite thick and the pleochroism of the staurolite is very marked; the color varies from a light yellow (almost colorless) to a deep brownish yellow.

One section.

Age. Upper Keewatin(?) U. S. G.

No. 850. Aporhyolyte (?)

"Fine, crypto-crystalline form of the red rock at Duluth; of a reddish-brown color; the same as No. 42, but fresher, and less granular."
Ref. Annual Report, xii, page 40.

Meg. A fine-grained, brownish-red rock, containing some small, red, porphyritic feldspars and areas of a dark mineral.

Mic. The section shows a groundmass of red color, which under crossed nicols breaks up into the "patchy" areas so characteristic of these devitrified red rocks. The patchy nature is due to areas of poikilitic *quartz*, which are full of small grains of much altered and reddened *feldspar*. *Magnetite* is common and there is also some *chlorite*. There are a few small porphyritic feldspars, usually considerably altered. Some of these are of *plagioclase*. A few small quartz grains also occur. One section.

Age. Cabotian.

Remark. This rock is similar to Nos. 42 and 45. These rocks are called aporhyolytes, but at the same time it is seen that they may be of a more basic nature than are the rhyolytes. U. S. G.

No. 851. Granite.

Courtland, Nicollet county, opposite New Ulm.
Ref. Annual Report, xiii, page 40.

Meg. A coarse-grained granite, composed of much reddish feldspar, less quartz, and some black mineral, which now seems to be largely chlorite. There are a few large, red, porphyritic feldspars.

Mic. The section is very thick, and is made up largely of *feldspar* much stained by *hematite*. The feldspar appears to be *orthoclase*, *microcline* and acid *plagioclase*. Some *chlorite* is present, as is also *ilmenite* largely altered to gray *leucoxene*.

One section.

Age. Archean. U. S. G.

No. 852. Conglomerate.

Courtland, Nicollet county, opposite New Ulm.
Ref. Annual Report, xiii, page 40.

Meg. A rough, coarse-grained, quartz conglomerate with a red cement.

Mic. The section is composed mainly of quartz pebbles in a sparse *hematite* cement. The *quartz* is full of dust-like inclusions. Some of the quartz pebbles are made up of several grains which show undulatory extinction and even granulation.

One thick section.

Age. Potsdam. U. S. G.

No. 852A. Taconyte.

Pebble from No. 852.
Ref. Annual Report, xiii, page 40.

Meg. A reddish, compact rock, resembling a very fine-grained quartzyte.

Mic. In ordinary light the slide presents a reddish appearance, due to finely disseminated *hematite* dust. Frequently small roundish granules are seen more or less distinctly outlined. These granules are the common feature of taconytes. Under crossed nicols the rock is seen to be composed mainly of very fine-grained *quartz*, both in and around the granules. So the granules are not so distinct under crossed nicols, although some of them can be seen, owing to an occasional variation in fineness of grain. A little *magnetite* is present.

One section.

Age. Pebble in Potsdam conglomerate. U. S. G.

No. 852B. Taconyte.

Pebble in No. 852.
Ref. Annual Report, xiii, page 40; American Geologist, vol. xvi, page 157, figure 2.

Meg. A red taconyte pebble, composed of red granules, usually smaller than a pin's head, in a matrix which is very fine grained, almost glassy.

Mic. The slide shows granules, composed of *hematite* and fine-grained *quartz*, in a matrix of fine-grained quartz. The accompanying figure, magnified about thirty diameters, shows the nature of this rock. In the figure the black represents hematite, and the white, both in and between the granules, represents very fine-grained quartz.

One section.

Age. Pebble in Potsdam conglomerate. U. S. G.

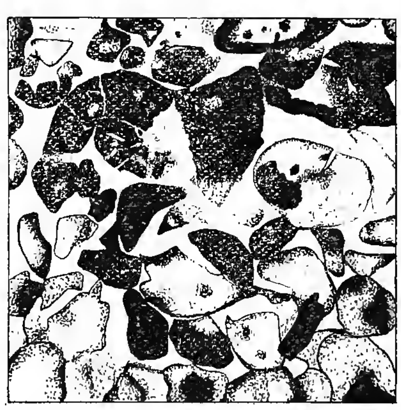

FIG. 32. TACONYTE IN NO. 852B.

FIG. 33. TACONYTE IN NO. 852C.

No. 852C. Taconyte.

Pebble in No. 852.
Ref. Annual Report, xiii, page 40; American Geologist, vol. xvi, page 157, figure 3.

Meg. A reddish rock, appearing like a fine-grained, impure quartzyte. Considerable hematite is present.

Mic. This rock is in general similar to No. 852B, and is shown in the accompanying figure, magnified about thirty diameters. The black represents *hematite*, and the white, both in and between the granules, represents very fine-grained *quartz*.

One section.

Age. Pebble in Potsdam conglomerate. U. S. G.

No. 852D. Taconyte.

Pebble in No. 852.
Ref. Annual Report, xiii, page 40.

Meg. Similar to the last. One of the pieces of this number has two reddish pebble-like forms of finer grain than the rest of the rock.

Mic. The section is composed of *quartz* and *hematite*, in fine grains. There are areas which somewhat resemble the granules of taconyte, although they are not as well defined as in Nos. 852B and 852C.

One section.

Age. Pebble in Potsdam conglomerate. U. S. G.

No. 852E. Quartzyte.

Pebbles in No. 852.
Ref. Annual Report, xiii, page 40.

Meg. Pebbles of vein quartz and of gray to reddish quartzyte, the latter being the larger.

Mic. The section shows a medium-grained quartzyte, composed of well rounded grains of quartz many of which show enlargements.

One section.

Age. Pebbles in Potsdam conglomerate. U. S. G.

No. 852F. Taconyte.

Pebbles in No. 852.
Ref. Annual Report, xiii, page 40.

Meg. Reddish, granular taconyte and some flinty taconyte.

Mic. The section shows the usual granular taconyte, the granules being composed largely of hematite.

One section.

Age. Pebbles in Potsdam conglomerate. U. S. G.

No. 853. Syenyte.

Mannheim's silver mine, Duluth, near Rice's point.
Ref. Annual Report, xiii, page 40.

Meg. A rather fine-grained, reddish, granitic rock, composed largely of feldspar. There is some pyrite and some soft, dark mineral present. Vein calcite also occurs.

Mic. The section is composed essentially of *feldspar*. This is much clouded and to some extent reddened by dust-like *hematite* inclusions. Some of it appears to be *orthoclase* and some is *plagioclase*. The plagioclase shows equal extinction angles up to about 13°; it is optically negative, and sections cut almost perpendicular to the obtuse bisectrix give extinction angles of 73° and 77°. The feldspar is thus a basic *oligoclase*. *Pyrite*, *calcite* and *green chloritic* material are present in small amounts. One section.

Age. Cabotian. U. S. G.

NO. 853A. CALCITE AND LAUMONTITE.

From a vein at Mannheim's silver mine, Duluth.
Ref. Annual Report, xiii, page 40.

Meg. Calcite and pink laumontite. The latter is in needle-like forms in a finer matrix of apparently the same mineral.

Mic. The slide is composed essentially of *laumontite*. Some *calcite* and green chloritic material are also present.

One section.

Age. Vein in Cabotian rocks. U. S. G.

NO. 853B. CALCITE.

From a vein at Mannheim's silver mine, Duluth.
Ref. Annual Report, xiii, page 40.

Meg. Rhombs of white calcite.

No section.

Age. Vein in Cabotian rocks. U. S. G.

NO. 854. DIABASE.

Taylor's Falls. Compare Nos. 797, 820–822.
Ref. Annual Report, xiii, page 40; Bulletin ii, page 114.

Meg. A fine-grained, greenish diabase showing "lustre-mottling."

Mic. M. E. Wadsworth's description of this slide is as follows:* "The thin section is similar to No. 797, but it has suffered further alterations. In the section are light green spots surrounded by a darker, greenish-brown groundmass. The light green spots are formed by *augite* individuals dissected and generally with the component parts entirely separated by the altered *plagioclase* and viridite. Sometimes these augite masses show in polarized light that they are composed of two or more individuals. The groundmass is mainly composed of *chlorite*, viridite, *epidote*, *feldspar*, *ferrite*, *opacite*, and some pseudomorphs, apparently after olivine."

One section.

Age. Cabotian.

**Bulletin ii*, p. 114.

Remark. This rock was stated when collected to contain metallic copper in minute particles. The small hand specimen at hand does not show these particles of copper, as oxidation since the specimen was collected has quite likely obscured them, and they do not seem to be present in the slide. U. S. G.

No. 855. Graywacke.

"Dark concretions from the slates at Thomson, thought by Hunt and Dawson to contain a keratose sponge."
Ref. Annual Report, xiii, page 40.

Meg. A fine-grained graywacke in which is part of a coarser-grained, softer, rusty-weathering mass.

Mic. The section was evidently made from the graywacke and shows small, more or less angular grains of *quartz* and *feldspar* in a greenish cement. Under a high power this cement is seen to be composed essentially of *chlorite*, *quartz* and minute *muscovite* scales.

One section.

Age. Animikie.

Remark. Compare Nos. 1607, 1609 and 1611. U. S. G.

No. 856. Laumontite.

Vein in Gabbro at Rice's point, Duluth.
Ref. Annual Report, xiii, page 40.

Meg. The vein is composed mainly of fine-grained red laumontite. There is a little greenish soft material also present. Piercing the fine-grained laumontite are small colorless needles, and similar needles exist in radiating bunches on the side of the vein.

Mic. The section shows the colorless needles, which appear to be *laumontite* embedded in a fine-grain red mass, apparently consisting of small grains of the same mineral.

One section.

Aeg. Vein in Cabotian rocks. U. S. G.

No. 857. Sandstone and Shale.

Fond du Lac.
Ref. Annual Report, xiii, page 40.

Meg. The specimen consists of soft red shale and gray sandstone intimately intermingled in a breccia or conglomerate, the sandstone acting as the matrix. The shale occurs as fragments, large and small, and as interrupted bands in the sandstone. In the sandstone are also a few pieces of a greenish-gray shale and in the red shale are spots of a color similar to the greenish-gray shale in the sandstone.

Mic. The section is made from the sandstone, but includes small pieces of the shale, which is dense and red. The section is too thick for careful study, but it shows more or less angular pieces of *quartz* and of *feldspar* in a gray, clouded matrix, which appears to be, in part at least, composed of *calcite*.

One section.

Age. Potsdam. U. S. G.

NO. 858. GRANITE.

"Average sample of the red syenyte (micaceous) at Sauk Centre, quarry of T. Carl."
Ref. Annual Report, xiii, pages 13, 40.

Meg. A medium-grained, reddish-gray granite, composed of feldspar, quartz and apparently biotite. Scattered through the specimen are some larger, sub-porphyritic crystals of white feldspar, the main feldspar of the rock being reddish.

Mic. The slides show a granite, composed essentially of *feldspar* and a smaller amount of *quartz*. The following other minerals are present in small amounts: *chlorite*, *biotite*, *magnetite*, *pyrite*, *apatite* and *epidote*. The feldspar is much clouded by alteration products and appears to be largely *orthoclase* with some acid plagioclase and a little *microcline*. Two sections.

Age. Archean. U. S. G.

NO. 859. GNEISS.

"Average sample of the hard, dark schist, or gneiss, Sauk Centre, quarry of T. Carl."
Ref. Annual Report, xiii, pages 13, 40.

Meg. A medium-grained, dark, banded gneiss, composed of hornblende, quartz and feldspar.

Mic. The section shows a granitic aggregate of *quartz* and much clouded *feldspar* with more or less green *hornblende*, *chlorite*, *magnetite*, *biotite*, *epidote* and *sphene*. One poor section.

Age. Archean. U. S. G.

NO. 860. GNEISS.

"Sample of the schist showing considerable mica, Sauk Centre."
Ref. Annual Report, xiii, pages 13, 40.

Meg. A banded gneiss composed of hornblende, quartz and feldspar, with much rusty biotite along the cleavage planes.

Mic. The section is composed essentially of *quartz* (in great abundance), much clouded *feldspar*, green to blue-green *hornblende* and *chlorite*. One section.

Age. Archean. U. S. G.

NO. 861. DIORYTE.

"Average sample of the massive dioryte, Sauk Centre."
Ref. Annual Report, xiii, pages 13, 40. The same rock is described in Annual Report, xi, pages 72–74, 104.

Meg. A dark-gray, medium-grained, granitic rock composed essentially of hornblende and feldspar.

Mic. The section shows a quartz dioryte in which the following minerals are in considerable amounts: *feldspar*, *hornblende*, *quartz* and *iron ore*. The feldspar is much altered (saussuritized) and its species cannot be determined, although it is quite clearly a *plagioclase*. As a product of the alteration much *zoisite* has been developed, giving the feldspar a clouded appearance when examined under a low power; but with a higher power the cloudiness is seen to be largely due to the presence of numerous small grains of zoisite. The hornblende is brown and also green. The *brown hornblende* may be in part original, while the green is clearly secondary, most probably after augite, though no distinct augite was seen remaining. *Quartz* is common. The iron ore, as shown by its alteration to gray *leucoxene*, is *ilmenite;* it is common. In addition to these minerals there are also present *chlorite*, *epidote*, *pyrite* and *apatite*.

Two sections.

Chemical analysis. An analysis of dioryte, apparently from the same outcrop as No. 861 and closely similar to this number, is given by Streng and Kloos* as follows:

SiO_2	56.59
Al_2O_3	12.41
Fe_2O_3	5.39
FeO	10.28
CaO	6.70
MgO	2.02
K_2O	1.02
Na_2O	4.27
H_2O	1.45
CO_2	trace
Total	100.13
P_2O_5	.44
TiO_2	.22

Age. Archean.

Remark. This rock may have been originally a gabbro with or without brown hornblende and quartz. U. S. G.

No. 862. Quartzyte.

"Pinkish, white quartzyte, Garden Valley, seven miles from Merrillan, Jackson county, Wisconsin; probably shows Irving's 'deposited quartz.' It is also probably from this that Whitfield's *Palæacmæa irvingi* was obtained. (See vol. iv, page 173, Geology of Wisconsin.)"

Ref. Annual Report, xiii, page 40.

Meg. A white to pinkish, fine-grained, vitreous [granular] quartzyte. The fracture is nearly conchoidal.

Mic. The section shows a distinctly granular quartzyte, which is composed of closely crowded, usually well rounded grains of *quartz*. Surrounding each grain and forming a part of the cement of the rock, is a small amount of a yellowish substance, which, in reflected light, is white. A thin coating of this material exists

**Eleventh Annual Report*, pp. 73, 74.

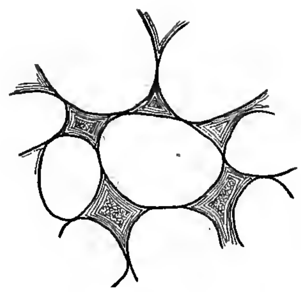
FIG. 34.

around each grain, except where one grain comes directly in contact with another. Under a low power this cementing substance appears homogeneous and isotropic. Under a high power each grain is seen to be surrounded by one or more bands of chalcedony, and sometimes in the interstices between the grains, and thus surrounded by the chalcedony is very minutely crystallized quartz. The general appearance of the rock is shown in the accompanying figure. Whether the chalcedonic bands are distinctly fibrous or not cannot be readily told from the section at hand, as it is too thick and the chalcedonic bands overlap the quartz grains; thus the structure of the bands as seen in polarized light is not clear. Between the grains is at times a little iron oxide, apparently both *limonite* and *hematite*.

One section.

Age. Middle Cambrian, perhaps of the age of the Puckwunge. U. S. G.

Remark. On having made a better section the chalcedonic envelope of the grains is seen to be fibrously crystallized and to have a negative elongation, the fibres standing vertical on the peripheries of the grains. N. H. W.

NO. 863. SANDSTONE.

"St. Peter sandstone, from the small island in the Minnesota bottom-lands near Fort Snelling, cemented with iron and ('deposited'?) silica, so as to be hard and show different colors."
Ref. Annual Report, xiii, page 40.

Meg. A medium-grained sandstone, which varies from red to yellow in color. Some of the quartz grains show the development of crystal faces. On what appears to be the outside of the specimens, or the side exposed to the weather, the rock is a vitreous quartzyte rather than a somewhat friable sandstone.

Mic. The section shows well rounded *quartz* grains in a cement of *limonite*. Some of the quartzes show enlargements.

One section.

Age. St. Peter. U. S. G.

NO. 864. SCHIST. *(Black.)*

South side of Jones bay, Vermilion lake; N. E. ¼ sec. 3, T. 61-16 W.
Ref. Annual Report, xv, pages 276, 386; Bulletin ii, pages 45, 421.

Meg. A hard, fine-grained, almost black, glistening, schistose rock. It contains small particles, usually no larger than a pin's head, which are common, and would make the term "Knotenschiefer" applicable to this rock.

Mic. The sections show a schistose rock of fine grain, the schistose structure being due to a more or less marked elongation of the component grains in one direction. Scattered all through the rock, both in and between the mineral grains, is a large amount of a black, dust-like material, which may be carbonaceous matter. *Quartz* makes up the bulk of the rock. *Calcite, chlorite* and *muscovite* flakes are also common. The "knots" are due to a colorless mineral which includes little of the black, dust-like material. In the description of this rock in Bulletin ii this colorless mineral is spoken of as *chiastolite;* but it does not seem to have a high enough index of refraction or a strong enough double refraction for chiastolite. Moreover, it was found to be optically negative instead of positive. Its species was not determined, but it may be some form of feldspar. In it small *muscovite* flakes have developed and also numerous minute grains which are perhaps *zoisite.*

Two sections.

Age. Keewatin. U. S. G.

No. 865. Quartzyte.

Point in Vermilion lake near S. W. ¼ sec. 34, T. 62–16 W.
Ref. Annual Report, xv, pages 278, 386.

Meg. A fine-grained, light, brownish-gray, somewhat schistose rock containing some fine micaceous scales.

Mic. The section shows a rock composed largely of a fine-grained mosaic of quartz. With the *quartz* are numerous small flakes of *muscovite* and *chlorite.* The arrangement of these flakes gives the schistose structure to the rock. There are a number of feldspar grains of irregular outline and of larger size than the usual quartz grains. These are considerably clouded by the development of minute muscovite, and perhaps also kaolinite flakes.

One section.

Age. Keewatin. U. S. G.

No. 866. Jaspilyte.

Jasper ridge, Tower; sec. 29, T. 62–15 W.
Ref. Annual Report, xv, pages 264, 266, 386; Bulletin vi, pages 79, 421.

Meg. The usual banded, red, white and black jaspilyte. The bands vary from a sixteenth of an inch to two inches in width, and some of the red bands are very finely laminated by red and gray colors. The black bands are the narrowest and are composed essentially of magnetite. The white bands are of finely crystallized quartz and the red bands of quartz and hematite.

Mic. The section is composed of a very fine-grained mosaic of *quartz,* with which is much *hematite.* The latter is commonly in more or less rounded grains which vary from minute, dust-like particles to those nearly the size of the quartz grains. The hematite occurs both between and in the quartz grains. A few scattered grains of *magnetite* occur throughout the rock. The finely-laminated nature of the red bands is due to a concentration of hematite along certain parallel lines, but this concentration is more noticeable when the slide is examined with a low power than with a high one. The bands of magnetite, mentioned in the description of the hand sample, are seen to be sponge-like bands of this mineral holding some quartz and a little hematite. (See the description of No. 867.)

Three sections.

Age. Lower Keewatin. U. S. G.

No. 866A. Quartzyte. *(Ferruginous.)*

From nodules embraced in No. 866.
Ref. Annual Report, xv, pages 265, 266, 386; Annual Report, xvi, page 65.

Meg. A medium-grained rock, bright red, dull red and gray black in color, the latter color being due to a considerable amount of specular hematite.

Mic. The section shows a rock composed of interlocking grains of quartz which is more or less completely saturated with other material. This material can be divided into three principal groups: (1) Blood-red hematite scales and grains; (2) Magnetite grains, not very abundant; and (3) A yellowish to brownish, somewhat earthy substance. The last is very abundant and exists in irregular areas and also collected into arborescent forms, which at times assume the aspect of branching sea weeds. This substance seems to have no effect on polarized light. Just what it is, is not clear.

One thick section.

Age. Lower Keewatin.

Remark. The bright red parts of the hand specimen resemble No. 2279.

U. S. G.

No. 866B. Jaspilyte.

Near the same place as No. 866.
Ref. Annual Report, xv, pages 265, 266, 386; Annual Report, xviii, page 34.

Meg. A light-gray to dark-gray, finely laminated jaspilyte. Some porous bands of limonite are present.

Mic. The section shows the usual mosaic of quartz grains. Thickly scattered through the slide is black, opaque, dust-like material. This is probably in large part *magnetite*, as the powdered rock yields a number of particles to the magnet. There is also considerable *limonite* present.

One section.

Age. Lower Keewatin. U. S. G.

No. 867. Jaspilyte.

Near the same place as No. 866.
Ref. Annual Report, xv, pages 265, 266, 386; Bulletin ii, pages 10, 72–79, 81, 421, plate VII, and figure 1 of plate VIII.

Meg. The usual red, white and black, banded jaspilyte. The white bands are of quartz in fine grains, the black of hematite with a little magnetite, and the red of quartz and hematite.

Mic. The sections show the typical jaspilyte, composed of *quartz*, *hematite* and some *magnetite.* The quartz is a little coarser grained than in the usual jaspilyte and has a tendency to a common hexagonal outline. The grains of quartz are pretty uniform in size, averaging about .05 millimetre, and the extremes are about one-half and one and a half times as large as the average.

Four sections.

Remarks. In the description of this rock in Bulletin vi, the silica was regarded as not completely crystalline or partly amorphous. That the silica is ordinary quartz in small grains is clear and has been so stated by several, including C. R. Van Hise,* J. E. Spurr† and the writer. U. S. G.

No. 868. Greenwacke.

From a low ridge southeast of the main jasper ridge, N. W. ¼ N. E. ¼ sec. 32, T. 62-15, northwest from Tower.

Ref. Annual Report, xv, pages 266-268, 387, 389; Annual Report, xvii, pages 194, 215; Bulletin vi, pages 25, 42, 43, 68, 421.

Meg. The rock is fine grained and nondescript. It evidently has been sheared and altered much. Its color is light gray, but in many places it is brown with iron oxide, and has visible pyrite crystals.

Mic. The rock is much chloritized, having a fibrosity due to the elongation of the minerals prevailingly in one direction. This is quite conspicuous in the section. Besides *chlorite*, *muscovite* is also present in considerable amount. *Calcite* is shown by its high polarization and black cross in convergent light. It is quite abundant and in large areas. *Quartz*, frequently embracing a considerable amount of the other minerals poikilitically, is secondary and quite abundant. A plagioclase feldspar is also common, but it is completely obscured by the growth of minute crystalliths which fill its area. *Zoisite* is in small isolated grains, scattered everywhere. The rock is difficult to characterize because of the extreme alteration. It was originally probably a debris of eruptive materials, mainly basic. Occasional lighter areas, in natural light, show the forms of large feldspars. Small flakes of a cherry-red to brownish-red and opaque mineral, indicating a ferruginous product of change, may be *hematite.* *Zoisite* and epidote grains show as globules or short, blunt rods, the former having no color between crossed nicols, white and colorless in natural light, and of high refractive index.

Five sections examined.

Age. Keewatin. N. H. W.

**Annual Report Arkansas Geological Survey*, 1890, vol. iii, p. 184.

†*Bulletin x*, p. 222.

No. 868A. Greenwacke.

From the same rock as No. 868, continuous with it; a rhomboidal mass showing a more rough and granular weathered surface.
Ref. Annual Report, xv, pages 246, 268, 387; Bulletin vi, pages 25, 41–43, 421, plate V, figure 6.

Meg. Gray, rough, sheared rock, the weathered surface being roughened by projecting feldspar and quartz.

Mic. This rock is hardly distinguishable from No. 868. Its greatest difference consists in the more evident forms of old feldspathic grains which speck the surfaces. There is no structure visible that proves the rock to have been originally plutonic or effusive, though there is no question that the materials had an eruptive origin. *Zoisite* is abundant, especially in the fragmental grains of feldspar. Some of the green coloring matter is *hornblende*, and there are a few grains of *epidote*.

Two sections. N. H. W.

No. 868B. Greenwacke.

"Shows the gneissic structure sometimes seen in No. 868; same locality."
Ref. Annual Report, xv, pages 246, 268, 387; Bulletin vi, pages 43, 421.

Meg. Similar to Nos. 868 and 868A.

Mic. The section is similar to No. 868A, but is more markedly schistose and the feldspars are more altered.

One section.

Age. Keewatin. U. S. G.

No. 868C. Quartz and Chlorite.

"Quartz from a vein, inclosing green chlorite and having a schistose structure; same exposed surface."
Ref. Annual Report, xv, pages 246, 268, 387; Bulletin vi, pages 43, 421.

Meg. A mass of coarse, white, vein quartz and fine-grained, schistose greenstone.

Mic. The section was made from the greenstone. It is markedly schistose and is composed essentially of *chlorite*.

One section.

Age. Keewatin. U. S. G.

No. 868D. Chlorite.

"Contains a piece of chlorite from a fissure and a grain resembling a changed crystal of feldspar; same locality."
Ref. Annual Report, xv, pages 246, 268, 387; Bulletin vi, pages 43, 421.

Meg. Chlorite, similar to the chlorite of No. 868C. The supposed feldspar crystal is considerably altered, soft, and of a greenish-gray color. No section.

Age. Keewatin. U. S. G.

No. 868E. Greenwacke.

Same rock surface as No. 868; most usual and typical form of No. 868; near the west end of the small ridge.
Ref. Annual Report, xv, pages 246, 387; Bulletin vi, pages 43, 421.

Meg. Similar to No. 868.

Mic. This is a little finer-grained than Nos. 868 or 868A, but otherwise it is the same in all respects. In the section is one large rounded *quartz* grain with inclusions of *hornblende* and *calcite*. One section.

Age. Keewatin. N. H. W.

No. 868F. Chlorite Schist.

"Gneissic or schistose structure of No. 868, adjacent to No. 868E."
Ref. Annual Report, xv, pages 246, 387; Bulletin vi, pages 43, 421.

Meg. A fine-grained, greenish to brownish, schistose, rather soft rock.

Mic. The section, which is quite thick, appears to be composed essentially of small flakes of *chlorite* and *muscovite* and small grains of *quartz*. The chlorite and muscovite flakes are in general arranged with their long axes in a common direction. Some yellow stain is present in considerable quantity. One section.

Age. Keewatin. U. S. G.

No. 868G. Chlorite Schist.

Same exposed surface with No. 868E.
Ref. Annual Report, xv, pages 246, 387.

Meg. Similar to No. 868F, but more markedly schistose.

Mic. The section resembles that of No. 868F, but contains more *chlorite*.

One section.

Age. Keewatin. U. S. G.

No. 868H. Chlorite Schist.

Same locality as No. 868E.
Ref. Annual Report, xv, pages 246, 387.

Meg. Similar to No. 868F.

Mic. The section is similar to that of No. 868F, but in places contains large *quartz* grains. One section.

Age. Keewatin. U. S. G.

No. 868I. Jaspilyte (?)

Same exposed surface with No. 868E.
Ref. Annual Report, xv, pages 246, 387.

Meg. A very fine-grained, slaty, black rock.

Mic. The section is very fine grained and is made up of *quartz* and a black, opaque substance. This latter is finely divided and is very abundant. It may be carbonaceous material. The rock powder yields no particles to the magnet.

One section.

Age. Archean.

Remark. Nos. 868 to 868B and 868E to 868H, appear to be different facies of the same rock mass, but No. 868I is entirely different. U. S. G.

No. 869. Chlorite Schist *(with rutile).*

From the southeast side of the same ridge as No. 868; sec. 32, T. 62–15 W.; Tower.
Ref. Annual Report, xv, pages 247, 248, 266–268, 387; Bulletin ii, pages 44, 45, 234, 421.

Meg. A soft, fine-grained, green, fissile schist.

Mic. The section shows a schistose rock, the minerals being elongated in a common direction. The principal components are *quartz*, *chlorite*, *muscovite* and *rutile.* The quartz is in fine grains, more or less elongated. The chlorite and muscovite are in plates, the former being much more abundant than the latter. The most noticeable feature of the section is the presence of large numbers of minute rutile prisms. These are commonly arranged with their long axes parallel to the elongation of the other minerals. A few heart-shaped twins of rutile occur.

Two sections.

Age. Keewatin. U. S. G.

No. 870. Argillyte.

Same place as No. 869.
Ref. Annual Report, xv, pages 266, 268, 387.

Meg. A fine-grained, gray-black argillyte.

Mic. The section is composed of minute grains of *quartz*, perhaps also grains of *feldspar* and flakes of *chlorite* and *muscovite.* Scattered through the rock is considerable black, dust-like material, and there are also some minute *rutile* prisms.

Two sections.

Age. Keewatin. U. S. G.

No. 871. Hematite.

Lee mine, Tower.
Ref. Annual Report, xv, pages 249, 387.

Meg. Black, specular hematite, the ore of the Lee mine.

No section.

Age. Keewatin. U. S. G.

No. 871A. Hematite.

Lee mine, Tower.
Ref. Annual Report, xv, pages 249, 387.

Meg. Specular hematite, with cavities which are lined with small crystalline plates of *hematite.*

No section.

Age. Keewatin. U. S. G.

No. 872. Amphibolyte. *(Camptonyte?)*

From a dike running E. 10° S.; sec. 21, T. 62–15, Stuntz island.
Ref. Annual Report, xv, pages 308, 310, 314, 387. Compare No. 1847.

Meg. The rock is granular, but much altered.

Mic. The original feldspar is entirely changed. That which now takes its place was formed later than the hornblende, even later than the more recent portion of the hornblende, since it encloses the hornblende crystals. It is triclinic and quite fresh. It has n_g in the acute axial angle; hence, its optical sign is +. It has the twinning characters of albite. The lamellæ are irregular in width and in length, and interrupted before reaching the limit of the crystalline grain, and may therefore be accepted as *albite*, at least provisionally.

The augite is changed to green *hornblende*, which shows its prismatic cleavages conspicuously, as well as its high polarizing colors. The crystals show two epochs of growth, this being evinced by a colorless portion surrounding or irregularly intergrown with the green portion, *i. e.*, in irregular patches or areas, though always limited in their growths by the geometric form of the mineral. In some cases the geometric forms are not completed, and then the extremities of the section are jagged or "fringed," as described by Williams.* The view of Van Hise,† however, that these are secondary growths rather than the frayed ends of dynamically deformed crystals, seems here to be applicable, since these growths, which are fresh and colorless, and extinguish coincident with the original nucleus of the crystals, sometimes pass into zoned increments. These colorless enlargements are simply later growths of the same mineral. The parts of these enlarged crystals do not polarize with the same colors although they extinguish in unison. For instance, the older portion, which always is green in common light, perhaps assumes a greenish yellow, and the colorless part becomes lemon yellow. Sometimes the green mineral becomes a dirty dark yellow and the colorless increment a purplish red, or again the green part becomes brownish yellow, and the colorless part blue. This does not indicate a difference of mineral species, but is due to the difference of the initial coloration. That is, since the older hornblende is green in common light, and the later is colorless, the points from which the double refraction is reckoned are different.

It is not to be presumed that the second growth followed immediately after the first. It is apparent that the original crystal suffered a long history, and was corroded and decayed. The uninterrupted growth of a crystal could hardly be distributed to its various parts so capriciously as the colorless parts are distributed in the colored. This capriciousness may be shown by the accompanying figure, in which *a* shows where colorless areas appear in one crystal, *b* where they are in a second crystal, and *c* where they are in a third. In the slide are various other combinations, the second growths, in several instances, being rather intimately ingrown with

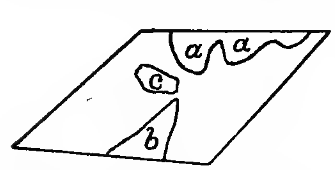

FIG. 35. DISTRIBUTION OF SECONDARY GROWTHS IN HORNBLENDE.

*Greenstone schist areas of the Marquette and Menominee areas in Michigan. *U. S. Geol. Survey, Bulletin lxii*, p. 126, fig. 10, 1890.

†Secondary enlargements of hornblende crystals. *American Journal of Science*(3), xxx, 231, 1885.

the older crystal in such a manner as no crystal can be supposed to have been built up without interruption. These colorless parts are certainly not due to dynamic degradation. They are not broken. They are the purest and the highest doubly-refracting parts.

They are, no more, due to the decoloration of a once wholly idiomorphic crystallization, for their present integrity of form and of optic characters is inconsistent with such transformation. They extinguish simultaneously with the colored areas, but the difference of double refraction indicates that these increments may be of a different species of hornblende.

Zoisite is quite abundant in this rock.

Six sections.

Age. Archean dike in Keewatin.

Remark. Except for the double development of the hornblende (which may not be a fatal objection), this rock might be classed as *camptonyte,* a rock that is found in form of dikes in the Adirondack region and in Vermont. A similar dike occurs at Ely. (See No. 1786.) On the nature of these "secondary growths" see the remark after No. 1786, at Ely. N. H. W.

No. 872A. Amphibolyte (?)

"No. 872A was taken from the side of a narrow dike of the main system on Stuntz island [Vermilion lake]. This dike is not more than one and a half inches thick where the piece was taken off, and pinches out entirely toward the west further, in about ten feet."

Ref. Annual Report, xv, page 310.

Meg. A fine-grained, greenish-gray, rusty-weathering rock.

Mic. The section is composed largely of a fibrous, colorless to greenish mineral, which appears to be a form of *hornblende.* Besides this mineral there is a little *quartz,* perhaps also some *feldspar,* and considerable *zoisite.* The latter occurs in irregular grains throughout the section and is also collected in areas composed of larger grains. The section is clouded by a light yellowish material; when examined with a high power this yellowish material is seen to be composed of minute grains having a rather high index of refraction and little effect on polarized light; they may also be zoisite. The section shows one, considerably altered, porphyritic feldspar.

One section.

Age. Dike cutting Keewatin rocks.

Remark. The original nature of this dike rock is uncertain. It is now much altered. It is quite likely that it is of the same nature as No. 872, which is suggested to be a camptonyte. U. S. G.

No. 873. Camptonyte (?)

From another set of dikes on Stuntz island, Vermilion lake; sec. 21, T. 62-15 W.

Ref. Annual Report, xv, pages 308, 314, 387.

Meg. A fine-grained, gray, roughly schistose rock. The matrix, which is too fine grained for the macroscopic determination of its constituents, contains small, scattered, porphyritic hornblendes and more numerous, glistening, silvery, porphyritic micas. The latter are especially noticeable on cleavage surfaces of the rock, the cleavage of the mica being approximately parallel with the cleavage of the rock. One of the hand specimens contains a fragment of dark-gray, flinty argillyte.

Mic. A noticeable feature of the section is the presence of porphyritic, light-brown *hornblendes.* These lie in a confused groundmass of fine grain and of a very schistose character. The groundmass is composed essentially of *quartz*, probably also *feldspar, zoisite, calcite,* and small fibres of a nearly colorless *amphibole.* There is also considerable *limonite* which seems to have originated from the alteration of *pyrite.* The porphyritic mica crystals are not prominent in the thin sections, and where they do appear they are seen to be much clouded and altered and in general have little or no effect on polarized light. Two sections.

Age. Dike cutting Keewatin rocks. U. S. G.

No. 873A. Amphibolyte (?)

Rounded mass of green rock in No. 873.
Ref. Annual Report, xv, pages 309, 387.

Meg. A gray rock of medium grain, composed largely of hornblende and effervescing freely with hydrochloric acid.

Mic. The section shows numerous, crowded, brownish *hornblendes* in a sparse cement. The hornblendes frequently show crystal outlines. The cement is fine grained and is composed essentially of *calcite* and *quartz*, with some hornblende.

One section.

Age. Mass in dike which cuts Keewatin rocks. U. S. G.

No. 874. Conglomerate. *(Matrix.)*

Stuntz island, Vermilion lake; sec. 21, T. 62-15 W.
Ref. Annual Report, xv, pages 314, 387.

Meg. A light-gray, fine-grained, roughly schistose rock, containing numerous quartzes; the rock in general resembles a schistose quartz-porphyry with numerous quartz phenocrysts.

Mic. The sections show a very fine-grained matrix which is composed essentially of *quartz, feldspar* and some flakes of *muscovite.* A little *calcite* is also present. In this matrix and interlocking with it are numerous fragments of various shapes and sizes of quartz and feldspar. The feldspar is somewhat altered and clouded; it appears to be both *orthoclase* and acid *plagioclase.* A considerable number of these quartz and feldspar fragments seem to have been broken since they were included in the rock. Four sections.

Age. Stuntz conglomerate (base of Upper Keewatin).

Remark. In some of the slides the rock looks decidedly like a quartz-porphyry somewhat sheared. In fact the rock really is a "recomposed" quartz-porphyry. In connection with Nos. 874 and 874A, compare the descriptions of Nos. 2010 to 2030.

U. S. G.

No. 874A. Pebbles *(from conglomerate)*.

Pebbles from No. 874.
Ref. Annual Report, xv, page 387.

Meg. The pebbles collected are largely of light-gray quartz-porphyry. There are also some pebbles of different facies of jaspilyte.

Sections from part of the matrix attached to one of the pebbles are similar to sections of No. 874. Sections from the pebbles show a porphyritic rock, the phenocrysts being of considerably altered feldspar, and the groundmass consisting largely of trachitic *feldspars*, with apparently some *quartz*, and flakes of *muscovite*. *Calcite* is quite common.

Four sections.

Age. Pebbles in Stuntz conglomerate (base of the Upper Keewatin). U. S. G.

No. 874B. "Greenstone."

"Olivinitic greenstone, found in No. 874, near some quartz veins, Stuntz's island, sec. 21, T. 62–15."
Ref. Annual Report, xv, pages 310, 387.

Meg. Specimen not found.

No section.

Age. Keewatin. U. S. G.

No. 875. Dioryte.

Dike in southern part of sec. 12, T. 62–15 W.; east end of Vermilion lake.
Ref. Annual Report, xv, pages 306, 387. Compare Nos. 872 and 873.

Meg. A medium-grained, dark-gray, granitic rock, composed of hornblende and white to flesh-colored feldspar. One end of the specimen is much finer grained than the main part of the rock, but is apparently of the same composition. There is a pretty sharp contact between the coarser and finer grained parts of the specimen.

Mic. The sections were made from the coarse part of the hand sample. The rock is composed essentially of *hornblende* and *feldspar*, with a little *quartz*. The hornblende is brownish to green to almost colorless. The brownish hornblende is more massive than the other, which is fibrous. In many cases a brownish grain or one of the darker green grains has a border of a lighter color, the border being optically continuous with the central part of the grain. The feldspar is considerably altered and clouded and affects polarized light rather weakly. In general it is not twinned, but frequently shows perthitic intergrowths. In a few places it is intergrown with quartz to form micropegmatyte. The feldspar is in some cases twinned according to the albite law. Its species was not determined.

Two sections.

Age. Dike in the Upper Keewatin rocks. U. S. G.

No. 876. Hematite.

Tower mine, Soudan.
Ref. Annual Report, xv, pages 251, 387.

Meg. Steel black, hard, massive hematite; the ore of the Tower mine.

No section.

Age. Lower Keewatin. U. S. G.

No. 877. Amphibolyte.

From a green dike on Menan island in Vermilion lake, near the centre of sec. 36, T. 63-17.
Ref. Annual Report, xv, pages 289, 290, 387.

Meg. The rock has a fibrous schistosity and an irregular distribution of the dark elements, giving it a spotted appearance.

Mic. It is an amphibolic rock, much resembling the rock from the dyke in Stuntz island, already examined (No. 872), but the *amphibole* has distinct dichroism, being green when parallel and yellow when perpendicular to the lower nicol or vertical thread of the eye-piece. *Zoisite* is here found in the same finely divided particles.

One section.

Age. Archean (Keewatin). N. H. W.

No. 878. Granite.

From a dike on Menan island, Vermilion lake; sec. 36, T. 63-17 W.
Ref. Annual Report, xv, pages 289, 290, 387.

Meg. A rather fine-grained, pinkish granite, composed of feldspar, quartz and a little biotite.

Mic. The rock is a granite composed essentially of *quartz* and *feldspar*. The size of the component grains varies considerably. The feldspar is mostly untwinned and apparently is *orthoclase*. Greenish *biotite (?)*, *chlorite*, *epidote* and *magnetite* occur in small amounts. Three sections.

Age. Dike in Archean rocks. U. S. G.

No. 879. Mica Schist.

West side of Outlet bay, Vermilion lake; one-fourth mile north of the south side of sec. 14, T. 63-17 W.
Ref. Annual Report, xv, pages 293, 388.

Meg. A medium-grained, hard, rather massive, biotite schist.

Mic. The rock is composed of grains, of rather uniform size, of *quartz, feldspar* and biotite. The feldspar is highly altered and in its alteration has developed considerable *kaolinite*. The biotite grains have their cleavage in general parallel, and this mineral is more or less altered to *chlorite*. A little *garnet* is present.

Two sections.

Age. Archean. U. S. G.

No. 880. Granulyte.

Nodules of irregular forms embraced in the mica schist, No. 879; sec. 14, T. 63–17.
Ref. Annual Report, xv, pages 293, 388.

Meg. Of medium grain, gray, of a syenitic aspect.

Mic. Apparently consisted at first of *feldspar* and *quartz*, but now, by pressure and probably some shearing, the feldspars are filled with *muscovite*, though still showing albite twinning lines, and the quartz is broken into many fragments, showing undulatory extinction.

One section.

Age. Archean. N. H. W.

No. 881. Amphibolyte.

From a dike, cut by later dikes, north part of sec. 35, T. 63–16, north part of Vermilion lake, on Pine island.
Ref. Annual Report, xv, pages 302, 388.

Meg. The rock is gray, weathering light-colored; feldspathic and amphibolic, with fine specks of pyrite. There is a marked fibrosity, the minerals being prevailingly elongated in one direction.

Mic. *Amphibole* makes up a large part of the slide, and the rest is principally a secondary feldspar. Yet there are present accessory amounts of *mica* and of *sphene*, with some *zircon* and *garnet* and a little *quartz*. The last is identifiable only by the observation of a dark cross, since it closely resembles the feldspar. The feldspar has n_p for acute bisectrix, which precludes albite but allows *oligoclase*. This oligoclase shows no polysynthetic twinning. It is of later date than the amphibole, and usually is in very small grains. The older feldspars are crowded with *zoisite*.

Two sections.

Age. Archean. N. H. W.

No. 882. Granite. *(Schistose.)*

From the extremity of the point that projects eastwardly from section 35, into the N. W. ¼ sec. 36, T. 63–16 W.; Pine island, Vermilion lake.
Ref. Annual Report, xv, pages 302, 388.

Meg. A medium-grained, roughly-schistose, pinkish-green rock composed of red feldspar, chlorite and biotite.

Mic. The section shows a granitic aggregate of much-altered and clouded feldspar, some *quartz*, *chlorite* and *biotite* altering to *chlorite*.

One thick section.

Age. Archean. U. S. G.

No. 883. Sericite Schist.

N. E. ¼ sec. 5, T. 62-15 W., Vermilion lake.
Ref. Annual Report, xv, pages 303, 388. Compare No. 397.

Meg. A soft, greenish-gray, fine-grained, schistose, rather fissile rock.

Mic. The sections show a very fine-grained rock, composed of *quartz, feldspar, chlorite,* and micaceous scales which are probably both *muscovite* and *kaolinite.* Scattered through the rock are small, sharply outlined rhombs of a carbonate which from its absorption and its yellow color in places, appearing as if altering to limonite, is thought to be largely *siderite.* Part of this carbonate may be calcite. Some opaque, dust-like material is scattered through the slide, and there is some *magnetite.* There are a few grains of quartz of larger size than the average and these interlock around their borders with the smaller grains.

Two sections.

Age. Keewatin. U. S. G.

No. 884. Schist. *(Earthy.)*

Breitung mine, Soudan, near the west end of the North ridge.
Ref. Annual Report, xv, pages 249, 250, 270, 388. Compare No. 384.

Meg. A soft, earthy, buff or nearly white, very fine-grained schist.

Mic. The section is too thick for careful study. The rock is markedly schistose and of fine grain and greenish color in section. The minerals appear to be mostly *chlorite* and a micaceous mineral. There are a few grains of *quartz* of considerable size and one shows an embayment similar to some of the quartzes of the quartz-porphyries. *Magnetite* is common in minute particles and there are many minute prisms which look like *rutile,* but they are nearly opaque and have no effect, as far as can be determined in this thick section, on polarized light. With these supposed rutile prisms are some heart-shaped twins which also look like rutile.

One section.

Age. Keewatin.

Remarks. The original nature of this rock is uncertain. It may perhaps have been a quartz-porphyry, but, if such, it has been very highly altered. U. S. G.

Remark. This rock, on re-examinatiau, appears to be a fragmental one, composed of very fine (jaspilitic) quartz mingled with some clastic quartzes from some quartz-porphyry and a considerable amount of much altered fine debris from some basic source, probably from the pre-existing ridges of the Lower Keewatin in the near vicinity, and to be therefore a part of the Upper Keewatin. It appears that the irregular loose masses of jaspilyte which characterized the Breitung and the West Breitung mines are comparable to the large masses seen at the south side of the South ridge, near Tower, and that, like them, they are not of the original ore deposit of the North ridge, but belong in the base of the Upper Keewatin. N. H. W.

No. 885. Chlorite Schist.

North end of a cut on the Duluth and Iron Range railroad, about one-third mile northwest of the southeast corner of sec. 5, T. 61–15 W. South from Soudan.
Ref. Annual Report, xv, pages 270, 388.

Meg. A fine-grained, soft, green schist.

Mic. The section shows a schistose rock composed of *chlorite*, *quartz* and probably also *feldspar*. There are varying amounts of *calcite*, *magnetite* and *epidote*. Thickly scattered through the section are minute grains which have a high index of refraction and very weak double refraction; they are probably *zoisite*. One thick section.

Age. Keewatin. U. S. G.

No. 886. "Greenstone."

South end of the same cut from which No. 885 came.
Ref. Annual Report, xv, pages 270, 388.

Meg. A fine-grained, compact greenstone.

Mic. The section shows lath-shaped *plagioclases* in a mass of alteration products composed mainly of green *hornblende*, *chlorite* and finely divided *magnetite*. *Calcite* is common, and *epidote* is present. The rock was probably originally a diabase.

One section.

Age. Keewatin. U. S. G.

No. 887. Graywacke.

Cut on the Duluth and Iron Range railroad; S. E. ¼ sec. 8, T. 61–15 W. South of Soudan.
Ref. Annual Report, xv, pages 271, 388.

Meg. A hard graywacke of medium grain.

Mic. More or less angular, prominent feldspars and fewer quartzes are embedded in a much finer grained groundmass, although there are grains of sizes intermediate between the grains of the groundmass and these more prominent grains. The feldspars are usually considerably altered and cloudy, though some still show albite twinnings. The groundmass is composed essentially of *quartz*, *feldspar*, *chlorite*, *muscovite* and *calcite*. One section.

Age. Keewatin. U. S. G.

No. 888. Argillyte.

Same place as No. 887.
Ref. Annual Report, xv, pages 271, 388.

Meg. A fine-grained, dark-gray, slaty argillyte with mica scales along the cleavage planes.

Mic. The rock is composed chiefly of fine grains of *quartz* and probably also of *feldspar* and flakes of *biotite* and *chlorite*. *Magnetite* and *pyrite* are present, and there are some minute grains which appear to be *epidote*. One section.

Age. Keewatin. U. S. G.

No. 889. "Greenstone" *(with pebbles of jaspilyte).*

Point in the S. E. ¼ sec. 20, T. 61-15 W., Vermilion lake.
Ref. Annual Report, xv, pages 231, 388; Bulletin vi, pages 233, 421.

Meg. A fine-grained, roughly-schistose, green rock, having many small, irregular areas of jaspilyte-like white quartz. On some of the cleavage surfaces is a brownish, micaceous mineral. These areas of white color give the rock a peculiar appearance, suggesting a sheared and decayed greenstone amygdaloid, or perhaps a greenstone conglomerate with white pebbles.

Mic. The section shows a very fine-grained rock composed mainly of *chlorite* and minute grains of quartz, and perhaps also of feldspar. A few *muscovite* scales are also present. The white areas so noticeable in the hand sample are composed of finely crystallized quartz similar to the *quartz* of the jaspilytes. In one of these white areas was a large grain of quartz surrounded by finer grains of the same mineral, its margin interlocking with the fine grains. These areas of quartz are a little coarser grained than the main mass of the rock.

One section.

Age. Upper Keewatin.

Remark. Compare No. 897. U. S. G.

No. 890. Sericitic Schist. *(Brown.)*

Stone mine, Soudan.
Ref. Annual Report, xv, pages 235, 253, 388.

Meg. A fine-grained, roughly-schistose, brown rock. The specimen has an indistinct mottled appearance and a rough texture.

Mic. One noticeable feature of the section, when examined with a low power or with the naked eye, is the presence of small, often not very distinct, areas which are darker than the main mass of the rock. Under the microscope these darker areas are not so distinct, and they are seen to be of essentially the same composition as the rest of the rock, except for the abundance of grains of *iron ore*, which is commonly accompanied by *chlorite.* The main mass of the rock is very fine grained and is composed of *quartz*, or quartz and *feldspar*, *muscovite* and iron ore. These are all common, and chlorite is less common. The iron ore seems to be both *limonite* and *hematite.* The rock may be a very fine breccia. One section.

Age. Keewatin. U. S. G.

Remark. This rock is plainly a finely fragmental one, and the quartz is finely divided like that of the jaspilyte. The irregular dissemination of the iron ores suggests that originally the rock was of the nature of a volcanic tuff. Indeed, there is is an indistinct patchy distribution of the other minerals concordant with that hypothesis. N. H. W.

No. 891. Red Shale.

Stone mine, Soudan.
Ref. Annual Report, xv, pages 253, 254, 388.

Meg. A soft shale, at times finely banded. It varies from a greasy-feeling, white material to soft, earthy hematite.

No section.

Age. Keewatin. U. S. G.

No. 892. Jaspilyte.

North wall of Stone mine, Soudan.
Ref. Annual Report, xv, pages 233, 256, 388; Annual Report, xvii, page 194.

Meg. The usual gray, black and red banded jaspilyte, somewhat brecciated.

Mic. The sections show the ordinary jaspilyte, composed of iron ore and fine-grained quartz.

Two sections.

Age. Keewatin. U. S. G.

No. 893. Jaspilyte.

From a dark slaty crag in the South ridge, near Tower.
Ref. Annual Report, xv, pages 224, 269; Bulletin vi, pages 230, 421.

Meg. A gray to reddish-brown, slaty, non-banded jaspilyte.

Mic. The section shows fine-grained *quartz* and *iron ore (hematite* and *limonite)* with some greenish-yellow, earthy, staining material.

One section.

Age. Keewatin. U. S. G.

No. 894. Green Schist and Jaspilyte.

Near the railway cut in Ely mine, Soudan.
Ref. Annual Report, xv, pages 224, 230, 388; Bulletin vi, pages 52, 230, 232, 421.

Meg. A roughly schistose rock, composed of irregular bands and lens-shaped masses of green, fine-grained schist and gray material which resembles the fine-grained quartz of the jaspilytes. Considerable pyrite is present.

Mic. The green parts of the section, the green schist of the hand sample, are composed of closely matted fibres of *chlorite*; in some places a few grains of *quartz* occur in the chlorite mass, and, on approaching the gray material, the jaspilyte of the hand sample, the quartz increases in amount, usually occupying roughly lens-shaped areas in the chlorite mass. The gray material is mainly fine-grained quartz, with some flakes of chlorite. Pyrite and magnetite are common. One section.

Age. Keewatin. U. S. G.

No. 895. Jaspilyte. *(Schistose.)*

Same place as No. 894.
Ref. Annual Report, xv, pages 230, 388; Bulletin vi, pages 232, 421.

Meg. A roughly schistose rock, gray, brownish and greenish in color. The gray material is fine-grained quartz, the brownish contains a micaceous mineral, and the greenish appears like the material of the green schists. The specimen was collected to represent a transition between jaspilyte and green schist.

Mic. The section shows various irregular, but more or less lens-shaped, areas of three kinds: (1) Colorless, jaspilitic *quartz;* (2) Green *chlorite*, and (3) Micaceous, probably *muscovite*, areas rich in iron ore. Iron ore *(limonite* and *hematite)* is abundant throughout the rock. The areas of different kinds are not always sharply marked off from each other. The rock perhaps represents a schistose breccia of rocks similar to Nos. 894 and 895.

One section.

Age. Keewatin. U. S. G.

No. 896. Chlorite Schist. *(Siliceous.)*

Railroad cut at the Ely mine, Soudan.
Ref. Annual Report, xv, page 388.

Meg. A fine-grained, brownish-green, slaty and schistose rock.

Mic. A very fine-grained rock composed essentially of the following minerals: *quartz*, perhaps also *feldspar*, *chlorite*, *iron ore* and *muscovite.*

One section.

Age. Keewatin. U. S. G.

Remark. In this slide are evidences that the iron ore is somewhat titaniferous. These consist of the gray *leucoxene* substance in small masses. These sometimes show the characteristic *sagenite* web resulting from alteration of rutile. Fine, interlocking jaspilitic quartz, in individual grains, permeates the whole rock. N. H. W.

No. 897. Chlorite Schist *(holding pebbles of jaspilyte).*

Ely mine, Soudan.
Ref. Annual Report, xv, pages 231, 268, 388; Bulletin vi, pages 233, 421.

Meg. Fine-grained, green schist, having angular white areas of jaspilitic quartz. The rock is similar to No. 889. There is one larger lenticular area of gray to reddish jaspilyte an inch and a half in diameter included in the schist.

Mic. The section shows *chlorite*, *quartz*, perhaps also feldspar, *muscovite* and *iron ore.* The section resembles in general character that of No. 889. One section.

Age. Keewatin. U. S. G.

No. 898. Chlorite Schist.

Near Tower, but exact locality uncertain.
Ref. Annual Report, xv, page 388.

Meg. Fine-grained, brownish-green, schistose rock. The brownish color seems to be due to areas rich in a micaceous mineral and iron ore (probably limonite).

The sample was collected to show a blending of the green schists and the jaspilyte, but this sample seems to contain but little more quartz than the ordinary green schist.

Mic. A schistose rock composed of *quartz*, perhaps also feldspar, *chlorite*, *muscovite* and *iron ore*. Similar to No. 896. One section.

Age. Keewatin. U. S. G.

No. 899. Jaspilyte.

Near Tower.
Ref. Annual Report, xv, pages 232, 388; Bulletin ii, pages 234, 421.

Meg. A white jaspilyte with spots and blotches of reddish. A little weathered pyrite is present.

Mic. The section is made up essentially of the fine-grained *quartz* common to the jaspilytes, but in this case the grains are some larger than is customary. Scattered through the slide are small grains of *iron ore*, some of which are octahedrons, probably of *magnetite*. There are also irregular areas which show a brownish stain. One section.

Age. Keewatin. U. S. G.

No. 900. Jaspilyte *(with magnetite crystals)*.

Near Tower.
Ref. Annual Report, xv, pages 232, 388; Bulletin vi, pages 234, 421.

Meg. Gray to black, banded jaspilyte. The black is due to magnetite, and small, glistening crystals (usually octahedrons) of this mineral are scattered through the sample.

Mic. The section is composed of fine-grained *quartz* and crystals of *magnetite*. One section.

Age. Keewatin. U. S. G.

No. 901. Hematite. *(Earthy.)*

Lee mine, Tower.
Ref. Annual Report, xv, page 388.

Meg. Soft, impure, dark-red, earthy hematite. The field notes designate this as "'baked clay,' near contact with the jaspilyte."

No section. Compare No. 904.

Age. Keewatin. U. S. G.

No. 902. Jaspilyte *(with veinlets)*.

Stone mine, Soudan.
Ref. Annual Report, xv, page 388.

Meg. Banded jaspilyte, composed of broad, deep red bands, and narrow black ones. The red bands are of hematite and quartz, and the black ones of hematite, quartz and crystals of magnetite. The hand specimen shows nicely the folding of the rock.

Mic. The section shows the usual jaspilyte, except that the iron ore is more abundant than is commonly the case and that there is much *magnetite* in crystals. A noticeable feature of the section is the presence of many small, colorless veins. These are composed of minute grains of *quartz* similar to the quartz of the usual jaspilyte, thus showing that what has been termed "chalcedonic silica" in the reports of this survey does form in veins.

One section. Compare No. 903.

Age. Keewatin. U. S. G.

No. 903. Jaspilyte.

Stone mine, Soudan.
Ref. Annual Report, xv, page 389; Annual Report, xvii, pages 194, 215.

Meg. Similar to No. 902, except for two things: (1) In this specimen the magnetite crystals occur to some extent in the red bands, while in No. 902 they are confined to the black bands; (2) No. 903 has a few pyrite crystals; these seem to be confined to the red bands.

Mic. The usual jaspilyte with very abundant iron ore, some of which is *magnetite* in crystals. The black bands are composed of *quartz*, of coarser grain than in the red bands, of less *hematite*, and of many coarser crystals of magnetite. There are also, as in No. 902, veinlets of fine-grained quartz cutting the section. Considerable of a very strongly doubly refractive mineral—calcite or siderite, most probably the latter—is present. Two sections.

Age. Keewatin. U. S. G.

Remark. The fine sideritic element is in granular microscopic patches distributed amongst the fine quartz and hematite. It also sometimes surrounds the magnetite crystals or adheres to them. It is fresh and non-limonated. It is coarsest in those parts of the slide where the magnetite crystals are coarsest, and is finest in the reddened (hematite) parts where the quartz is also finest. So far as can be determined from this slide, these irou minerals, whether oxides, sulphide or carbonate, stand on an equal footing as to date of origin. The veinlets of quartz cut across all the other bands, and are necessarily later in date. In this slide, and in that of No. 902, are traces of a green chloritic element which is apparently the same as that which constitutes the bulk of the green schists which enclose the iron ore lodes.

In the thinner section, made by Marchand, it can be seen distinctly, in high power, and on lowering the condensing lens, that the sideritic groups embrace many of the finer hematitic dark grains, or dust particles, and also that frequently such dust particles seem to serve as central nuclei of the individual siderite grains. But sometimes several such dust groups are embraced in a single siderite grain.

N. H. W.

No. 904. Hematite. *(Earthy.)*

Stone mine, Soudan.
Ref. Annual Report, xv, page 389.

Meg. The field-notes designate this as a siliceous nodule from the "baked clay." The nodule is evidently the ordinary jaspilyte and it appears to grade imperceptibly into dark red, soft, earthy hematite, like No. 901.

Mic. The section is too thick and was evidently made from the earthy "baked clay" part of the specimen. It shows much hematite, and probably also some limonite. There are irregular areas of a colorless material which has very little effect on polarized light and when viewed in such light seems homogeneous and isotropic, except for a few minute, very weakly doubly refractive flakes.

One section.

Age. Keewatin. U. S. G.

No. 905. Hematite. *(Specular.)*

Stone mine, Soudan.
Ref. Annual Report, xv, pages 231, 389.

Meg. Specular, more or less schistose hematite, in some places laminated and then passing into laminated gray and reddish jaspilyte.

No section.

Age. Keewatin. U. S. G.

No. 906. Hematite. *(Brecciated.)*

Stone mine, Soudan.
Ref. Annual Report, xv, page 389.

Meg. A fine breccia of hematite cemented by dark red jaspilyte.

No section.

Age. Keewatin. U. S. G.

No. 907. Jaspilyte *(with siderite)*.

Stone mine, Soudan.
Ref. Annual Report, xv, page 389.

Meg. White to greenish-gray jaspilyte, sometimes finely laminated. The rock has been somewhat brecciated and now contains vitreous quartz veins. A little pyrite is present.

Mic. When examined with the naked eye the section is seen to be transparent in places and gray or clouded in others. Under the microscope this appearance is seen to be due to the massing of the two constituents of the rock in irregular areas; the transparent areas are composed of the usual fine-grained *quartz* of the jaspilytes, and the clouded areas are composed of *siderite*, with perhaps a little calcite. The siderite has a granular structure and occurs in irregular granular masses and also in definite rhombs, but even the rhombs seem to be granular. That this mineral is siderite rather than calcite is shown by its frequently marked absorption,—stronger than calcite commonly shows,—and by the fact that the powdered rock effervesces very freely in hot hydrochloric acid, while there is almost no effervescence in the cold acid.

One section.

Age. Keewatin. U. S. G.

No. 908. Conglomerate.

North of the Cady house on the South ridge, Tower.
Ref. Annual Report, xv, pages 268, 269, 389; Annual Report, xvii, pages 194, 215.

Meg. A fine-grained, gray, schistose rock which contains small grains of feldspar, some of quartz and rock fragments. One of the specimens contains a piece of a black, hard, slaty rock. The rock is a rusty weathering one. On fresh fractures very minute, silvery, micaceous scales are abundant.

Mic. Angular grains of feldspar and quartz are embedded in a finer-grained groundmass, but there are all variations in size between the feldspars and quartzes visible in the hand sample and the minute ones of the groundmass. The rock is schistose and the groundmass is composed essentially of *quartz, feldspar, muscovite, chlorite, calcite,* dust-like black material, and probably also *kaolinite.* One of the slides shows a fragment of a black rock which consists of a few scattered, lath-shaped feldspars, in a confused dark background.

Two sections.

Age. Upper Keewatin. U. S. G.

No. 908A. Pebbles *(from No. 908).*

Same locality as No. 908.
Ref. Annual Report, xv, page 389.

Meg. There are four of the pebbles, or rather fragments of pebbles. One is a fine-grained, granular, somewhat crumbling, white quartzyte or jaspilyte. Another is a fine-grained, hard, black, slaty rock. Another is a very fine-grained, gray rock, with a few small grains of quartz. Another is fine grained, greenish gray and somewhat porous. Another is fine-grained, hard, almost flint greenstone. Another is black, slaty jaspilyte.

Mic. The section was evidently made from the first-mentioned pebble, which is seen to be an almost pure, completely crystallized, fine-grained quartzyte, or a rather coarse-grained jaspilyte. One section.

Age. Pebbles in Upper Keewatin rock. U. S. G.

No. 909. Jaspilyte.

A little north of, but near, Tower.
Ref. Annual Report, xv, pages 229, 268, 389. This rock is embraced in a clastic green schist similar to No. 910.

Meg. Red jaspilyte with some irregular, black laminæ which contain small *magnetite* crystals. The rock is in places schistose, and specular *hematite* has been developed along the cleavage planes. The hand specimen is crossed by a white quartz vein, less than an eighth of an inch in thickness, and along this vein are some cavities holding *quartz* crystals, *hematite* and apparently *limonite.* No section.

Age. Upper Keewatin. U. S. G.

No. 910. Chlorite Schist.

From a narrow band between two jasper masses, near Tower.
Ref. Annual Report, xv, page 389.

Meg. A fine-grained, soft, schistose, green rock, containing many minute, glistening crystals (magnetite). The hand sample also embraces fine siliceous nodules that appear to be jaspilyte.

Mic. The section shows a schistose rock, composed essentially of three minerals: (1) *Chlorite* in small flakes, abundant; (2) *Quartz* in fine grains, abundant; (3) Small octahedra of *magnetite,* common. One section.

Age. Upper Keewatin. U. S. G.

No. 911. Conglomerate. *(Jaspilitic.)*

Sec. 20, T. 62–15 W., near Tower.
Ref. Annual Report, xv, pages 316, 389.

Meg. There are three hand samples of this number. Two of these are of indistinctly mottled and blotched gray to green jaspilyte; in general in these two specimens the fragments are not distinctly visible. In the other specimen the fragmental character of the rock is evident. There are pieces, usually not more than half an inch in diameter, and partly rounded, of gray, greenish and reddish jaspilyte in a cement of green jaspilyte.

Mic. There are two sections, one of which is too thick and shows a little green chloritic material. The other section has a fragmental character, although this is partially obscured owing to the similar nature, at times, of the fragments and the cement, both of which are composed of aggregates of fine-grained *quartz* and granular *siderite.* The fragments are angular in shape and are composed of jaspilyte of finer grain than the matrix and also containing finely divided iron ore. The fragments are also richer in siderite than the matrix and in these fragments this mineral is sometimes aggregated in irregular, but approximately spherical masses.

Two sections.

Age. Upper Keewatin.

Remark. From what is seen in the hand specimens and the slides, one cannot be certain that the rock is a conglomerate; it is possible that it is a breccia.

U. S. G.

No. 912. Breccia. *(Pyritic.)*

Lee mine, Tower.
Ref. Annual Report, xv, pages 248, 389.

Meg. A breccia in which the fragments are rather soft, earthy hematite, and the cement is pyrite and hematite. There is present a small amount of a soft, green, chloritic or earthy substance as a part of the cement.

No section.

Age. Keewatin. U. S. G.

No. 913. Quartz-Porphyry. *(Hornblendic.)*

Low hills, southeast of Tower, near the Duluth and Iron Range railroad; sec. 33, T. 62–15 W.
Ref. Annual Report, xv, pages 271, 273, 389.

Meg. The rock is gray in color and is apparently somewhat schistose. It shows a very fine-grained groundmass in which are small porphyritic crystals of hornblende and larger ones of feldspar and quartz.

Mic. The rock is a quartz-porphyry, which has been altered and sheared, and the section is too thick for careful study. The porphyritic crystals are *feldspar*, *quartz* and *hornblende.* The feldspar is considerably kaolinized and clouded; some of it shows no twinning and is perhaps orthoclase, while some of it is twinned according to the albite law and is perhaps near *oligoclase.* The quartz is not abundant; two of the crystals show an approach, though somewhat rounded, to a bipyramidal form. The hornblende varies in color from brownish, to green, to almost colorless; it is frequently fibrous and perhaps none of it is original, although some of the brown crystals may be.

The groundmass of the rock is very fine grained and is composed of quartz, feldspar, flakes of hornblende, of chlorite and of muscovite, and epidote. The last named mineral is sometimes in distinguishable grains, and also, apparently, as very minute grains scattered all through the groundmass.

One section.

Age. Keewatin. U. S. G.

No. 914. Quartz-Porphyry (?)

Southeast of Tower, near the Duluth and Iron Range railroad; sec. 33, T. 62–15 W.
Ref. Annual Report, xv, pages 271, 273, 389.

Meg. A fine-grained, gray rock, containing some large porphyritic quartzes and some smaller, less apparent feldspars.

Mic. The most noticeable feature of the section is presence of an abundance of *epidote*, which has permeated the whole rock; it is scattered in small grains throughout the groundmass, which is mainly composed of fine-grained *quartz*, and it replaces what appear to have once been porphyritic feldspars. There are a few areas of fibrous *hornblende* encroached upon by epidote; these seem to represent some original, porphyritic, ferromagnesian constituent. A few larger quartz grains occur, and there is one which shows an approach to a bipyramidal form.

One section.

Age. Keewatin. U. S. G.

No. 915. CAMPTONYTE (?)

"Greenstone, from dike cutting the graywacke near the railroad, southeast of Tower; sec. 33, T. 62–15."
Ref. Annual Report, xv, pages 271, 273, 389.

Meg. A fine-grained, compact, massive, grayish-green rock. It weathers to a greenish gray.

Mic. The section shows a rather fine-grained rock, whose chief component is feldspar. This occurs in irregular grains and forms the background of the rock. The feldspar is sometimes untwinned and sometimes shows albite twinning. Its species was not carefully determined, but equal extinction angles in twinned sections indicate a feldspar near *andesine* or perhaps andesine-oligoclase. *Hornblende* is abundant. It is brownish green and pale green to almost colorless. The brownish-green hornblende occurs in elongated prisms, whose size in cross sections is considerably less than that of the feldspars. The prismatic planes on this brownish-green hornblende are often developed, but the terminal planes rarely. Frequently these hornblendes have borders and fibrous elongations of the pale-green hornblende, and the latter occurs in irregular masses and small fibres abundantly throughout the section. *Epidote* is common, and there is a little iron ore. One section.

Age. Keewatin. U. S. G.

No. 916. BRECCIA. *(Hematitic.)*

Breitung mine, Soudan.
Ref. Annual Report, xv, pages 250, 389; Annual Report, xvii, pages 194, 215.

Meg. A rough, heavy rock, brecciated, and composed of small fragments of hematite in a cement of the same. Scattered all through the rock are small, irregularly shaped areas of a soft, white, earthy substance. Some of this substance was examined under the microscope and found to consist of a very finely divided, gray, practically isotropic material. Specimens collected later under this number show a breccia of jaspilyte. No section.

Age. Keewatin. U. S. G.

No. 917. JASPILYTE.

From the extreme eastern extension of the ridge affording No. 868; sec. 32, T. 62–15 W., Tower.
Ref. Annual Report, xv, pages 268, 389.

Meg. Brecciated, somewhat crumbling, white, black, gray and red jaspilyte. No section.

Age. Keewatin. U. S. G.

No. 918. Dioryte *(with quartz).*

From a boulder near the railroad, Breitung mine, Soudan.
Ref. Annual Report, xv, pages 275, 336, 389.

Meg. A coarse-grained granitic rock, composed largely of hornblende, but with some white to red feldspar and quartz. Some of the hornblendes have compact borders and cores which are granular.

Mic. The section shows much green *hornblende* and smaller amounts of *feldspar* and *quartz.* The feldspar is generally much clouded and kaolinized, but in places still retains traces of albite twinning. *Epidote, sphene, magnetite* and *hematite* are also present.

One section.

Age. Boulder, probably from the Archean. U. S. G.

No. 919. Chlorite Schist. *(Jaspilitic.)*

Railroad cut south of the Stone mine, Soudan.
Ref. Annual Report, xv, pages 224, 389; Bulletin vi, pages 44, 52, 231, 421.

Meg. A fine-grained, grayish-green, schistose rock. It contains considerable white, fine quartz.

Mic. The rock is composed essentially of small grains of *quartz,* similar to the quartz of the jaspilytes, and flakes of *chlorite.* These are sometimes intimately mingled together, but quite commonly each is massed in areas largely free from the other. A few *magnetite* crystals are present.

Three sections.

Age. Keewatin.

Remarks. This is one of the rocks intermediate in composition between jaspilyte and green schist. Compare Nos. 885, 894, 895, 897. U. S. G.

No. 920. Quartz-Porphyry (?)

S. E. ¼ sec. 6, T. 62-15 W.; east side of bay on south shore of Pine island, Vermilion lake.
Ref. Annual Report, xv, pages 303, 389.

Meg. A gray schistose rock of fine grain and holding many small hornblendes.

Mic. The groundmass of the section is of fine grain and is composed of *quartz, feldspar, chlorite, muscovite,* pale green *hornblende* and *epidote.* In this groundmass are larger grains of feldspar and quartz. These are without crystal outlines, interlock irregularly with the smaller grains of the groundmass, and in many cases have been fractured and their parts more or less separated. There are also some larger grains of brownish-green hornblende, which often have attached to them growths of pale green hornblende.

One section.

Age. Keewatin.

Remark. From the field notes and the slide this rock may be regarded as a quartz-porphyry which has been sheared, but this origin for the rock is not absolutely certain, as a tuffaceous deposit or a recomposed quartz-porphyry might take this form. Compare No. 913, which is a similar rock and seems to be clearly a quartz-porphyry. U. S. G.

No. 921. Slate. *(Black.)*

South shore of Pine island, Vermilion lake, at the west line of sec. 6, T. 62–15 W.
Ref. Annual Report, xv, pages 303, 389; Annual Report, xvii, pages 194, 215.

Meg. A fine-grained, hard, black slate.

Mic. The rock is very fine grained and is composed of *quartz*, probably also *feldspar*, *chlorite*, *muscovite*, *kaolinite*, *epidote* and *pyrite*. There is also much dust-like, black material.

One section.

Age. Keewatin. U. S. G.

No. 922. "Greenstone."

South shore of Pine island, Vermilion lake; S. W. ¼ sec. 1, T. 62–16 W.
Ref. Annual Report, xv, pages 303, 304, 389.

Meg. A fine-grained, grayish-green rock, resembling some of the "greenstones" of the Keewatin. Calcite is present in small seams.

Mic. The section shows a fine-grained rock, which is probably an altered, basic, igneous rock, but its original species cannot be told. The constituent minerals form a confused mass composed of *zoisite*, fibrous, almost colorless *hornblende*, *epidote*, *feldspar*, *muscovite*, *quartz* and *calcite*, the minerals being named approximately in the order of their abundance, the most abundant being named first.

One section.

Age. Keewatin.

Remark. From the field notes one might judge that this specimen was part of a "greenstone" dike. U. S. G.

No. 923. Granite *(in contact with biotite schist).*

Southwest corner of Avis island, Vermilion lake, near centre of sec. 35, T. 63–17 W.
Ref. Annual Report, xv, pages 291, 389.

Meg. The granite is of medium grain and light gray in color. It is composed of feldspar, quartz and muscovite. The biotite schist is of medium grain for such a rock and is dark gray in color. The contact between the two rocks is sharp and distinct and runs about parallel with the cleavage of the schist.

Mic. The granite is composed of grains which vary considerably in size and which interlock irregularly. The rock seems to have suffered some granulation. The essential minerals are *quartz*, *feldspar* and *muscovite*. The quartz frequently shows undulating extinction. The feldspar is apparently largely *orthoclase*, and there is a small amount of plagioclase (probably *oligoclase*) present. Associated with the *muscovite* is some chlorite and with the *chlorite*, and commonly included in it, are a few small grains of *epidote*.

The schist is composed largely of *biotite*, quartz and feldspar. The last named mineral shows no twinning and commonly no cleavage; its species was not determined. *Chlorite*, *muscovite* and *pyrite*, are also present, as well as a little *epidote*.

The sections do not show the contact of the two rocks.

Three sections.

Age. Archean. U. S. G.

No. 924. Granite. *(Biotitic.)*

S. W. ¼ sec. 35, T. 63–17 W., west side of the channel west of Avis island, Vermilion lake.
Ref. Annual Report, xv, pages 291, 389.

Meg. A rather fine-grained, gray granite, composed of quartz, feldspar and biotite.

Mic. The section shows a granite whose essential minerals are *feldspar*, *quartz* and *biotite*. The feldspar is more or less clouded and apparently both *orthoclase* and acid plagioclase *(oligoclase)*. *Muscovite*, *chlorite* and iron ore are also present.

One section.

Age. Archean. U. S. G.

No. 925. Hornblende Schist.

Same locality as No. 924.
Ref. Annual Report, xv, pages 291, 389.

Meg. A fine-grained, schistose, greenish-gray rock, having along its cleavages many dark glistening scales.

Mic. The section shows a rock composed essentially of feldspar, quartz and green hornblende. The feldspar is much kaolinized. Chlorite, epidote and pyrite are rather common.

A minute vein crosses one end of the hand sample and is included in the section. The vein is composed of a colorless mineral at times somewhat clouded by impurities or alteration products. This mineral has an index of refraction higher than quartz and a double refraction considerably stronger than quartz. It has one pretty good cleavage and sometimes a poorer cleavage or cross fracturing approximately at right angles to the good cleavage. The mineral is biaxial, with a rather small optic angle, and the character of the double refraction is positive. The acute bisectrix is apparently perpendicular to the good cleavage. The hardness is apparently 6 or more. The species of the mineral is not known, but it may be *thomsonite*. One section.

Age. Archean. U. S. G.

No. 926. Diabase.

N. E. ¼ sec. 31, T. 63–17 W.; Bear narrows, Vermilion lake.
Ref. Annual Report, xv, pages 295, 389.

Meg. A fine-grained, dark-gray diabase, with some pyrite.

Mic. The section shows a rock consisting essentially of *plagioclase* and *augite.* The former is usually in lath-shaped forms and is considerably altered. The augite is in polysomatic areas and in plates which have an ophitic relation to the feldspars. The augite is also some altered, and secondary minerals have been developed throughout the slide. These secondary minerals are mainly *chlorite, hornblende, biotite* and *quartz. Magnetite* and *pyrite* also occur in the slide.

One section.

Age. Probably a dike cutting Archean rocks. U. S. G.

No. 927. Granite.

From the point near the centre of sec. 23, T. 63–18 W.; West bay, Vermilion lake.
Ref. Annual Report, xv, pages 295, 389.

Meg. A medium-grained granite, composed of quartz, white to pink feldspar and a dark mineral which appears to be largely chlorite.

Mic. A granitic rock, composed essentially of feldspar, which is highly altered, isolated *quartz* grains and *chlorite. Epidote* and *magnetite* are present.

One section.

Age. Archean. U. S. G.

No. 928. Chlorite Schist.

"Graywacke-like rock containing syenyte in lenticular patches, southwest corner sec. 9, T. 63–17;" Long bay, Vermilion lake.
Ref. Annual Report, xv, page 390.

Meg. The specimens vary from a fine-grained, green, somewhat schistose, chloritic rock, with some feldspathic material, to a rock of a little coarser grain and resembling somewhat a dark graywacke.

Mic. The section shows a rock which is composed essentially of three minerals, *quartz, feldspar* and *chlorite.* The feldspar is considerably clouded by decay and the texture of the rock is almost granitic.

One section.

Age. Archean. U. S. G.

No. 929. Biotite Schist.

N. E. ¼ sec. 14, T. 63–18 W.; north shore of West bay, Vermilion lake.
Ref. Annual Report, xv, pages 296, 390.

Meg. The specimen is a dark-gray, biotite schist of medium grain for such a rock.

Mic. The section is composed largely of quartz, feldspar (apparently *orthoclase* and some acid *plagioclase*), *biotite* and *chlorite*, with a little *epidote* and *pyrite.*

One section.

Age. Archean.

Remark. Nos. 929 to 932 were collected to illustrate mica schist and granite and intermediate stages between these two rocks. Compare American Geologist, vol. xx, pp. 41–48. U. S. G.

NO. 930. HORNBLENDE SCHIST *(with granite).*

Same locality as No. 929.
Ref. Annual Report, xv, pages 296, 297, 390.

Meg. There are two samples of this number; one is a uniform, rather fine-grained hornblende schist, rich in feldspar; the other is a dark amphibolyte in contact with a pinkish granite. In the granite the hornblende is sometimes collected in patches.

Mic. The section was evidently made from the granite. It consists essentially of *quartz, feldspar* (apparently *orthoclase* and acid *plagioclase*), and green *hornblende,* the latter mineral being collected on one edge of the slide.

One section.

Age. Archean. U. S. G.

NO. 931. GRANITE. *(Hornblendic.)*

Same place as No. 929.
Ref. Annual Report, xv, pagee 296, 390.

Meg. A rather fine-grained, pinkish-gray, hornblende granite.

Mic. An ordinary granite, the essential minerals being *quartz, feldspar* (apparently *orthoclase* and acid *plagioclase*) and green *hornblende. Chlorite, epidote, biotite* and *sphene* are also present.

One section.

Age. Archean. U. S. G.

NO. 932. GRANITE.

Same place as No. 929.
Ref. Annual Report, xv, pages 296, 390.

Meg. A rather coarse-grained, pinkish granite composed of quartz, feldspar and a small amount of a dark mineral.

Mic. A granite, composed mainly of *quartz* and *feldspar*. The latter mineral is in three forms which are apparently *orthoclase*, acid *plagioclase* and *microline. Hornblende* seems to have been the ferro-magnesian constituent of the rock, but it was in small amount and is now represented by *chlorite.* One section.

Age. Archean. U. S. G.

No. 933. Gneiss. *(Hornblendic.)*

Sec. 14, T. 63-18 W.; north shore of West bay, Vermilion lake.
Ref. Annual Report, xv, pages 296, 390.

Meg. A rough, schistose, green rock, composed largely of hornblende with some feldspar. There are a few narrow bands, parallel to the schistosity, of feldspathic material. The rock may be called a banded gneiss.

Mic. The section was evidently made from the green part of the rock. It consists essentially of green *hornblende* and *feldspar*, which is much kaolinized and sometimes shows albite twinning lamellæ.

One section.

Age. Archean. U. S. G.

No. 934. Granite.

"Intrusive granite, obtained at the mouth of Rice river, so called, N. E. ¼ sec. 15, T. 63-18." North shore of Vermilion lake.
Ref. Annual Report, xv, page 390.

Meg. Coarse-grained, reddish granite. The minerals are feldspar, quartz and a dark mineral, in small amount, which is sometimes hornblende or chlorite and sometimes biotite. One of the specimens shows a small band of this rock cutting dark hornblende schist.

Mic. A coarse granite, composed mainly of *feldspar* and *quartz*, with a little *chlorite*. The feldspar is more or less kaolinized and appears to be acid *plagioclase perthite* and *orthoclase*. One section.

Age. Archean. U. S. G.

No. 935. Granite. *(Biotitic.)*

Small island in Partridge lake near the east line of sec. 11, T. 63-18 W., or perhaps from a reef in Vermilion lake in N. W. ¼ sec. 26, T. 63-18 W. There is uncertainty as to which of these localities is the correct one.
Ref. Annual Report, xv, pages 297, 390.

Meg. The specimen is a medium-grained, gray, biotite granite. On one side is a layer, probably a vein, of quartz and a little pink feldspar.

Mic. The section shows a granite, composed essentially of *feldspar*, *quartz* and *biotite*. The feldspar is apparently *orthoclase* and acid *plagioclase*. Considerable *chlorite* is present, and *epidote*, *sphene*, *muscovite* and iron ore also occur.

One section.

Age. Archean. U. S. G.

No. 936. Granite. *(Biotitic.)*

From a small island at the northwest corner of sec. 32, T. 63-17 W., Vermilion lake.
Ref. Annual Report, xv, pages 294, 390.

Meg. A medium-grained, light-gray granite, composed of feldspar, quartz and a comparatively small amount of biotite.

Mic. The rock is an ordinary granite; the essential minerals are feldspar, *quartz* and *biotite.* The feldspar is apparently *orthoclase* and *oligoclase*, with a little *microcline.* The quartz often shows undulatory extinction. The following accessory minerals occur in varying amounts: *chlorite, muscovite, epidote, magnetite* and *sphene.*

Two sections.

Age. Archean. U. S. G.

No. 937. Granite. *(Biotitic.)*

From a small island just east of Big island, Vermilion lake; N. W. ¼ sec. 22, T. 63–18 W.
Ref. Annual Report, xv, pages 297, 390.

Meg. A medium-grained, light-gray granite, composed of quartz, white feldspar and a comparatively small amount of biotite.

Mic. An ordinary granite, in general similar to No. 936, the essential minerals being *quartz*, feldspar (apparently *orthoclase, oligoclase* and a little *microcline*) and *biotite.*

One section.

Age. Archean. U. S. G.

No. 938. Schist *(with zoisite).*

West side of Oak island, Vermilion lake; S. W. ¼ sec. 23, T. 63–17 W.
Ref. Annual Report, xv, pages 294, 390.

Meg. A hard, gray, compact, fine-grained, but little schistose, rock looking like a graywacke or impure quartzyte.

Mic. The section is composed mainly of *quartz, feldspar* (considerably altered) and a mineral of high index of refraction and weak double refraction, which is thought to be *zoisite;* this is very abundant. Other minerals are *hornblende, chlorite, muscovite, magnetite* and *sphene.*

One section.

Age. Archean. U. S. G.

No. 939. Chlorite Schist.

Small island in S. E. ¼ sec. 31, T. 63–16 W.; Vermilion lake.
Ref. Annual Report, xv, pages 299, 390.

Meg. A soft, fine-grained, green schist. The specimen contains part of a lenticular mass of coarse, white vein quartz.

Mic. The section is fine grained, and consists essentially of *calcite, chlorite, epidote* and *quartz.* One section.

Age. Archean. U. S. G.

No. 940. Pegmatyte.

North shore of a bay of Vermilion lake, north of Pine island; S. W. ¼ sec. 23, T. 63–16 W.
Ref. Annual Report, xv, pages 301, 390.

Meg. A coarse-grained, granitic rock composed of quartz, feldspar (white and pink in color) and biotite.

Mic. *Quartz,* feldspar and biotite are the chief minerals of the section. The feldspar is considerably clouded, and appears to be *orthoclase* and acid *plagioclase.* The *biotite* is altering to *chlorite.* One section.

Age. Archean. U. S. G.

No. 941. Granite.

Same place as No. 940.
Ref. Annual Report, xv, pages 301, 390.

Meg. Pinkish, medium-grained granite, composed of quartz, feldspar and a very small amount of a dark micaceous mineral. On one side of the specimen is a contact with a much finer-grained, reddish granite.

Mic. The slide shows principally *feldspar* and *quartz.* The former is commonly much clouded and appears to be *orthoclase,* acid *plagioclase* and *perthite.* A little *chlorite* is present. One section.

Age. Archean. U. S. G.

No. 942. Granite.

N. W. ¼ sec. 25, T. 63-16 W., Vermilion lake.
Ref. Annual Report, xv, pages 301, 390.

Meg. A rather fine-grained granite, composed of feldspar and quartz, with very little of a dark mineral.

Mic. The section shows a granite, composed largely of *quartz* and feldspar, which seems to be *orthoclase* and *oligoclase,* with a small amount of *microcline.* A little *chlorite,* probably an alteration product of biotite, is present.

Age. Archean. U. S. G.

No. 943. Granite.

Locality uncertain, but north of Pine island; either the same as No. 940 or from N. E. ¼ sec. 27, T. 63-16 W., Vermilion lake.
Ref. Annual Report, xv, pages 301, 390.

Meg. A rather fine-grained, pinkish granite.

Mic. An ordinary granite, with the feldspar much clouded by alteration. The dark mineral is not abundant and is chlorite. One section. U. S. G.

No. 944. Granite. *(Biotitic.)*

Near centre of sec. 27, T. 63-16 W., Vermilion lake.
Ref. Annual Report, xv, pages 301, 390.

Meg. A fine-grained, gray to pinkish granite.

Mic. An ordinary biotite granite, with the feldspar much clouded by alteration and the biotite altering to chlorite. Some muscovite is present. One section.

Age. Archean. U. S. G.

No. 945. Gneiss. (*Dioritic.*)

S. W. ¼ sec. 23, T. 63–16 W.; north shore of Vermilion lake.
Ref. Annual Report, xv, pages 301, 390.

Meg. A medium-grained, dark-gray rock, composed mainly of hornblende and feldspar. The specimen is somewhat banded by bands in which the relative proportion and size of the grains of the two constituents vary.

Mic. The section shows a granitoid rock, composed almost entirely of green *hornblende* (in great abundance), *feldspar* (common and usually much kaolinized) and *quartz* (in small amount).

One section.

Age. Archean. U. S. G.

No. 946. Gneiss. (*Granitic.*)

N. E. ¼ sec. 27, T. 63–16 W.; north shore of Vermilion lake.
Ref. Annual Report, xv, pages 301, 390.

Meg. Fine grained, red, and composed of *feldspar*, *quartz* and a dark micaceous mineral, whose flakes are arranged with their cleavage planes nearly parallel, thus giving a gneissic structure to the rock.

Mic. An ordinary granitic rock, composed essentially of *feldspar* (commonly clouded, and in part acid *plagioclase*), *quartz* and *chlorite*.

One section.

Age. Archean. U. S. G.

No. 947. Graywacke (?)

N. E. ¼ sec. 3, T. 62–15 W.; northeast shore of Vermilion lake.
Ref. Annual Report, xv, pages 301, 390.

Meg. A greenish-gray rock of fine grain. There are small hornblendes and feldspars scattered through the rock.

Mic. This section is quite similar to No. 920.

One section.

Age. Keewatin. U. S. G.

No. 948. Chlorite Schist.

"On the N. W. ¼ sec. 28, T. 63–11 [Garden lake], a diabasic green rock (No. 949) cuts a greenish, hard, finely schistose rock (No. 948), the contact being well exposed on the south side for a distance of a few feet."
Ref. Annual Report, xv, pages 329, 390.

Meg. A soft, green, fine-grained schist.

Mic. The section shows *chlorite*, *calcite*, *quartz* (and perhaps also feldspar) and *epidote*. There is much fine, granular material which is perhaps *epidote*.

One section.

Age. Keewatin. U. S. G.

No. 949. "Greenstone."

See under No. 948.
Ref. Annual Report, xv, pages 329, 390.

Meg. A fine-grained, soft, much decayed greenstone.

Mic. The section is a poor one. It shows irregular grains of *feldspar* and *quartz*, also some *hornblende* and much chloritic indistinct secondary material. The feldspar is much altered, *zoisite* and *kaolinite* having been developed in the alteration, and some of it still shows albite twinning lamellæ.

One section.

Age. Keewatin. U. S. G.

No. 950. Cummingtonite Schist.

"At the lower end of the rapids which are formed where White Iron lake descends to Garden lake, N. E. ¼ sec. 32, T. 63–11, are two short, small tunnels, running in opposite directions, into a siliceous schist or bedded quartzyte, which disturbs the compass needle by magnetic attraction. It dips N. N. E. 80° to 85°. It is somewhat brecciated, and recemented by chemical silica and pyrites. In some places this bedded quartzyte is black, and in others blue, sonorous and brittle, recalling the Animikie quartzytes. It is represented by No. 950. The quartz in which the tunnels were excavated is represented by No. 951. This locality is known locally as *Silver City*, so named by the proprietor of the tunneling."
Ref. Annual Report, xv, pages 329, 390; Annual Report, xvii, pages 194, 208; Bulletin vi, pages 8, 421.

Meg. A fine-grained, hard, gray, siliceous schist.

Mic. The rock is composed of three minerals, *quartz*, *cummingtonite* and *magnetite*. The main part of the rock is of quartz, and the other minerals vary considerably in amount. The quartz is in interlocking grains of nearly uniform size. The cummingtonite is in small flakes scattered through the rock, the elongation being usually in a common direction. This mineral at times shows twinning lamellæ parallel with the elongation and the cleavage, and an extinction angle as high as 15°. These characters agree with grünerite, but on account of the double refraction of this mineral, which is approximately .02, it is referred to *cummingtonite* rather than to grünerite, whose double refraction is much stronger (.056). The magnetite is scattered through the rock and is often included in the quartz; the magnetite is in grains and crystals (octahedrons) of varying size.

Three sections.

Age. Keewatin. U. S. G.

No. 951. Quartz.

Same locality as No. 950.
Ref. Annual Report, xv, pages 329, 390; Bulletin vi, pages 8, 421.

Meg. Gray, vitreous, rusty-weathering, vein quartz.

Mic. The section shows quartz grains of various sizes interlocking by very irregular sutures. Considerable of a dark, earthy material is scattered through the rock in small masses. One section.

Age. Vein in Keewatin rocks. U. S. G.

No. 952. Syenyte. *(Hornblendic.)*

West side of White Iron lake; sec. 6, T. 62–11 W.
Ref. Annual Report, xv, pages 329, 390.

Meg. A medium-grained, pinkish-gray, hornblende syenyte.

Mic. The section is composed essentially of feldspar and green, more or less fibrous *hornblende.* The feldspar is *orthoclase* and acid *plagioclase* and perhaps also *anorthoclase.* Other minerals present in small amount, are: *chlorite, magnetite, epidote, sphene* and *quartz.* A microchemical test, with hydrofluosilicic acid, of a grain of feldspar showed the presence of soda and lime, but practically no potash.

One section.

Age. Archean. U. S. G.

No. 953. Granite. *(Porphyritic.)*

Sec. 19, T. 62–11 W.; river bank on the portage from White Iron lake to Birch river.
Ref. Annual Report, xv, pages 329, 334, 336, 390.

Meg. A medium-grained, pinkish, hornblende granite, with porphyritic crystals of flesh-colored feldspar.

Mic. The rock is quite similar to No. 952, except for the presence of more *quartz* and some *microcline.* A microchemical test, with hydrofluosilicic acid, of one of the porphyritic feldspars gave much soda and potash and almost no lime, thus indicating *anorthoclase.* A test of a grain of feldspar from the groundmass gave the same result.

One section.

Age. Archean. U. S. G.

No. 954. Gabbro. *(Olivinitic.)*

Near the N. W. ¼ sec. 17, T. 61–11 W.; east side of Birch lake.
Ref. Annual Report, xv, pages 332, 333, 390; Annual Report, xvii, pages 194, 207.

Meg. A rather coarse-grained, gray gabbro. Feldspar is the most abundant mineral and occurs in grains and plates which frequently show the striation due to polysynthetic twinning. Biotite is quite noticeable, and pyroxene, olivine and magnetite also occur. The mass is in laminæ due to the linear arrangement of the olivine grains.

Mic. The sections show a fresh gabbro. The minerals are feldspar (probably *labradorite), olivine, pyroxene* (*augite* and some pleochroic pyroxene which is probably *hypersthene*), *biotite, magnetite, pyrite* and greenish and brownish alteration products of the olivine. The rock exhibits many interesting features and would make a good subject for detailed study.

Three sections.

Age. Cabotian. U. S. G.

No. 955. Gneiss. *(Granitoid.)*

From boulders in N. W. ¼ sec. 26, T. 61–12 W.; north shore of Birch lake.
Ref. Annual Report, xv, pages 333, 334, 391.

Meg. A medium-grained, dark-gray, granitic gneiss.

Mic. A schistose rock appearing like a sheared granite, the grains being broken and apparently granulated around the edges. The chief minerals are *quartz*, *feldspar* and dark brown *biotite*.

One section.

Age. Boulders of Archean rocks. U. S. G.

No. 956. Gneiss. *(Hornblendic muscovadite?)*

From boulders in N. W. ¼ sec. 26, T. 61–12 W.; north shore of Birch lake.
Ref. Annual Report, xv, pages 333, 391.

Meg. A dark-gray gneiss of medium grain.

Mic. The section shows a somewhat confused aggregate composed essentially of the following minerals: *feldspar*, *biotite*, *hornblende*, *chlorite*, *magnetite* and *quartz*. The feldspar is in irregularly interlocking grains and commonly forms the background of the rock, this mineral holding the other minerals poikilitically.

One section.

Age. Boulders of Archean (?) rock. U. S. G.

No. 957. Cummingtonite Schist.

From boulders in N. W. ¼ sec. 26, T. 61–12 W.; north shore of Birch lake.
Ref. Annual Report, xv, pages 333, 391.

Meg. Similar to No. 950.

Mic. This rock appears similar to No. 950, except that it (No. 957) is coarser grained and the *cummingtonite* is of a greenish tint, is slightly pleochroic and is often colored brownish, due to staining or alteration.

Two sections.

Age. Boulders of Archean rock. U. S. G.

No. 958. Granite. *(Breccia.)*

N. E. ¼ S. E. ¼ sec. 21, T. 61–12 W.; point on the north side of Birch lake.
Ref. Annual Report, xv, pages 333, 391; Annual Report, xvii, pages 195, 207.

Meg. Irregular masses of dark-gray, fine-grained rock, inclosed in a cement of rather fine-grained, light-gray to pinkish granite.

Mic. The dark masses are composed of a granitic aggregate of *hornblende*, *feldspar*, much of which is clearly *plagioclase*, and *quartz*. The cementing rock is an ordinary biotite granite. The sections do not show the junction of the two kinds of rock.

Two sections.

Age. Archean. U. S. G.

No. 958A. Granite.

Same place as No. 958.
Ref. Annual Report, xv, pages 333, 391.

Meg. A fine-grained, dark-gray, granitic rock. This sample represents the dark masses included in No. 958, and is spoken of in the field notes as a mica schist. The hand specimen is too small to show the schistose character of the rock.

Mic. A granitic aggregate of *feldspar, quartz, hornblende* and *biotite.* Some micropegmatyte is present. The rock may be a quartz dioryte rather than a granite; the feldspar was not determined, but considerable of it is plagioclase.

One section.

Age. Archean. U. S. G.

No. 958B. Granite. *(Vein.)*

Same place as No. 958.
Ref. Annual Report, xv, pages 333, 391.

Meg. From a small vein or dike in No. 958A. The component minerals are quartz and feldspar.

No section.

Age. Archean. U. S. G.

No. 959. Granite. *(Biotitic.)*

Sec. 23, T. 61–12 W.; north shore of Birch lake.
Ref. Annual Report, xv, pages 334, 336, 391.

Meg. A fine-grained, gray granite.

Mic. A granite whose essential components are *quartz, feldspar* and *biotite.* Magnetite and chlorite are also common.

One section.

Age. Archean. U. S. G.

No. 960. Iron Ore *(with olivine, etc.)*.

S. E. ¼ S. W. ¼ sec. 24, T. 61–12 W.; near north shore of Birch lake.
Ref. Annual Report, xv, pages 335, 339, 391; Annual Report, xvii, page 195.

Meg. A heavy, crystalline rock, composed largely of magnetite and with another mineral which is in large plates. Compare Nos. 976, 1138.

Mic. The rock is one of the "olivinitic iron ores," which are found in a number of places along the north side of the gabbro. There are several sections of this number, showing varying conditions. The essential minerals present are *magnetite, pyroxene, olivine, quartz* and amphibole (perhaps *grünerite*). The pyroxene is both monoclinic *(diallage)* and orthorhombic *(enstatite* or *hypersthene)* and the two are sometimes intergrown. Five sections.

Age. Keewatin or Animikie. U. S. G.

No. 961. Granite. *(Contact.)*

"Rock No. 961 shows the contact between the coarse syenyte like No. 953, as it occurs near the southwest corner of sec. 24, T. 61–12, and the granite Nos. 955 and 959."

Ref. Annual Report, xv, pages 334, 391.

Meg. A coarse-grained, sub-porphyritic, hornblende biotite granite, in sharp contact with a fine-grained biotite granite.

Mic. The slide was evidently made from the coarse-grained part of the hand sample. The rock is a granite, the essential minerals being *feldspar*, *quartz* and *biotite*. Chlorite, magnetite and sphene also occur. One section.

Age. Archean. U. S. G.

No. 962. Gabbro (?)

About one-fourth mile west of No. 961.

Ref. Annual Report, xv, pages 336, 391.

Meg. The hand specimens vary some in grain and in general appearance. Some look like fine-grained, magnetic rocks, recrystallized by the gabbro, and others seem to be fine-grained gabbros.

Mic. The rock has a granitic texture and consists of *pyroxene* (at least some of which appears to be orthorhombic), brownish *hornblende*, *magnetite*, *feldspar* and *quartz*. One of the sections shows light colored areas in a dark background. These areas are composed mainly of feldspar and pyroxene, the latter sometimes in poikilitic plates, while the background consists largely of hornblende.

Two sections.

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

Remark. This rock is apparently allied to No. 960. One specimen, of which no section was made, is a fine-grained heavy iron ore. N. H. W.

No. 963. Syenyte. *(Biotitic.)*

S. W. ¼ S. W. ¼ sec. 24, T. 61–12 W., just east of the line between sections 23 and 24; near the north shore of Birch lake.

Ref. Annual Report, xv, pages 336, 391; Annual Report, xvii, pages 195, 207.

Meg. Fine-grained, reddish syenyte, with some porphyritic reddish feldspars.

Mic. The rock is a granitic one, composed largely of feldspar, which seems to be mostly *orthoclase*. *Biotite* is common, and *magnetite* and *chlorite* occur.

Two sections.

Age. Archean. U. S. G.

No. 964. Granite. *(Hornblendic.)*

"Rock No. 964 shows a coarse syenyte, lying on No. 965, apparently conformably; No. 964A is from a vein (or dike) of fine granular granite, six inches wide, running across the bedding of No. 964 and blending with No. 965. No. 964B is mica schist, a condition of No. 964A, in small patches." S. E. ¼ sec. 22, T. 61–12 W.; point on north shore of Birch lake.

Ref. Annual Report, xv, pages 334, 335, 391.

Meg. A medium-grained, reddish, hornblende granite.

Mic. A granite, composed essentially of feldspar, quartz and hornblende, which last is largely replaced by biotite and chlorite.

One section.

Age. Archean. U. S. G.

No. 964A. Granite. *(Biotitic.)*

See under No. 964.
Ref. Annual Report, xv, pages 334, 335, 391.

Meg. A rather fine-grained, pinkish, biotite granite.

Mic. An ordinary granite, the essential minerals being quartz, feldspar and biotite.

One section.

Age. Archean. U. S. G.

No. 964B. Mica Schist.

See under No. 964.
Ref. Annual Report, xv, pages 334, 391.

Meg. Hand specimen not found. No section.

Age. Archean. U. S. G.

No. 965. Granite. *(Biotitic.)*

"Rock No. 965 is fine-grained granite, in bedded regular dip E. 30°. No. 965A is from a vein (or dike) of coarse syenyte running zigzag in No. 965." Same place as No. 964.
Ref. Annual Report, xv, pages 334, 335, 391.

Meg. A fine-grained, gray, biotite granite.

Mic. A granitic aggregate essentially of feldspar (considerably clouded), quartz and biotite. One section.

Age. Archean. U. S. G.

No. 965A. Pegmatyte.

See under No. 965.
Ref. Annual Report, xv, pages 335, 391.

Meg. A coarse-grained aggregate of quartz and pinkish feldspar.

Mic. Quartz and feldspar, the latter commonly showing fine albite twinnings.

One section.

Age. Archean. U. S. G.

No. 966. Granite.

Same place as No. 964.
Ref. Annual Report, xv, pages 335, 391.

Meg. Rather coarse-grained granite composed of quartz, white, pinkish and red feldspar and apparently both hornblende and biotite, *Mic.* Quartz and feldspar make up most of the rock. The latter mineral is usually clouded by alteration and is sometimes reddened. Magnetite is present, and there are alteration products, chief among which is chlorite.

One section.

Age. Archean. U. S. G.

No. 967. Granite. *(Epidotic.)*

North side of sec. 21, T. 61–12 W.; bay on the north side of Birch lake. Occurs in the form of a dike cutting coarse granitic rock.
Ref. Annual Report, xv, pages 336, 391.

Meg. A medium-grained, reddish granite.

Mic. The section shows much feldspar, considerably clouded, and some epidote, hornblende, chlorite, magnetite and quartz.

One section.

Age. Archean. U. S. G.

No. 968. Granite. *(Hornblendic.)*

Near the same place as No. 967.
Ref. Annual Report, xv, pages 336, 337, 391.

Meg. A rather coarse-grained, gray granite. The specimen is crossed by a band of lighter color and finer grain.

Mic. The essential minerals of this granite are feldspar, quartz, hornblende and biotite. Chlorite, epidote, sphene and magnetite also occur.

One section.

Age. Archean. U. S. G.

No. 969. Dioryte.

From a dike, eighteen inches wide, in the S. E. ¼ sec. 29, T. 61–12 W.; Birch lake.
Ref. Annual Report, xv, pages 337, 391; vol. iv, page 261.

Meg. A medium-grained, greenish rock, composed largely of hornblende. It is crossed by a vein-like form of rusty, porous, feldspar rock.

Mic. The dark portion of the rock is composed very largely of green hornblende, while the vein of feldspar rock is made up of much clouded feldspar.

One section.

Age. Archean. U. S. G.

No. 970. Dioryte.

Schistose part of same dike as No. 969.
Ref. Annual Report, xv, pages 337, 391.

Meg. A fine-grained, dark-gray rock, with coarser feldspars.

Mic. The section shows a rock composed essentially of green hornblende and more or less altered feldspar. Sphene is common. One section.

Age. Archean. U. S. G.

No. 971. Dioryte.

Schistose part of the same dike as No. 969.
Ref. Annual Report, xv, pages 337, 391.

Meg. Rock similar to No. 970, in sharp contact with a coarse-grained, gray, hornblende syenyte.

Mic. The section was made from the syenyte. It is composed essentially of feldspar, commonly clouded, and hornblende.

One section.

Age. Archean. U. S. G.

No. 972. Gneiss. *(Granitoid.)*

From a point a little north of No. 969.
Ref. Annual Report, xv, pages 337, 392.

Meg. A fine-grained, gray, biotite granite or granitoid gneiss. The hand sample does not show the gneissic structure of the rock very markedly.

Mic. The section shows an ordinary granite, the essential minerals being feldspar, quartz and biotite.

One section.

Age. Archean. U. S. G.

No. 973. Gneiss. *(Dioritic.)*

"Hornblende gneiss, a phase of No. 972, from the northwest corner of sec. 30, T. 61–12." Birch lake.
Ref. Annual Report, xv, pages 338, 392.

Meg. Medium-grained, dark-gray, dioritic rock. Parts of the specimens are light colored, but the gneissic structure is not well shown in the hand samples.

Mic. The section shows a granitoid rock the essential minerals of which are hornblende and feldspar. The latter mineral is usually much clouded by kaolinization.

One section.

Age. Archean. U. S. G.

No. 974. Gneiss. *(Dioritic.)*

"Shows the same rock (No. 972) undergoing a change toward mica schist; from the same locality."
Ref. Annual Report, xv, pages 338, 392.

Meg. A dark-gray, rather fine-grained, roughly schistose rock.

Mic. The section is in general similar to that of No. 973. One section.

Age. Archean. U. S. G.

No. 975. Gneiss. *(Dioritic.)*

"Two other samples of No. 972, here a mottled schist, from the extreme west end of Birch lake, south of the mouth of Birch river."
Ref. Annual Report, xv, pages 339, 392.

Meg. A gneissic rock, varying in color, composed mainly of feldspar and hornblende.

Mic. The section is similar to those of Nos. 973 and 974, but in this rock (No. 975) the feldspar is more abundant than in the other two.

One section.

Age. Archean. U. S. G.

No. 976. Magnetite, Olivine, Quartz. *(Ferruginous muscovadyte.)*

From a boulder a quarter of a mile south of the second trail-crossing of Dunka river; S. W. ¼ sec. 10, T. 62–12. (Compare Nos. 960 and 1138.)
Ref. Annual Report, xv, pages 341, 392; Annual Report, xix, pages 121, 127.

Meg. Black, magnetic, with quartz and olivine apparent.

Mic. *Quartz*, *olivine*, *magnetite* and *grünerite* (?) make up this rock, magnetite being most abundant and olivine next, all being of secondary generation from the jaspilyte lodes of the Keewatin when impure with intermingling of basic sedimentary material, the recrystallization having resulted from the action of the gabbro. In the olivine of this section is a good illustration of a fact which is not uncommon in the generation of secondary minerals, viz.: The larger olivines often embrace a number of fine globular grains of the same mineral, as illustrated by figure 6, plate II.

Age. In the annual report this ore was placed as the bottom of the Animikie, but is now believed to be a modified condition of the Keewatin ores, always accompanied by muscovadyte.

Remark. Although the specimen was obtained from a boulder, the rock is *in situ* in the immediate vicinity.

According to Hintze the grünerite, determined by Lane and Sharpless, should have been called cummingtonite (Handbuch der Minéralogie, Bd. II, page 1230). Examined by Prof. Dodge this ore gave no titanium. The structure of this rock is illustrated by figure 5, plate II. N. H. W.

No. 977. Gabbro. *(Olivinitic.)*

S. W. ¼ sec. 10, T. 62–12 W.; at the second crossing of the river by the trail which runs from Birch lake southward along Dunka river.
Ref. Annual Report, xv, pages 341, 392.

Meg. A fine-grained, yellowish-gray, granular rock.

Mic. The section shows a granitoid rock consisting chiefly of *plagioclase*, pyroxene and *olivine*. At least some of the *pyroxene* is orthorhombic, apparently *hypersthene*. *Magnetite* and *biotite* are common.

One section.

Age. Cabotian. U. S. G.

No. 978. Dioryte.

S. E. ¼ sec. 28, T. 61–12 W.; Birch lake.
Ref. Annual Report, xv, pages 340, 392.

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

Mic. The section shows a granitoid rock, whose essential minerals are *feldspar* and *hornblende.* The former is largely *plaigoclase.* Some magnetite and quartz are present.

One section.

Age. Archean. U. S. G.

NO. 979. GRANITE.

From "the palisades" on the east shore of the Kawishiwi river; N. W. ¼ S. W. ¼ sec. 4, T. 62–10 W.
Ref. Annual Report, xv, pages 343, 344, 392; Annual Report, xvii, pages 195, 207.

Meg. Fine-grained, gray to reddish granite.

Mic. The section shows a granitè, composed essentially of feldspar and quartz. The latter is much clouded and is sometimes reddened.

One section.

Age. Archean. U. S. G.

NO. 980. "GREENSTONE"(?) *(Flinty.)*

Small island near the north shore of the Kawishiwi river; S. E. ¼ N. W. ¼ sec. 19, T. 63–9 W.
Ref. Annual Report, xv, pages 346–348, 392.

Meg. The specimens show a rock which seems to be banded. Parts of the rock are very fine grained, flinty and green or greenish gray in color, while others are of a somewhat coarser grain and are almost black in color.

Mic. In thin section the rock appears of fine, but varying grain, composed of quartz, feldspar, biotite, chlorite, hornblende, epidote and magnetite.

One section.

Age. Keewatin.

Remark. This rock probably represents a crystallized clastic. U. S. G.

NO. 981. GNEISS. *(Biotitic.)*

From a small island a short distance southeast of the island from which No. 980 was obtained.
Ref. Annual Report, xv, pages 346, 347, 392.

Meg. A fine-grained, gray, biotite gneiss.

Mic. The section shows a granitoid rock, whose chief constituents are feldspar, quartz and biotite, the latter in part altering to chlorite.

One section.

Age. Archean. U. S. G.

NO. 982. GABBRO (?) *(Granulitic.)*

"Northeast ends of the little northeast and southwest lakes, secs. 15 and 16, T. 63–9." Kawishiwi river.
Ref. Annual Report, xv, pages 351, 392; Annual Report, xxi, page 145.

Meg. The specimens vary, but in general consist of a fine-grained, yellowish-gray, granular rock, in which biotite scales are noticeable.

Mic. The section is a poor one. The rock is granular in texture and many of the grains of the ferromagnesian minerals have rounded outlines. The minerals appear to be *feldspar*, *quartz*, *pyroxene*, *hornblende* and *magnetite.* The magnetite of this rock was tested for titanium, but none was found.

One section.

Age. Probably Keewatin metamorphosed by Cabotian gabbro.

Remark. This rock is in general similar to No. 983. U. S. G.

No. 983. Noryte (?) *(Granulitic.)*

Same place as No. 982.
Ref. Annual Report, xv, pages 351, 352, 392; Annual Report, xxi, pages 144–146.

Meg. A grayish rock of rather fine grain. The hand specimen is homogeneous throughout and shows no gneissic or other parallel structures. It is compact and not crumbling. Numerous glistening scales of biotite are easily seen, and under the lens the rock appears granular, but the constituent minerals cannot be made out, although one would judge that quartz formed a large part of the rock. Rock appears fresh. Does not effervesce with cold hydrochloric acid.

Mic. The section shows a closely-compact, fine-grained granular mixture of quartz, feldspar, biotite, iron ore, and a mineral referred to pyroxene. The grain is so fine that under crossed nicols the different grains are not all distinctly separated, nor do some of them extinguish completely; this, however, is due to the overlapping of the grains; there is no "amorphous" or "chalcedonic" silica present (compare section of jaspilyte in Bulletin vi, plate VIII, figure 1). The rock is thus completely crystalline, and is quite fresh.

The *biotite* is the most noticeable mineral; it occurs in large flakes which often hold many pieces of quartz, some magnetite, and occasionally pyroxene.

The *pyroxene* is in small rounded grains and elongated ones which, however, never show any crystal faces. It has quite a high index of refraction. It contains enclosures of magnetite and numerous transparent areas which seem to be liquid cavities. A slight cleavage is often developed parallel to the long axes of the grains. The extinction is almost always parallel to this cleavage and the mineral often is slightly pleochroic; from these two facts it is referred to the group of orthorhombic pyroxenes—probably it is *enstatite* or *bronzite.* On account of the smallness of the grain and the difficulty of obtaining a good interference figure with the instrument in use, the optical properties were not further studied. This mineral is greenish in color. In the pleochroic individuals the ray vibrating parallel to the cleavage is colorless or greenish and the other of a very light pinkish or reddish shade. This corresponds to the pleochroism of orthorhombic pyroxenes. Monoclinic pyroxene is probably present in small amount.

The *iron ore* is undoubtedly magnetite; it is in small grains with more or less distinct faces, but with the angles rounded.

The pyroxene and iron ore are probably older than the mass of the rock, which is composed of quartz and feldspar, and the biotite encloses all.

The *feldspar* is abundant; it frequently shows polysynthetic twinning, and is thus plagioclase; but the kind of plagioclase is uncertain. There is also considerable feldspar which is not twinned and which may be orthoclase, or untwinned plagioclase.

The *quartz* is in fine grains, even finer than most of the feldspar. There are many grains, which show no cleavage, or twinning, whose nature it is not easy to determine. Many of such grains, supposed to be quartz, give a biaxial interference figure; and others give no distinct figure. I examined about twenty sections which I thought might be basal sections of quartz; only one out of these twenty gave a distinct uniaxial interference figure; this was tested and found to be +. Four or five gave biaxial figures, and the others gave no definite figures. The feldspar is unaltered, and so is hard to distinguish from quartz, when twinning, cleavage or interference figures are not to be seen. It is my opinion that there is much less quartz in the rock than I had supposed. Thus, so far, I am sure of but one grain; there are, however, undoubtedly more, but I should guess that quartz makes up less than one-tenth of the rock, and I feel certain that it does not make up one-fifth of the rock.

The magnetite of Nos. 982 and 983, was tested for titanium, but none was found.

Age. Probably Keewatin metamorphosed by Cabotian gabbro.

Remarks. This rock is one of those to which the term "muscovado" has been applied. This specimen now shows nothing that can be taken as proof of an original clastic nature. It is lithologically a fine-grained quartz biotite noryte. It may be a recrystallized sediment or an original eruptive; but from its field relations and from general considerations, it is thought probably not to be in its present condition a true eruptive. It seems to represent a Keewatin rock modified by the gabbro, although originally it may have been of igneous origin. Compare rocks Nos. 1089-1092. U. S. G.

NO. 984. GABBRO (?)

Same place as No. 982.
Ref. Annual Report, xv, pages 351, 392.

Meg. A fine-grained, gray, granular rock with biotite.

Mic. This rock is in general similar to Nos. 982 and 983. The section shows apparently *quartz*, feldspar (usually kaolinized), *biotite*, *hornblende*, *pyroxene* and *magnetite*.

One section.

Age. Probably Keewatin metamorphosed by Cabotian gabbro. U. S. G.

No. 985. Gabbro.

S. W. ¼ sec. 16, T. 63–9 W.; near the Kawishiwi river.
Ref. Annual Report, xv, pages 352, 392.

Meg. A fine-grained, yellowish-gray, granitoid rock.

Mic. The section is too thick for study, but it shows a fine-grained gabbro whose chief minerals are plagioclase, diallage and magnetite.

One section.

Age. Cabotian. U. S. G.

No. 986. Gneiss.

N. W. ¼ sec. 20, T. 63–9 W.; north side of the Kawishiwi river.
Ref. Annual Report, xv, pages 352, 392.

Meg. A fine-grained, gray, granular rock.

Mic. The section is of fine grain and the chief minerals are *quartz, feldspar, hornblende* and *biotite.*

One section.

Age. Probably Keewatin metamorphosed by Cabotian gabbro. U. S. G.

No. 987. Greenstone.

From the hill in sec. 18, T. 63–9 W.; north of the Kawishiwi river.
Ref. Annual Report, xv, pages 346, 347, 354, 392.

Meg. One of the fine-grained, non-schistose greenstones.

Mic. The section shows a greenstone composed largely of green hornblende with some feldspathic material. In places there are indications that the feldspar in part existed in small, scattered, lath-shaped forms.

One section.

Age. Keewatin. U. S. G.

No. 988. Amphybolyte.

From the summit of a small ridge between No. 987 and the shore of the Kawishiwi river.
Ref. Annual Report, xv, pages 346, 347, 392.

Meg. A rather coarse-grained, dark-gray rock composed mainly of hornblende.

Mic. The section shows large amounts of green, commonly fibrous hornblende, with smaller amounts of fine-grained feldspar and perhaps also quartz. Biotite and magnetite are also present. One section.

Age. Keewatin. U. S. G.

No. 989. Gneiss.

N. W. ¼ N. W. ¼ sec. 27, T. 63–10 W.; south shore of the Kawishiwi river.
Ref. Annual Report, xv, pages 352, 392; Annual Report, xvii, pages 195, 206.

Meg. A fine-grained, gray rock varying somewhat, but in general gneissic and feldspathic.

Mic. The section shows a granitoid rock in which the chief mineral is *feldspar;* this is considerably kaolinized, and sometimes shows albite twinnings, but much of it is too far altered to exhibit these twinnings, even if they originally existed. In addition to the feldspar, *quartz, chlorite* and *epidote* are seen.

One section.

Age. Archean. U. S. G.

No. 990. Gneiss.

N. W. ¼ sec. 27, T. 63–10 W.; shore of the Kawishiwi river north of No. 989.
Ref. Annual Report, xv, pages 352, 392; Bulletin vi, pages 68, 421.

Meg. A hard, fine-grained, creamy-white rock.

Mic. The section shows a granitoid rock composed essentially of the following minerals: *quartz, feldspar*, much clouded by kaolinization, and *epidote.*

One section.

Age. Archean. U. S. G.

No. 991. Gneiss.

N. W. ¼ N. W. ¼ sec. 27, T. 63–10 W.; island in the Kawishiwi river.
Ref. Annual Report, xv, pages 352, 353, 392; Annual Report, xvii, pages 195, 206; Bulletin vi, pages 68, 421.

Meg. A gray, red-weathering, fine-grained, lightly feldspathic gneiss.

Mic. The sections show a granitoid rock in which feldspar is the chief constituent, and quartz is less abundant. The *feldspar* is usually considerably clouded by kaolinization and is plagioclase and apparently *orthoclase. Epidote, green hornblende* and chlorite are the chief accessory minerals. There is one small crystal, perhaps *zircon,* surrounded by hornblende. Two sections.

Age. Archean. U. S. G.

Remark. The decayed feldspars of Nos. 989, 990 and 991 are in remarkable contrast with the other minerals. *They never interlock*, although in contact. They are surrounded, more or less, and sometimes reconstructed, by secondary granular quartz and feldspar. Occasionally the green hornblende also surrounds small grains of decayed feldspar, and otherwise shows its date of origin was later than the feldspars; but other hornblendes were coeval with or earlier than the feldspars. In several respects these rocks resemble the granites of Kekequabic lake. One hornblende (which surrounds a small zircon) is bounded by the prism faces and is twinned. It is nearly a perfect crystal and must date (as augite) from the earliest condition of the rock. A little of the feldspar, some of the hornblende, all of the epidote and all of the quartz are secondary. The earliest condition of these rocks probably embraced feldspar and quartz chiefly, with a little augite and zircon, and perhaps hornblende, constituting a graywacke. The fine, fragmental, weathered surface of this rock (No. 991) is shown by photograph in plate II, figure 7. N. H. W.

No. 992. Syenyte. *(Epidotic.)*

N. W. ¼ sec. 27, T. 63-10 W.; north shore of the Kawishiwi river and a little east of No. 990.
Ref. Annual Report, xv, pages 352, 392; Bulletin vi, pages 68, 421.

Meg. A medium-grained, reddish, decayed syenyte.

Mic. The section shows two chief minerals, *feldspar* and *epidote.* There is also some *chlorite* and some quartz. The rock is considerably altered.

One section.

Age. Archean. U. S. G.

No. 993. Syenyte.

N. W. ¼ sec. 27, T. 63-10 W.; near No. 992.
Ref. Annual Report, xv, pages 353, 354, 392, 393; Bulletin vi, pages 68, 421.

Meg. A rather coarse-grained, reddish syenyte.

Mic. The section is composed largely of considerably altered feldspar. Other minerals are *chlorite, quartz, magnetite, muscovite* and *tourmaline.*

One section.

Age. Archean. U. S. G.

Remark. The section was taken from a slickensided and crushed mass, and, although the grains may have had an interlocking structure originally, they are now so crushed and decayed, though re-cemented by quartz, that they do not show it. N. H. W.

No. 994. Granite.

N. E. ¼ N. W. ¼ sec. 26, T. 63-10 W.; south shore of the Kawishiwi river.
Ref. Annual Report, xv, pages 353, 393; Annual Report, xvii, pages 195, 207; Bulletin vi, pages 68, 421.

Meg. A fine-grained, reddish granite.

Mic. A granitoid rock whose chief minerals are feldspar (often considerably altered), quartz, epidote, chlorite, magnetite and pyrite. Two sections.

Age. Archean. U. S. G.

No. 995. Gneiss. *(Hornblendic.)*

Rapids in the Kawishiwi river; north part of sec. 8, T. 63-10 W.
Ref. Annual Report, xv, pages 353, 393; Bulletin vi, pages 68, 421.

Meg. A rather fine-grained, gray, granitoid rock.

Mic. A granitoid rock composed chiefly of feldspar (often considerably altered), quartz and hornblende. Epidote, chlorite, magnetite and apatite are present.

One section.

Age. Archean. U. S. G.

No. 996. Greenstone.

N. W. ¼ sec. 21, T. 63-10 W.; from a hill range just north of the foot of a portage along the Kawishiwi river.
Ref. Annual Report, xv, pages 346, 393.

Meg. A fine-grained, dark-green, soft, much fractured rock.

No section.

Age. Keewatin. U. S. G.

No. 997. Greenstone.

Kawasachong falls.

Ref. Annual Report, xv, pages 319, 320, 346, 393; Bulletin vi, pages 39, 421. (Compare No. 356.)

Meg. Soft, fine-grained, roughly schistose greenstone. There are two specimens, one finer grained than the other.

Mic. The finer-grained section is composed largely of chlorite and altered feldspar. There is some *hornblende*, *quartz* and *magnetite*. In places, the feldspar takes a lath-shaped form, suggesting that the original rock may have been a diabase. The other section consists mainly of hornblende and altered feldspar. Chlorite, quartz and a gray opaque substance, are present; the last is perhaps an alteration product of ilmenite.

Two sections.

Age. Lower Keewatin. U. S. G.

No. 998. Greenstone.

Rapids above Kawasachong falls.

Ref. Annual Report, xv, pages 319, 320, 393; Bulletin vi, pages 37, 39, 40, 421, plate V, figure 5. (Compare No. 356.)

Meg. A medium-grained, green rock, composed largely of hornblende.

Mic. Dr. H. Hensoldt's description of this section is as follows:*

"A hornblende-dioryte of similar structure and composition as No. 999, but containing a perceptible admixture of quartz. The hornblende scales are much larger than in No. 999, but their feeble dichroism indicates a more advanced chloritization. The feldspar is exceedingly turbid and has lost its optical properties, no twinning lamellation being perceptible in any of the crystals, but the forms of the original prisms are still preserved. The quartz grains have a fragmental appearance and do but seldom show rounded forms; they are small and easily distinguished by their transparency and brilliant polarization. This dioryte contains little if any magnetite, but we observe in the section numerous crystals of titaniferous iron, surrounded by a peculiar grayish-white alteration product."

One section.

Age. Lower Keewatin. U. S. G.

No. 999. Greenstone.

Above No. 998 and near Garden lake.

Ref. Annual Report, xv, pages 319, 320; Annual Report, xvi, page 111; Bulletin vi, pages 37, 39, 40, 421, plate V, figure 4.

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*Bulletin vi, p. 40.

Meg. A medium-grained, dark-gray, massive rock, with much hornblende. Compare No. 356.

Mic. Dr. H. Hensoldt's description of this section is as follows:*

"The principal constituents of this rock are *plagioclase, hornblende* and a greenish alteration product, which may be termed viridite. If we examine a section under a magnification of, say, sixty diameters, we observe a grayish feldspathic matrix or groundmass, in which numerous crystals of hornblende of a dark-green color lie embedded. These crystals vary considerably in size; some exceed one millimeter in actual diameter while others are barely distinguishable on account of their minuteness; their shape is mostly that of elongated scales or prisms, though rhombohedral outlines are by no means uncommon. These hornblende crystals have been rendered more or less turbid by decomposition and have become clouded by ferric hydroxide or dust-like magnetite, as alteration products, but in the main their characteristics are preserved.

"In addition to the hornblende crystals, large, irregular, colorless patches, surrounded by a pale, greenish fringe, are noticeable in the feldspathic matrix, and in many instances these colorless masses present distinct hexagonal outlines. It is extremely probable that these are pseudomorphs after biotite, the latter having been completely changed into calcite and greenish fibrous epidote.†

"In the original condition of the rock, the grayish matrix was doubtless a colorless triclinic feldspar (possibly labradorite) which has been rendered turbid by partial kaolinization. Its optical properties are now almost completely destroyed, no twin lamellation and only a very faint chromatic display being noticeable. A few small colorless hexagonal sections indicate the presence of *apatite.*

"Dust-like grains of *magnetite* are scattered all over the field and a number of larger crystals with distinct cubical and octahedral outlines are likewise observable."

One section.

Age. Lower Keewatin. U. S. G.

No. 1000. Quartz Schist. *(Magnetic.)*

From the upper end of the rapids from Garden lake to Fall lake.
Ref. Annual Report, xv, pages 319, 320, 393.

Meg. Very fine-grained, dark, and heavy with magnetite.

Mic. In the midst of the interlocking fine quartzes and the grains of magnetite, are acicular sections of a rather highly polarizing mineral with no apparent pleochroism, and constant multiple twinning, which is probably *grünerite.* One section.

Age. Lower Keewatin. N. H. W.

**Bulletin vi*, pp. 39, 40.

† All the smaller biotite scales have been transformed into chlorite or epidote, without a trace of calcite.

No. 1001. Iron Ore.

Harvey test pits, S. E. ¼ sec. 27, T. 63–12.
Ref. Annual Report, xv, page 393.

Meg. Compact, fine-grained magnetite.

Mic. This iron ore is crossed by veins of microscopic size of secondary quartz, but in general the section is opaque. One section.

Age. Lower Keewatin. N. H. W.

No. 1002. Greenstone. *(Tuff?)*

South shore of Long lake; sec. 28, T. 63–12.
Ref. Annual Report, xv, pages 325, 326, 393; Annual Report, xxiii, pages 204, 213.

Meg. Fine-grained, gray, siliceous, almost aphanitic.

Mic. The large amount of *calcite* in this rock is the most striking peculiarity. The masses are not large, but scattered widely, and frequently. The rock has a rather firm frame-work, apparently of secondary *quartz* and feldspar, the latter clouded principally by chlorite and *zoisite.* The rock darkens sometimes over small areas in which are embraced numerous crowded grains of all the other substances, most of which are undeterminable, but in the main it is finely granular. There are evident feldspars, some being twinned on the albite plan. Fine grains of *leucoxene* were probably derived from ilmenite.

In general, the rock is a congeries of secondary minerals that have arisen from the decay of evidently eruptive matter, but, from this specimen alone, it is impossible to say whether originally massive or fragmental. Its structural relations, however, and its complete alteration indicate that it is one of the basic tuffs of Keewatin so common in the vicinity.

Age. Lower Keewatin. N. H. W.

No. 1003. Greenstone. *(Tuff?)*

From about half way from the shore of Long lake to Patterson's trenches; sec. 28, T. 63–12.
Ref. Annual Report, xv, pages 325, 326, 393.

Meg. Slaty or schistose, more green than the last, fine grained.

Mic. With an equal amount of chlorite and *calcite,* and less *quartz,* this rock differs from the last also in having a large amount of green *hornblende.* It also shows the outlines of the old feldspars which are crowded with *chlorite, calcite* and minute hornblendes. In some parts of the slide are many tabular microlitic feldspars which extinguish nearly or quite parallel with their longer sections, although the included calcite does not allow perfect extinction. These may indicate an original diabasic nature for the whole rock, or they may appertain to fragments of diabase included in the debris. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1004. Tuff.

From the bluff, centre of sec. 19, T. 63–11; west from Kawasachong falls.
Ref. Annual Report, xv, pages 320–322, 325, 393.

Meg. Fissile schist, lenticularly disintegrating, confused, near the water, underlying the next.

Mic. Rather fine-grained, in general consisting largely of *chlorite* in elongated patches and fine mesh-work. Through this fine mass are distributed numerous coarse angular grains of *quartz*, *leucoxene* and of striated *feldspar*, and indistinct rounded pieces of rock of differing granular aspect and slightly differing composition; the last, however, being uniformly fine grained and allied in general to the main rock itself.

Age. Archean (Lower Keewatin).

Remark. This rock, although its coarser grains are sharply angular, was probably accumulated beneath the ocean, and it would correctly be styled submarine tuff.

N. H. W.

No. 1005. Tuff.

Same place as the last but overlying it.
Ref. Annual Report, xv, pages 320, 322, 325, 393.

Meg. Resembling the rock of Kawasachong falls.

Mic. Finely granular, rather homogeneous, containing much *quartz* in minute angular grains and crossed by small veins of quartz and *calcite*. Evidently a finer-grained condition of rock like the last.

Age. Archean (Lower Keewatin). N. H. W.

No. 1006. "Greenstone."

South shore of Fall lake; N. E. ¼ sec. 19, T. 63-11 W. Schist near the dike No. 1009.
Ref. Annual Report, xv, pages 322, 323, 393.

Meg. One of the fine-grained, roughly schistose "greenstones." This specimen contains some pyrite. No section.

Age. Archean (Lower Keewatin). U. S. G.

No. 1007. Calcite and Pyrite.

Same locality as No. 1006. In contact with No. 1006.
Ref. Annual Report, xv, pages 322, 323, 393.

Meg. A small mass of fine-grained, granular calcite, with considerable disseminated pyrite. No section.

Age. Archean (Lower Keewatin). U. S. G.

No. 1008. "Greenstone."

Same locality as No. 1006. Obtained two feet from the dike, on the south side.
Ref. Annual Report, xv, pages 322, 323, 393.

Meg. Very similar to No. 1006. No section.

Age. Archean (Keewatin). U. S. G.

No. 1009. Amphibolyte.

From a dike that rises in the midst of the rocks Nos. 1004–1008; spreads and extends widely toward the east. *Ref.* Annual Report, xv, pages 322, 323, 393.

Meg. Greenstone of medium grain.

Mic. *Green hornblende* and *chlorite* make up a large part of this rock, probably more than one-half. They are so cut by the *feldspars* that it is evident that they have taken the place of an ophitic *pyroxene.* The feldspars are twinned microliths, much better preserved than those in rocks Nos. 1004 and 1005. There are occasional areas of *calcite* and of *pyrite,* and numerous patches of *leucoxene.* There is no olivine visible. A few *apatite* spicules pierce the feldspar. One section.

Age. Archean (dike in Lower Keewatin). N. H. W.

No. 1010. Greenstone *(at contact with a dike).*

Contact between the fragmental rocks represented by Nos. 1002–1008 and the dike No. 1009. *Ref.* Annual Report, xv, pages 323, 393.

Meg. In the hand sample the two rocks are quite similar, the dike rock, however, not being schistose.

Mic. The slide contains a portion of the granular rock and a portion of the igneous, but the latter is more altered than in No. 1009, and the feldspars are broken by rock movements, and their fragments are dislodged. There is so much alteration that no ophitic structure remains. The hornblende in general is not in distinct crystals, but is broken into myriads of scattered grains, which, mingled with chlorite and with *leucoxene,* give a confused and dirty aspect to the whole slide. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1011. Greenstone.

At various places between the lake shore (Fall lake) and the hill in S. E. ¼ sec. 19, T. 63–11. *Ref.* Annual Report, x, pages 324, 393.

Meg. Green, medium grained, and ambiguous in character, structurally appears to be in range of the rock that forms Kawasachong falls.

Mic. The rock is essentially made up of *green hornblende* and tabular *feldspars,* the latter having such relation to the former as to suggest, though not prove, a former ophitic structure in this rock, in that respect resembling rock No. 1009. There is also *pennine,* filling some large cavities. *Epidote* and *leucoxene* are common. These indicate an alteration of a basic igneous rock, and taken in connection with the partial ophitic structure, rather favor that interpretation. Still, owing to the uncertainty, the term greenstone is applied to this rock, a term which accommodates either interpretation. Notwithstanding the great alteration there is no quartz.

Age. Archean (Lower Keewatin). N. H. W.

No. 1012. Quartz Schist. *(Magnetic.)*

From boulders, which are angular, evidently from the rock near. Top of hill S. E. ¼ sec. 19, T. 63–11, south of Fall lake.
Ref. Annual Report, xv, pages 324, 393. Compare Nos. 2111, 2112.

Meg. Black, banded, magnetic, fine grained.

Mic. In the *quartz*, which composes the most of the rock, is a powder of *magnetite*. The latter is in grains of ultra-microscopic size, which by aggregation form larger masses of irregular shape. The quartz is pierced also by the same spicules as mentioned under No. 1000, supposed to be *grünerite* from its twinning and its high double refraction.

Age. Archean (Lower Keewatin). N. H. W.

No. 1013. Quartz. *(Chalcedonic.)*

From a vein in quartz schist, top of the hill, S. E. ¼ sec. 19, T. 63–11.
Ref. Annual Report, xv, pages 245, 393; Annual Report, xviii, page 11; Annual Report, xxii, page 6; Bulletin vi, page 69.

Meg. Apparently the same kind of fine granular quartz as that of the quartz schist, frequently called "chalcedonic quartz," but incorrectly, because the quartz has not the fibrous structure characteristic of chalcedony, nor its negative, optical character.

Mic. The quartz is wholly recrystallized, whatever its original condition, in interlocking grains which vary in size, being coarser along the centre of the vein. Along the edges of the vein the quartz grains have about the same size as in the rock in general. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1014. Greenwacke.

Just south of the section line between sections 19 and 30, west of the trail; T. 63–11, south of Fall lake.
Ref. Annual Report, xv, pages 324–326, 393.

Meg. An indefinite green rock or graywacke.

Mic. There is much *chlorite*, *hornblende*, *calcite* and *leucoxene*, also considerable *quartz* in scattered small grains of secondary origin, in this rock. There are forms of some original *feldspars*, indicated by the greater transparency in areas, which are crowded with calcite and other impurities, but the distribution of the elements is so promiscuous that no ophitic structure is discernible.

Age. Archean (Lower Keewatin). N. H. W.

No. 1015. Greenstone.

N. E. ¼ sec. 30, T. 63–11; south of Fall lake, near Garden lake.
Ref. Annual Report, xv, pages 325, 394.

Meg. Appearing like a fine, brecciated graywacke, rough and angular in general outward aspect.

Mic. The forms of sections of microlitic *feldspars* are common in the section, but these are dimmed by alteration products, appearing greenish and grayish in natural light. Between them is a confused gray matrix, somewhat coarser grained and so pierced by the feldspars, which lie in all directions, as to allow the suggestion that the rock was once a fine-grained, ophitic diabase, but this matrix has no trace of pyroxene, consisting rather of *calcite*, probably some *leucoxene* and irregular forms of what is apparently a secondary *feldspar*. The green coloring matter is apparently chloritic. Probably a clastic rock. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1016. Jaspilyte *(with magnetite)*.

Centre of sec. 30, T. 63–11.
Ref. Annual Report, xv, pages 325, 368, 394. Compare Nos. 2111, 2112.

Meg. The usual banded iron ore of the Keewatin.

Mic. The section is black in reflected light, like *magnetite*. The *quartz*, which occupies angular openings in the magnetite, is crossed by intersecting fine bands of black powder which is doubtless *magnetite*. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1017. Greenwacke.

N. W. ¼ sec. 28, T. 63–11, Garden lake.
Ref. Annual Report, xv, pages 327, 328, 394.

Meg. Green schist, with megascopic crystals of white calcite and some granular quartz like that of the jaspilyte.

Mic. The slide shows none of the white masses and only a small amount of fine, granular *quartz*, *calcite* and *chloritic* debris. The rock is evidently from a debris of eruptive material. One poor section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1018. Greenstone.

N. W. ¼ sec. 28, T. 63–16; same rock surface as the last.
Ref. Annual Report, xv, pages 327, 328, 394.

Meg. Similar green schist as the last, but without evident calcite.

Mic. Many microlitic *feldspars*, much decayed, originally twinned in twos, are promiscuously disseminated in this rock. Much *calcite* is seen, not only within the areas of the feldspars, but also in isolated grouped masses. There are clusters of minute grains of a yellowish-gray, nearly opaque mineral, which in its thinnest edges and projecting points is seen to be highly doubly refracting when highly magnified, and is probably a form of *leucoxene* more dark than is usual. The distribution of the feldspars in the mass hardly suggests a possible original diabase. There are a few grains of *pyrite*. The green coloring mineral is the same as seen in most of these rocks, but it is difficult to say whether it is hornblendic or chloritic. It composes the most of the matrix of the feldspars, but is not entirely wanting in them. Quartz is wanting or scarce. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1019. Greenstone.

Same place; same rock surface as the last.
Ref. Annual Report, xv, pages 327, 394.

Meg. Similar schist, schistose.

Mic. Rock is very like the last, a little coarser grained, with less frequent feldspar microliths, but with a large area in which either a rock fragment was enclosed of a different sort, or a different alteration has progressed. In this area are numerous angular *quartzes.* The *leucoxene* is lighter colored than in the last. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1020. Greenstone.

Same place; same rock surface as the last.
Ref. Annual Report, xv, pages 327, 394.

Meg. Coarsely schistose, but similar to the last.

Mic. A little coarser grained, but essentially the same as the last. There is, however, a stronger suggestion of an original ophitic structure in the disposition of the feldspars, and especially as in two or three instances one is seen to cross another at a considerable angle without change of orientation by either. Brown *leucoxene* is common. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1021. Greenstone. *(Granular.)*

Same place as the last; same exposed surface.
Ref. Annual Report, xv, pages 327, 394.

Meg. Similar to the last, but evidently changed from an igneous debris.

Mic. There is much *epidote,* which is yellowish and granulated and bunched, but the granules retain their polarizing power, characteristic of epidote. The feldspars are also deprived of their microlitic shapes, and are scarce, scattered in isolated fragments, there being no ophitic structure preserved. There is much dark *leucoxene,* and much of the same coloring green chloritic substance, which last is almost monorefringent between the nicols, and a very little of *quartz* and of *magnetite.* One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1022. Greenstone. *(Granular.)*

Same place; same exposed surface.
Ref. Annual Report, xv, pages 327, 394.

Meg. Similar to the last.

Mic. *Epidote* is here common. The feldspar is but little more common than in the last, and is fragmental; that is, it is in scattered rounded pieces, not in angular, and is sufficiently preserved to show its albite twinning. The green coloring matter is *chloritic*, in general, and sometimes hornblendic, in the latter case strongly pleochroic and faintly doubly refracting, the changing colors of pleochroism being very light yellow and pale green. *Leucoxene* is abundant, and scattered in small grains throughout the slide. A very little *quartz* in fine grains is seen. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1023. Greenstone. *(Dense, fine.)*

Same place and exposed rock surface.
Ref. Annual Report, xv, pages 328, 394.

Meg. More firm, fine-grained, schistose in the same direction. Taken in the midst of the schists above.

Mic. This is an average rock of the series above described. It has scattered, chloritized, fine feldspars rather scarce, distributed in a dark-green, structureless matrix, containing chlorite, calcite, quartz, a little epidote, leucoxene and finer feldspars. One section.

Remark. This series of greenstones was collected for the purpose of studying the minute transitions between a fine green schist (No. 1017), presumed to be of clastic origin, and a coarser greenstone (Nos. 1022 and 1023), which, in the field, was assumed to be of igneous origin. The conclusion arrived at was that they were all derived from originally massive igneous rock, and that the fine schist (No. 1017) was formed by shearing of a rock like a diabase. It is evident now, however, that one of these assumptions must be erroneous. A subsequent microscopic examination of the slides, followed by a review of their characters in the light of long study and comparison with known altered diabases, leads to the conclusion that they are all of clastic origin, and of the nature, primarily, of basic debris which was perhaps tuffaceous, the supposed igneous rock (Nos. 1022 and 1023) being simply coarser debris of the same sort as No. 1017.

Age. Archean (Lower Keewatin). N. H. W.

No. 1024. Magnetite Schist.

S. W. ¼ sec. 23, T. 63-11. Julian Bausman's, east of Farm lake.
Ref. Annual Report, xv, pages 328, 394; Annual Report, xix, pages 121, 127.

Meg. The rock is fibrous, but dark with magnetite, blue black in color.

Mic. The cementing background is a long fibrous mineral, having a low double refraction and parallel extinction. Its highest color rotated between nicols is bluish gray in the first order. There is not enough of this mineral visible in the section to allow of its specific determination. The magnetite, which, on analysis, gave a trace of titanium, is in form of a fine powder, distributed through this matrix. One poor section.

Age. Archean (Lower Keewatin). N. H. W.

NO. 1025. IRON ORE. *(Magnetic.)*

Near the same locality as the last.
Ref. Annual Report, xv, pages 328, 394.

Meg. Similar to the last, but not schistose; also lacking the bluish color of the last.

Mic. About one-half of this rock is of magnetite, the rest being apparently the same fibrous mineral as seen in the last, but here showing more favorably and having a colored double refraction, which, with other characters, denotes *actinolite.* One section.

Age. Archean (Lower Keewatin). N. H. W.

NO. 1025A. QUARTZ-PORPHYRY.

Apparently overlying the last.
Ref. Annual Report, xv, page 394.

Meg. Coarsely granular, with feldspar and quartz.

Mic. The large *feldspar* crystals and the rounded *quartz* grains lie in the midst of a fine, granular, secondary matrix. The feldspars are clouded with impurities, but show their coarse twinning (albite and pericline). The quartz is broken and also streaked by bands of impurities. The enclosing matrix has some *hornblendes* which are large, distinct and idiomorphic, and some that are partly changed to *chlorite*, much interlocking fine *quartz*, *leucoxene*, of which some larger grains are straw-yellow, but the most are white, passing to sub-opaque, a little fine epidote and muscovite and a single grain of *apatite.* One section.

Age. Archean (Keewatin).

Remark. This rock resembles the quartz-porphyry of Kekequabic lake.

N. H. W.

NO. 1026. AMPHIBOLYTE.

From the northern island crossed by the section line between secs. 11 and 12, T. 64-11. Basswood lake.
Ref. Annual Report, xv, pages 357, 394.

Meg. A fine-grained, fibrous, green rock.

Mic. The *hornblende*, broken by considerable secondary *quartz*, is mostly in a fibrous condition, but sometimes over the area of a crystal it shows not only its cleavages, but its polarization colors. Mixed with the hornblende is a considerable amount of a highly refractive and highly doubly refractive mineral, in fine detached grains which are sometimes grouped round black, opaque particles as centres, which are probably *epidote*. A few black, metallic particles are surrounded by a hematitic stain. One section.

Age. Archean (Keewatin). N. H. W.

No. 1027. Granite.

From an island in the lake, in sec. 1, T. 64–11, cut by an apparent dike of mica schist. Bassimenan lake.
Ref. Annual Report, xv, pages 357, 358, 394.

Meg. A fine-grained, pinkish, granitic rock.

Mic. *Quartz* constitutes most of this rock, but it also has *microcline* and *andesine-oligoclase*, the latter shown by an extinction angle of 72° on the bisectrix n_p. The feldspar is sometimes clouded by a gray substance, which gives it the appearance of the sub-opaque leucoxene, whose nature is unknown, but which may be of the nature of *kaolin*. These, with a little *hornblende* are the essentials of this rock. The large microcline crystals sometimes embrace poikilitically both quartz and andesine-oligoclase. One section.

Age. Archean (granite). N. H. W.

No. 1028. Mica Schist.

Same locality as No. 1027.
Ref. Annual Report, xv, pages 358, 394.

Meg. A fine-grained, micaceous (biotitic) schist with hornblende and apparently quartz and feldspar. The hand sample is crossed by a vein, one-fourth to one-half inch wide, of pegmatyte which is composed mainly of pink feldspar. No section.

Age. Archean. U. S. G.

No. 1029. Gneiss.

Same locality as No. 1027.
Ref. Annual Report, xv, pages 358, 394.

Meg. A medium-grained, dark-colored rock, gneissic in structure, composed of biotite, hornblende, pinkish feldspar and quartz. No section.

Age. Archean. U. S. G.

No. 1030. Granite.

From the same place as No. 1027, at three feet from the left of the contact on No. 1028.
Ref. Annual Report, xv, pages 358, 394.

Meg. A fine-grained, flesh-colored, granitic rock.

Mic. Essentially the same rock as No. 1027, but finer grained and having more *hornblende*. There are also small amounts of *biotite* and of *sphene*, as well as of *pyrite*. One section.

Age. Archean (granite). N. H. W.

No. 1031. Granite.

Same place as the last, at fifteen feet from the contact on No. 1028.
Ref. Annual Report, xv, pages 358, 394.

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

Mic. Similar to the last, but with more *hornblende* and biotite. Large feldspars (microcline) englobe many small hornblendes, as well as smaller feldspars, and *apatite.* One section.

Age. Archean (granite). N. H. W.

No. 1032. Granite.

Sec. 23, T. 65–10; northeast cape, Bassimenan lake.
Ref. Annual Report, xv, pages 358, 394.

Meg. Red weathering, gneissic and jointed, gray within.

Mic. *Quartz, orthoclase, microcline,* the feldspars clouded by decay; *hornblende, biotite, apatite.* One section.

Age. Archean (granite). N. H. W.

No. 1033. Gneiss.

From bands cutting the rock No. 1032 in a direction about east and west.
Ref. Annual Report, xv, pages 358, 394.

Meg. Dark gneiss.

Mic. *Orthoclase, hornblende, quartz,* the first frequently blurred by alteration, and a few grains of *plagioclase,* with many minute crystals of *apatite.* One section.

Age. Archean (gneiss). N. H. W.

No. 1034. Granite.

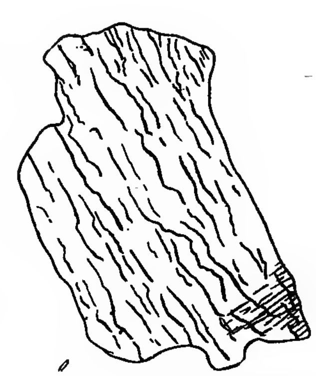
Vein rock, sec 23, T. 65–10.
Ref. Annual Report, xv, pages 358, 394.

Meg. Coarse grained, and apparently containing the same minerals as No. 1032, in form of a segregation in coarse veinings in No. 1032.

Mic. *Quartz, orthoclase, microperthite, plagioclase* and micropegmatyte.

Figure 36 represents the microperthite, apparently running parallel with the cleavage 001. Compare the description of No. 1051. One section.

Age. Archean. N. H. W.



Microperthite in 1034.
FIG. 36.

No. 1035. Biotite Schist.

East end of the portage from Ensign to Illusion lake, sec. 13, T. 64–8.
Ref. Annual Report, xv, pages 359, 394.

Meg. Fine grained, dark gray, in some places apparently schistose.

Mic. There are a few small *plagioclases* (?) which still are so much larger than the rest of the grain of the rock that microscopically they appear like porphyritic crystals, though they are not idiomorphic, and they may be *cordierite* instead. The most of the rock is micro-crystalline interlocking *quartz*, with bands and clusters of *biotite* scales. One section.

Age. Keewatin metamorphosed by the gabbro revolution. N. H. W.

No. 1036. Biotite Schist (*with hornblende*).

From Illusion lake, sec. 13, T. 64–8.
Ref. Annual Report, xv, pages 359, 394.

Meg. Fine grained. Similar to the last, evidently arenaceous, at least siliceous.

Mic. *Quartz* grains, as in the last, are the most abundant element of this rock. *Hornblende*, *biotite* and *magnetite* are scattered amongst them. One (thick) section.

Age. Keewatin metamorphosed by the gabbro revolution. N. H. W.

No. 1037. Gabbro. (*Muscovadyte.*)

East side of Illusion lake, sec. 13, T. 64–8.
Ref. Annual Report, xv, pages 359, 395; Annual Report, xxi, page 152.

Meg. Finely granular, gray or yellowish.

Mic. The rock is finely granular, with a tendency to globular outlines for all the minerals. There is no evidence of difference of date in the generation of the various minerals, except that the plagioclase in some cases was apparently the last to take form. These are *plagioclase*, *hypersthene*, *augite*, the hypersthene being most abundant and frequently embracing minute globules of the same mineral. One (thick) section.

Age. Cabotian; modification of the Keewatin.

Remark. The slightly rusty condition of the hypersthene and the thickness of the slide gives an appearance of olivine to much of the hypersthene, but, as no jelly was formed in HCl, it is presumed that no olivine is in the rock. N. H. W.

No. 1038. Gabbro.

South shore of Illusion lake, sec. 13, T. 64–8, south shore, and on a small island.
Ref. Annual Report, xv, pages 359, 395.

Meg. Coarse gabbro.

Mic. The most of the slide is occupied by a single plate of feldspar, but it surrounds several small areas of altered *augite* and *olivine*. This plate is cut nearly perpendicular to n_g as acute bisectrix, and has extinction at 24° from cleavage, indicating *labradorite*. The augite shows an alteration resembling the lamellation of diallage, but it is to be considered *uralitic*. One section.

Age. Cabotian. N. H. W.

No. 1039. Biotite Schist *(with cordierite)*.

First island south of the last, in Illusion lake; sec. 13, T. 64-8.
Ref. Annual Report, xv, pages 360, 395; Annual Report, xxi, page 146.

Meg. Biotite gneiss, showing a contorted structure.

Mic. Besides the *biotite*, which is idiomorphic, there is considerable *quartz* and scattered fine *magnetite*. But most of the slide is abundantly strewn with *cordierite*. The quartz embraces all the other minerals poikilitically, forming large plages as in the aporhyolytes. It is rather difficult to distinguish the cordierite from the quartz in numerous instances, the most available optic character being the Becke line, which always moves toward the mineral having the higher refractive index when the objective is slightly raised by the fine adjustment screw. There is a little *oligoclase-andesine* which forms, with *albite*, a *microperthite*. The crystals of this plagioclase are larger than the cordierite grains and enclose them, and are also broadly zoned. They were later to form than the biotite phenocrysts which pierce them.

The fortunate juxtaposition of these white minerals whose general aspects are so similar affords occasion and fine opportunity for the application of some of the nicer microscopical methods. The photographic illustration of this slide (plate II, figure 8) shows an oligoclase-andesine, somewhat zoned, containing the microperthitic albite, also quartz surrounding it and embracing numerous cordierite grains. The order of the minerals in date of generation seems to have been cordierite (not much earlier than biotite), biotite, oligoclase-andesine, quartz. One section.

Age. Keewatin modified by the gabbro revolution. N. H. W.

No. 1040. Magnetite *(with hypersthene)*.

A little west of the meander corner of sections 28 and 29. N. E. ¼ sec. 29, T. 64-7, Thomas lake.
Ref. Annual Report, xv, pages 360, 395.

Mac. Appearing like an iron ore.

Mic. The iron ore embraces masses of *hypersthene*, but between the ore and the hypersthene is usually an olivine rim. One (thick) section.

Age. Cabotian modification of Keewatin iron ore. N. H. W.

No. 1041. Peridotyte. *(Cumberlandyte.)*

The old mining place on Fraser lake, near the section line between secs. 23 and 24, T. 64-7.
Ref. Annual Report, xv, pages 360, 395.

Meg. A dark, heavy rock, apparently containing magnetite. A part of the banded muscovadyte accompanying the iron ore of the locality.

Mic. The slide consists almost entirely of olivine, which, having evident cleavages at right angles, and n_p in the acute optic angle, is *fayalite*. There are many dark bands of inclusions in this mineral, running parallel with the cleavage

100, and perpendicular to the optic plane. This mineral might be mistaken for hypersthene, owing to its good cleavage and parallel extinction; but it forms a stiff jelly quickly with hydrochloric acid. One section.

Age. Modified Keewatin, an appendage of the gabbro.

Remark. Magnetite is plentiful in some parts of this rock. It is quite probable that, on extended examination, very much of the olivine which accompanies the "olivinitic iron ore," would be found to be fayalite. N. H. W.

No. 1042. Cordierite Gneiss *(with hypersthene)*.

From the lake through which the river flows; sec. 11, T. 64-7.
Ref. Annual Report, xv, pages 361, 395. Compare No. 1039.

Meg. Gneissic, biotitic, quartzose.

Mic. Through a background of granular *cordierite* and quartz, the latter being secondary to the former, and both together occupying visibly more than half the total area, are *biotite* in large flakes which inclose *cordierite* and *magnetite* grains in a poikilitic manner, *hypersthene* which in the same manner surrounds *cordierite* and magnetite, and occasionally a grain of twinned *plagioclase* which is fresh and glassy. This feldspar, like all the other minerals, is of secondary origin. As to the relative dates of generation of the hypersthene and the biotite, they generally do not interfere, but on close examination it is easy to see that a few detached hypersthene grains of small size are surrounded by the biotite, which, therefore, excepting the quartz, was the latest of the secondary generations. One section.

Age. Modified condition of the Keewatin, due to the gabbro revolution.

No. 1043. Amphibolyte.

From the ridge which separates the above lake in the river from Kekequabic lake.
Ref. Annual Report, xv, pages 362, 395.

Meg. Dark greenish, finely granular.

Mic. The rock consists almost wholly of a faintly pleochloric green or colorless hornblende, or *pargasite*, whose maximum extinction angle is 18° to 21°, and whose acute bisectrix is n_g, with positive elongation. Sections perpendicular to n_p show little longitudinal cleavage, but a distant transverse cleavage. Hence, the mineral, while having a faint prismatic cleavage, has also an imperfect basal cleavage (001). Sections that show the highest coloration (010), also have very evident coarse longitudinal cleavage, which therefore must be parallel to 100. The pleochroism is so faint that in sections of normal thinness (.003 millimeter or less), it is hardly apparent.

There is also a notable amount of *biotite* and of *cordierite*, an occasional grain of *magnetite*, and also a little *feldspar*. Two sections.

Age. Probably Upper Keewatin. N. H. W.

No. 1044. Granite.

Southeast shore of the little gulf at the southeast side of Kekequabic lake; sec. 11, T. 64-7.
Ref. Annual Report, xv, pages 361, 395; Annual Report, xvii, pages 196, 205.

Meg. Apparently a massive granitic rock, with visible feldspars larger, almost porphyritic, in a fine matrix.

Mic. The *feldspars* are conspicuous, but they are in various parts mechanically sometimes out of orientation, so that extinction comes over them by patches. At the same time the margins are somewhat extended by later hooked small increments into the surrounding matrix. Occasionally, but rarely, while the original outline of the feldspar is distinctly set off from the matrix by a marginal increase of impurities, there is a sympathetic partial darkening in a small portion of the adjoining matrix, indicating the continuation of the feldspar growth into the surrounding materials by little hooked tongues. Very frequently, also, the large feldspars embrace numerous new growths of feldspars, these lying in independent orientations, each of all the others. They are few and scattered, or they are numerous and crowded. In one instance they occupy the central area of a large crystal, about one-half of the whole, the old crystal being intact only in a marginal band which still exactly outlines the original shape. The appearance of this central area is much like that of the surrounding matrix, but is less sprinkled with mica needles. For the most part these large crystals appear to be simple Carlsbad twins, but are sometimes nearly lost by the secondary micro-granulation.

The matrix is made up of fine secondary feldspars, of *quartz*, *muscovite*, *calcite*, *magnetite*, with a sprinkling of green due to shreds of *actinolite* and of *chlorite*, and a few grains of *sphene*, the whole of it, except the last, of secondary generation, quartz being the latest. One section.

Age. Archean.

Remark. This rock appears in the midst of a lot of green schists, referable to the rock No. 1043, to which its relation is not definitely known. It appears to be a regenerated condition of granitic debris. The feldspars resemble those of the porphyry on the north side of Kekequabic lake. N. H. W.

No. 1045. Granite.

South shore of Kekequabic lake, near the meander corner of section line between secs. 2 and 3, T. 64-7.
Ref. Annual Report, xv, pages 361, 395.

Meg. Thin-bedded, or gneissic, similar to No. 1044, but weathering red.

Mic. While this rock is similar, in general, to the last, the *feldspar* is stained with hematite, and appears not to be twinned, and the hornblendic ingredient is almost entirely wanting. The coarser grains make up a larger portion relative to the fine matrix. One (thick) section.

Age. Archean. N. H. W.

No. 1046. Granite.

From a small island in Kekequabic lake, near the centre of sec. 3, T. 64–7.
Ref. Annual Report, xv, pages 361, 364, 395.

Meg. Purplish red, sub-crystalline in aspect.

Mic. Similar to the last, but with a little more of the *hornblendic* mineral. In general, this is coarser than the rock described above (No. 1044), but the same fine matrix lies between all the grains. The original larger grains do not interlock as if crystallized from a magma, but seem to be simply compacted with much secondary deposition. One of the grains of *feldspar* is nearly surrounded by a clear rim, the central portion being clouded with *hematite* and alteration, but in general this relation is not noticeable. One (thick) section.

Age. Archean. N. H. W.

No. 1047. Tuff. *(Modified.)*

Southwest corner of Kekequabic lake; S. W. ¼ sec. 3, T. 64–7.
Ref. Annual Report, xv, pages 364, 395.

Meg. Fine grained, gray, much like No. 1035.

Mic. There is a fine, granular background, which serves as a matrix for the larger hornblende crystals. This fine matrix consists apparently wholly of a single glass-clear, limpid mineral whose refractive index is higher than that of Canada balsam (dipyre?), but the section examined is too thick to allow of further determination. In this matrix are myriads of *actinolite* spicules, whose cross parting perpendicular to their elongation gives them the appearance of apatite, an impression which is corrected at once on noting their colors of double refraction.

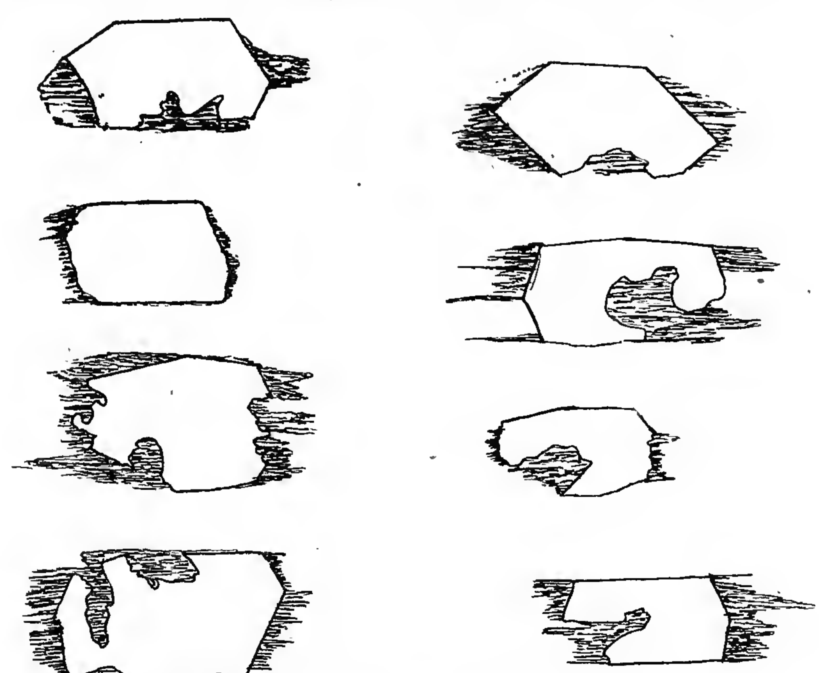


FIG. 37. SECONDARY GROWTH OF HORNBLENDE ON AUGITE FORMS.
Rock No. 1047.

These *hornblendes* are distinctly of two conditions of growth, like those seen in the dike on Stuntz island (No. 872), and in a similar manner they polarize in two colors. The central portion of these hornblendes is dichroic and sometimes still consists of *augite*, but the transparent second growths do not perceptibly show this quality (see figure 37). The non-dichroic growths are fibrous and spreading at the ends of the longitudinal sections, and also are scattered as slender threads through the matrix, the fine, thread-like sections swimming off separately in the fine matrix, but without much divergence. There are, besides, indistinct, non-polarizing, yellowish and dirty spots which appear to be the residue of some original crystal forms which cannot now be determined. One section.

Age. Archean.

Remark. This rock is very peculiar, and can only be said to be one of the products of the contact of the gabbro of the immediate vicinity on the clastics. N. H. W.

NO. 1048. AMPHIBOLYTE. *(Tuff, modified.)*

Same place as No. 1047. Occurs as rounded and subangular masses in No. 1047, into which it apparently shades.

Ref. Annual Report, xv, pages 364, 395.

Meg. Fine grained, dark gray.

Mic. The rock (consisting almost entirely of hornblende) is essentially the same as No. 1047, but much finer grained. The minute spicules and grains of *hornblende* appear between crossed nicols, much like muscovite scales, but when one is cut favorably it can be seen to be of hornblende, with the same secondary enlargements and without parallel extinction. One section.

Age. Archean (Keewatin).

Remark. The hornblendic element here also must have been derived from a fine debris of augite.* N. H. W.

NO. 1049. TUFF. *(Modified.)*

East side of sec. 4, T. 64-7. Six feet above the water at the shore of Kekequabic lake.

Ref. Annual Report, xv, pages 364, 365, 395; Annual Report, xvii, pages 196, 205.

Meg. Apparently a biotite gabbro, as judged in the field, but somewhat pebbly.

Mic. This rock is porphyritic with hornblende in the same manner as No. 1047, but the secondary growths are not so noticeable, but are visible in sections sufficiently thin. There are in the matrix with the hornblende crystals, some old triclinic feldspars in small grains and fragments, which have the altered aspect in the main of the feldspars described in No. 1044. The actinolite spicules penetrate only their margins. Two sections.

Age. Archean.

Remark. This rock seems in its matrix to be allied to No. 1044, and in its hornblendic porphyroidal aspect to the hornblendic porphyry of Mallmann's peak, No. 751,

* The sample preserved is apparently not exactly the same as that from which the slide was made.

while it is structurally and petrographically a part of the same series as Nos. 1047 and 1048. Another mineralogic link connecting this rock (No. 1049) with No. 1043, lies in the nature of the hornblende which has the characteristic which optically distinguishes *pargasite* from all the other hornblendes, viz.: it has the axis n_g in the acute optic angle.

N. H. W.

NO. 1050. TUFF. *(Modified.)*

From the same bluff, near the top.
Ref. Annual Report, xv, pages 364, 365, 395; Annual Report, xvii, pages 196, 206.

Meg. Grayish green, rather compact.

Mic. Essentially the same rock as the foregoing from this bluff. The fine matrix is not so abundant and the porphyritic aspect of the hornblendes is not so marked: They are also smaller, bringing the rock into greater homogeniety, still characteristically the same rock with the addition of a few small grains of quartz (or cordierite?) and a greater proportionate amount of hornblende. Two sections.

Age. Archean. N. H. W.

NO. 1051. TUFF. *(Modified, granitic.)*

West shore of Kekequabic lake; sec. 3, T. 64–7.
Ref. Annual Report, xv, pages 364, 395.

Meg. Aspect of an orthoclastic rock; in the field was styled orthoclase gabbro. from the top of the bluff which at the bottom is a pebbly green schist.

Mic. This rock seems to unite the characters of Nos. 1044, 1045 and 1046 with those of Nos. 1047 and 1050. The matrix material, however, is coarser, composed of a biaxial mineral of low refraction and low double refraction, having n_g in the small optic angle without cleavage and without twinning, which embraces all the other minerals poikilitically. The most of the rest of the rock is *hornblende* in small crystals and spicules which pierce the translucent mineral mentioned in all directions and with great freedom. This poikilitic translucent mineral, which in the hand sample is sometimes reddish, gives a fine granitic aspect to the rock.

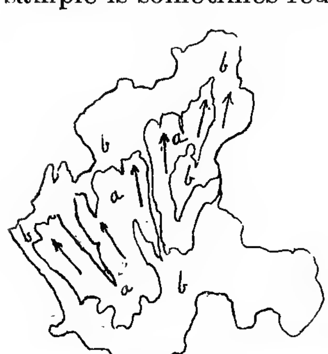


FIG. 38. INTERGROWN ORTHOCLASE (*a*) AND DEFORMED ORTHOCLASE (*b*) IN PSEUDO-SPHERULITIC OR LAMELLAR STRUCTURE. THE FORMER SHOWS n_g VERY OBLIQUE, THE LATTER n_m.

In one large grain there appear to be two growths, one (the later) surrounding and penetrating the other, the two extinguishing in common in a somewhat spherulitic succession, as shown by the accompanying figure. The later growth has slightly higher refraction, as indicated by the Becke line, and higher double refraction. But these differences may be due to different positions of the same mineral. The sketch herewith (figure 38) outlines roughly the manner in which the older feldspar(?) grains are related to the later growths. The later growths cross the older in fissures and in irregular lamellæ. They are of markedly different color, of double refraction, being light yellow (in the section examined), while the older grain is of the dark tint of the first order. The extinction occurs in a shadowy manner, and in fan-shaped patches, showing different orientations, somewhat in the manner of broad spherulitic groups having always positive elongation, but without any other visible spherulitic structure, the later feldspar (*b* in figure 38) having the same extinction as the earlier. The name of this poikilitic mineral was not determined, but is supposed to be orthoclase in two conditions, viz.: ordinary and deformed orthoclase, cut in the zone (001) (010), the pseudo-spherulitic or lamellar structure being parallel to the axis *b*, constituting a coarse microperthite. Compare No. 1034.

Age. Archean (probably Upper Keewatin). N. H. W.

No. 1052. Granite.

W. ½ sec. 3, T. 64-7. Kekequabic lake, from near the contact with No. 1051.
Ref. Annual Report, xv, pages 364, 395.

Meg. Red rock, same as No. 1046.

Mic. Though much finer grained, this is a rock like Nos. 1044–1046. The hornblende is in small, irregular areas, not in spicules. There is the same distinction between the old and the new feldspars, the latter being clear and glassy, and the former cloudy. The new growths form the cementing band, as they constitute interlocking arms and hooks, sometimes originating from the older grains and sometimes being apparently entirely free from them. The rock has the appearance of having quartz in the new material, but owing to the fineness of the grain none can be detected in convergent light. The feldspars are twinned on the albite and Carlsband plans and apparently on the microcline, and the larger ones are occasionally zoned. One section.

Age. Archean (igneous).

Remark. Were it not that this rock is so intimately connected in the field relations with rocks Nos. 1044–1046, and those through No. 1051 with rocks Nos. 1047–1050, it might be difficult to affirm its original fragmental character. But the microscopic characters entirely agree with the field relations and indicate that both groups are recrystallized debris. N. H. W.

No. 1053. Graywacke and Slate.

N. W. ¼ sec. 3, T. 64-7 W. West side of Kekequabic lake.
Ref. Annual Report, xv, pages 365, 395.

Meg. There are two small hand samples of this number. One is a rather fine-grained, gray, gritty rock. The other is a fine-grained, dark argillyte. Both hold pyrite. No section.

Age. Archean (Keewatin). U. S. G.

No. 1054. Graywacke.

Same locality as No. 1053.
Ref. Annual Report, xv, pages 365, 395.

Meg. Very similar to the first sample mentioned under No. 1053. No section.

Age. Archean (Keewatin). U. S. G.

No. 1055. Green Schist. (*Tuff.*)

Kekequabic lake, northwest end of the bay projecting northward into sec. 34, T. 65–7.
Ref. Annual Report, xv, pages 365, 395, 396.

Meg. Lenticularly and coarsely schistose; the northwest extension of rocks Nos. 1049 and 1050.

Mic. A mass of fine debris of the kind represented by rocks Nos. 1049 and 1050, argely *hornblendic*, but cemented by *calcite* and by secondary deposition. Carlsbad nd albite twinned fragments of *feldspar* are visible and a little *quartz* in independent grains, evidently a part of the original debris. The section is remarkable for he amount of contained calcite. One (thick) section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1056. Vein Rock.

Same locality as No. 1055.
Ref. Annual Report, xv, pages 365, 395.

Meg. From veins in No. 1055. The hand sample consists largely of milky white quartz and pinkish calcite. No section.

Age. Archean. U. S. G.

No. 1057. Green Schist. (*Tuff.*)

Near the meander corner between secs. 35 and 36, T. 65–7.
Ref. Annual Report, xv, pages 365, 395.

Meg. Variety of No. 1055, non-schistose nor pebbly.

Mic. This is like No. 1055 in composition, but the *hornblendes* are coarse and iore like those of Nos. 1049, 1050, etc., with a little feldspar debris. One section.

Age. Archean. N. H. W.

No. 1058. Green Schist. (*Tuff.*)

From the hill in N. W. $\frac{1}{4}$ sec. 36, T. 65–7; Kekequabic lake.
Ref. Annual Report, xv, pages 366, 368, 395.

Meg. Sometimes conglomeratic, but in general resembling the last. Two speciiens were obtained, one showing the conglomeratic structure and the other a hard, oarse-jointed, sometimes schistose, rock.

Mic. The section is made up of a debris like the last, but composed largely of *ornblendes*, which were probably originally augite fragments. They are short and ngular without fibrous enlargements. The fine-grained matrix is composed of the ame materials. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1059. Green Schist. *(Tuff.)*

N. E. ¼ sec. 36, T. 65–7; Kekequabic lake.
Ref. Annual Report, xv, pages 367, 372, 396; Annual Report, xvii, pages 196, 206.

Meg. Another phase of the same rock, non-schistose and coarse jointed. (Compare No. 751.) Rises perpendicular from the water nearly 100 feet.

Mic. Very fine grained, colored everywhere with a prevailing chloritic and *hornblendic* ingredient, but showing a few of the larger fragments of crystals, apparently of *feldspar*, but now permeated by decay. These do not show secondary growths. There is also distributed through this another coloring material, which is in fine, roundish grains, either isolated or grouped, highly polarizing and highly refractive, appearing like detached intercleavage pieces of *epidote*, and when elongated sufficiently to allow the test (which is rare) they are seen to have parallel extinction. As these highly-polarizing, angular grains are sometimes embraced in a network of hornblende fibres, whose nature is evident, and still maintain their identity, it is evident that they cannot be augite, to which, in some respects, they have a resemblance.

In the fine matrix are also scattered a few ragged remnants of old feldspars of large size. Three sections.

Age. Archean (Upper Keewatin). N. H. W.

No. 1060. Green Schist. *(Tuff.)*

N. W. ¼ sec. 31, T. 65–6; apparently an extension of No. 1055.
Ref. Annual Report, xv, pages 368, 396, 398.

Meg. Gneissic, apparently a mica schist.

Mic. This rock is the same in general character as the last, but is more largely hornblendic, and with secondary growths both in the feldspathic and in the hornblendic grains. Occasionally, in the centres of the *hornblendes*, or somewhat eccentric, are seen several rounded grains resembling *augite* remnants (figure 39). There are also a few grains that appear to be of *epidote*, and numerous patches of *calcite*. The sketch connected with the description of rock No. 1047 shows the manner of development from augite to *hornblende*. There are in this slide a great many grains whose original nature cannot now be determined. They may be wholly altered feldspars, or they may be remnants of a volcanic glass. They do not transmit light freely, but afford a cloudy, dirty aspect, and between nicols are wholly dark. These compose perhaps a fourth part of the slide. One section.

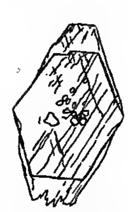


FIG. 39. HORNBLENDE DEVELOPED FROM AUGITE WITH REMNANTS OF AUGITE.

Age. Archean (Upper Keewatin). N. H. W.

No. 1061. Esterellyte.

East end of the narrows of Kekequabic lake; N. W. ¼ sec. 31, T. 65–6. (Compare No. 1094.)
Ref. Annual Report, xv, pages 367, 369, 396; see, also, Annual Report, xxi, pages 39–42.

Meg. "Porphyry."

Mic. In a fine-grained, transparent matrix, consisting mostly of interlocking fresh, glassy *feldspars*, with a very few *quartzes*, some *biotite*, *apatite* and *calcite*, frequent cubic grains apparently of *magnetite*, and some shreds of *hornblende* and fragments of *augite*, lie large crystals of other feldspar, of augite and of hornblende.

The feldspar crystals are much twinned on the Carlsbad, the albite and the pericline plans, and are rarely also surrounded by a zone, generally narrow, of a later growth. These feldspars are not fresh, but are dimmed by kaolinic disintegration. The zonal additions are dimmed also by the same disintegration, but far less than the central areas. They are worthy of very careful investigation. They are very interesting in their forms and especially in their twinning. But as the object of this examination is to throw light on the origin and relations of the rock masses principally, and as that purpose can be secured without further description, these are left for future research. Further, Dr. Grant, in one of the annual reports, has reported on this rock and has investigated the feldspar as well as the augite (Annual Report, xxi, page 43). From chemical analysis he determined it to be *anorthoclase*.

In this rock the feldspars are larger than seen elsewhere, and, with the augites, are better preserved. Many of the augites are uralitized (*i. e.*, converted to hornblende) and many of them are mere fragments, comparable with the fragments already noted in the green schists (Nos. 1058, 1059 and 1060). It is but rare that the form of a full crystal can be found in the three slides examined, while fragments of all dimensions are scattered everywhere, and in one slide it has furnished much hornblendic dust, which dims the matrix.

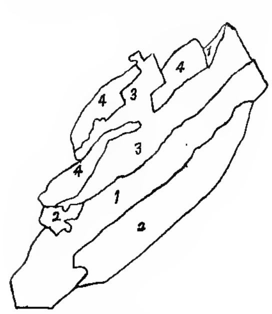


FIG. 40.

The feldspars in No. 1061 are rather compounded than twinned, and the rock might be described as glomero-porphyritic. The outline and compound structure of one of these crystals are shown in figure 40, magnified about twenty-five diameters. Three sections.

Age. Archean (cutting Upper Keewatin).

Remark. The name *esterellyte* was given by Michel Lévy in 1897 to a rock almost identical which occurs as laccoliths in the Mesozoic in southern France. (*Mémoire sur la porphyre bleu de l'Esterel*, Bulletin 57, Carte géologique de France, 1897.)

According to the determination of Michel Lévy, based on chemical as well as optical examination, the feldspar of esterellyte is of at least two kinds. The central cores are of *labradorite* and the zonal increments are of *andesine*, which is in accord with the optical specification of the feldspars in the porphyry of Kekequabic lake. (Compare No. 1094.)

N. H. W.

No. 1061A. Inclusions or Pebbles from No. 1061.

Same locality as No. 1061.
Ref. Annual Report, xv, pages 367, 396; see, also, Annual Report, xxi, page 51.

Meg. A few dark, sub-angular pieces of completely crystallized rock, made up almost entirely of hornblende or of hornblende and augite. No section.

Age. Archean. U. S. G.

No. 1061B. Esterellyte.

Same locality as No. 1061.
Ref. Annual Report, xv, pages 367, 396.

Meg. Similar to No. 1061, but showing a white weathered surface in which are a few large grains of quartz. No section.

Age. Archean. U. S. G.

No. 1062. Conglomerate.

Near the narrows in lake No. 6, or Zeta lake, sec. 28, T. 65–6, east of Kekequabic lake.
Ref. Annual Report, xv, pages 368, 369, 396.

Meg. Coarse conglomerate, with many evident large crystals of feldspar, with occasional visible quartz. Forms hills fifty to seventy-five feet high.

Mic. This consists of the same elements in evidently fragmental state as seen in the foregoing described porphyry (No. 1061) from Kekequabic lake. The augite is changed to *hornblende* and the *feldspars* are clouded by decay, containing *kaolin.* They are much twinned, often in remarkable combinations, as in rock No. 1061. These elements, though large and conspicuous in numerous large grains, are also of all smaller sizes, descending to the size of the grains of the matrix. They rarely, or never, are ingrown or interlock, except where twinned originally, but are separated uniformly by spaces filled with the fine elements. They are palpably all fragmental grains, and did not have their birth in the places in which they now lie except where they are embraced in some of the pebbles. The fine matrix is composed largely of secondary feldspars, but it is evidently more nearly in its original fragmental state than about Kekequabic lake, a fact that can be attributed to the non-action of great metamorphism at this point. This difference is also observable in the non-zoned condition of the large feldspars, and the absence of fibrous secondary enlargements on the hornblendes, which simply show, occasionally, the old augite outlines.

As to the species of the feldspar, extinction in two instances on the axis n_p indicate *andesine* or *andesine-oligoclase*, and one test on n_g gave 20°, which is near *albite*. Allowing for error and for some obliquity in the section, it can only be said that these observations show a feldspar of medium basicity. The remarkable twinning, in which the albite bands vary in width rather suddenly along their greater extension, and are confusedly intersected by pericline bands, and are interrupted by interferences amongst themselves, is a feature which is more like albite, but is not probably a reliable character as diagnostic, but is a marked feature of the feldspar (andesine) of esterellyte, as described by Michel Lévy. Two sections.

Age. Archean (Upper Keewatin).

Remark. This conglomerate is made up of pebbles of various grain, as to size, and of the above debris. Microscopically the sections of No. 1061, from Kekequabic lake are indistinguishable from this. This is supposed to be the conglomerate which spreads widely eastward, under the name Ogishke conglomerate, and, according to Dr. Grant, it extends also westward to the south shore of Kekequabic lake. (Annual Report xxi, page 27.) N. H. W.

No. 1062A. Feldspar.

Same locality as No. 1062.
Ref. Annual Report, xv, page 396.

Meg. Part of No. 1062, coated with a thin layer of small, pinkish crystals, probably orthoclase. No section.

Age. Archean. U. S. G.

No. 1063. Graywacke. *(Conglomeratic.)*

N. W. ¼ sec. 27, T. 65-6; northwest shore of the long bay from Ogishke Muncie lake.
Ref. Annual Report, xv, pages 369, 396.

Meg. Appearing conglomeratic and quartzose.

Mic. The greater part, by far, of the slide, consists of clouded *feldspars*, in which kaolinic and chloritic substances combine. There are some sub-rounded grains of *quartz*, some *calcite*, a little distinct *hornblende* and apparently considerable *leucoxene*. One section.

Age. Archean (Upper Keewatin).

Remark. This is a compact debris, rather coarser in average than the foregoing, and perhaps is more dependent on oceanic assortment, but in general it is a very similar rock, though the elements were more decayed prior to consolidation into the present rock mass. It is probable that much of the debris of this rock was of volcanic origin primarily. The feldspars rarely come into contact, at least they never interfere. N. H. W.

No. 1064. Conglomerate.

Shore of the bay last mentioned; taken so as to represent the average character of the rock about this bay.
Ref. Annual Report, xv, pages 370, 396.

Meg. Conglomerate, showing among the enclosed pebbles some of red jasper and of quartz.

Mic. Identical with the last in general character, but showing a few well-preserved *hornblendes*, though the most of the debris of the ferro-magnesian minerals is chloritized. In the slide are a few rounded *quartz* grains, some *sphene* and one pebble of *red jasper*. The feldspathic ingredient, which was originally the most abundant, presents an aspect of general decay. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1065. Conglomerate.

Same locality as No. 1064.
Ref. Annual Report, xv, pages 370, 396.

Meg. Appearing porphyritic by the presence of idiomorphic crystals of feldspar, as in No. 1062.

Mic. Rounded and subangular *quartzes*, *feldspar* fragments, *red jasper*, *leucoxene*, *epidote*, *calcite*.

This slide differs from all the preceding in having pebbles of *different sorts of rock* besides of jasper. These rocks are: fine diabase, wholly altered to a greenstone, but in which the manner of distribution of the feldspathic microliths shows that it was probably an ophitic diabase; and volcanic tuff and porphyry, containing fragments of augite, now changed to hornblende, and of feldspar identical with that seen at Kekequabic lake (Nos. 1061, etc.). One section.

Age. Archean (Upper Keewatin).

Remark. The discovery of pebbles of rock in this conglomerate, like the porphyritic rock of Kekequabic lake, and like the porphyrel of Zeta lake, seems at first view to indicate a later date for the Ogishke conglomerate; but that is not a necessary inference, since similar porphyritic pebbles are found in both those other rocks, rather indicating, instead, an identity of origin and age for all of them. N. H. W.

No. 1066. Graywacke.

Same locality as No. 1063; N. W. ¼ sec. 27, T. 65-6; Ogishke Muncie lake.
Ref. Annual Report, xv, page 396.

Meg. Rather quartzose, sometimes pebbly, generally with no signs of bedding.

Mic. *Feldspar* and *quartz* grains compose this rock essentially. They are frequently angular, the cement consists of the same in a finer state of comminution, of *calcite* and *kaolinic* debris. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1067. Green Schist.

East side of the second narrows of Ogishke Muncie lake; N. W. ¼ sec. 24, T. 65-6.
Ref. Annual Report, xv, pages 371, 396.

Meg. Schistose, almost fissile, a part of the conglomerate of the region.

Mic. There is a banding, evidently due to the occurrence of finer and coarser elements in bedding, which is seen to cross the slide. These bands are also characterized by greater or less amounts of a brightly polarizing mineral the nature of which, owing to the extreme fineness of the rock and the thickness of the section, cannot be determined, but which appears to be *calcite*, or muscovite. There are numerous feldspar fragments in the coarser bands, and one nearly entire crystal lying with its greatest dimension parallel with the banding. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1068. Greenstone.

From the hill a little north of the second narrows of Ogishke Muncie lake, east side of sec. 24, T. 65–6.
Ref. Annual Report, xv, pages 371, 372, 396; Annual Report, xvi, page 96; Annual Report, xvii, pages 196, 205.

Meg. Collected under the name doleryte.

Mic. The whole slide is composed of a very fine, green element, like some species of *chlorite*, with scattering remnants of feldspar (and secondary feldspar) and *calcite*. There were sundry small geodic cavities which have become filled with the same chloritic substance. Separating this chlorite from the walls of the original cavity is a coating of a transparent mineral of very low double refraction, uniaxial and probably *quartz*. One section.

Age. Archean (Keewatin).

Remark. In this rock there is no trace of ophitic structure. *Calcite* constitutes nearly one-half. There are a few *magnetite* grains, with accompanying *leucoxene*.

N. H. W.

No. 1069. Marble (*with greenstone inclusions*).

Hill just northwest of the last; sec. 24, T. 65–6.
Ref. Annual Report, xv, pages 371, 396; Annual Report, xvi, page 95; Annual Report, xvii, page 199.

Meg. Rusty, calcareous, fine grained. (Compare No. 746.) Rises about ten feet.

Mic. What remains of the slide, which is accidentally much wasted in the preparation, shows a rock like the last, but containing more *calcite*. One section.

Age. Archean (Keewatin).

Remark. As this rock was collected under the same "irony conglomerate," it is probable that the slide does not fairly represent it. N. H. W.

No. 1070. Conglomerate. (*Rusty.*)

Rapids of the stream connecting Ogishke Muncie and Town Line lakes; sec. 13, T. 65–4.
Ref. Annual Report, xv, pages 372, 396.

Meg. Pebbly, schistose conglomerate.

Mic. There is a little quartz amongst the pebbles of this conglomerate, but generally the pebbles are of some greenstone, either very fine grained and with much *calcite* or thickly porphyritic with microlitic *feldspars*, in both cases so altered that the hornblendic ingredient is chloritized. In the finer matrix embracing these is *pyrite* and *siderite*, the latter frequently surrounded by a rustiness due to its oxidation. In one case the pebble contains old feldspars of larger size, recalling the rocks of Kekequabic lake, but as the pebble has no porphyritic hornblendes nor secondary growths, but much scattered chlorite and calcite, it is hardly to be referred to that origin, but may be considered a case parallel with that mentioned under No. 1065. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1071. Tuff (?)

Northward projecting point south shore of Frog Rock lake; sec. 18, T. 65-5.
Ref. Annual Report, xv, pages 372, 396.

Meg. Porphyritic, apparently, with some pyroxene, but generally a green, amorphous rock. Contains pyrite.

Mic. Throughout the matrix, which is fine and chloritized and nearly dark between crossed nicols, are disseminated many fragments of uralitized *augite* and of *feldspar*. There are but few *hornblendes* that show secondary growths of *actinolite*. Epidote also is conspicuous. There are areas in the slide that are darker and of different grain from the rest, indicating a pebbly or tuffaceous accumulation. One section.

Age. Archean (Keewatin).

Remark. This rock seems to be allied in origin and age to the Kekequabic Lake fragmental green schists. N. H. W.

No. 1072. Tuff. *(Basic.)*

East end of Frog Rock lake; sec. 17, T. 65-5.
Ref. Annual Report, xv, page 372.

Meg. Greenstone-like rock. Contains pyrite.

Mic. Rounded and sub-angular quartzes and feldspars are disseminated as clastic debris in a green calciferous matrix, in which are also *leucoxene* and *pyrite*. In this slide is seen also a pebble of diabase which shows yet its ophitic structure. In this pebble the pyroxenic element is altered entirely to a chloritic green mineral of low double refrction in which is much fine-grained *calcite*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1073. Graywacke.

Mouth of Ogishkie Muncie creek; sec. 26, T. 65-6.
Ref. Annual Report, xv, pages 372, 376, 396, 397; Annual Report, xvii, pages 197, 205.

Meg. Coarse jointed, massive.

Mic. Rather quartzose, fragmental, containing also fragments of *microcline*, *plagioclase*, *zircon*, *calcite*. Two sections.

Age. Archean (Keewatin).

Remark. Judging from the fact that two slides bear this number but differ considerably, this rock varies from the above character to a more green, less siliceous one, in which the matrix is very chloritic and calcareous and contains but few quartz grains. N. H. W.

No. 1074. Graywacke.

Near the same place as No. 1073.
Ref. Annual Report, xv, pages 372, 396; Annual Report, xvii, pages 197, 204.

Meg. Irregular stratum of No. 1073, holding fragments of *fissile*, closely jointed slate.

Mic. Only a finer grained condition of rock resembling No. 1073. One section.

Age. Archean (Keewatin).

Remark. The section was probably made from one of fragments of slate.

N. H. W.

No. 1075. Greenwacke.

Near the same place as No. 1073.
Ref. Annual Report, xv, pages 372, 396.

Meg. Collected with the purpose of showing a blending of the characters of Nos. 1073 and 1074.

Mic. The sections are so similar and so thick and the rock so fine that no differences can be stated to exist between these rocks. Two sections.

Age. Archean (Keewatin). N. H. W.

No. 1076. Diabase.

From hills in the southern part of sec. 35, T. 65-6; south of Ogishke Muncie lake.
Ref. Annual Report, xv, pages 373, 374, 376, 397.

Meg. Tough, massive, coarse jointed.

Mic. The ophitic structure is evident, but the most of the pyroxene is altered to *hornblende*. A section of the feldspar cut so as to show n_g nearly perpendicular, and in the acute angle of the optic axes, has an extinction on cleavage of 9°, indicating *andesine*, according to the determinations of Fouqué. As this grain of feldspar holds minute *apatites* it appears to be one of the original generation, but it is not, as it lies, ophitic in respect to the surrounding ferro-magnesian minerals. There is also considerable *quartz* in the rock. One section.

Age. Archean (Keewatin). N. H. W.

No. 1077. Greenstone. (*"Pebbly."*)

Same place as No. 1076.
Ref. Annual Report, xv, pages 373, 374, 397; Annual Report, xvi, page 97.

Meg. In the field apparently graduating into No. 1076.

Mic. This slide has a varied composition. One part is made up of loosely set imperfect green spheruliths though without marked radial structure, lying in a matrix which is sub-translucent, or nearly isotropic. Amongst these spheruliths are a few scattering idiomorphic crystals of *feldspar*, each crystal about as large in cross section as 8 to 12 of the spheruliths. Another portion consists of *actinolite* and *chlorite*, with more or less of *feldspar*, being in general much more transparent than the last, though containing also some of the same spherulitic forms and some *magnetite*. A third portion, not well separated from either of these, is fine grained, but consists of about the same elements.

The porphyritic aspect, the fine and almost isotropic nature of the substance embracing the little spheruliths, the varied nature of the structure connected with the essential unity of the composition, conspire to indicate that this rock was originally a basic basalt, somewhat porphyritic, a diabase porphyryte. One (thick) section.

Age. Archean (Keewatin). N. H. W.

No. 1078. Greenstone.

Near the same place as Nos. 1076 and 1077; hills in sec. 35, T. 65-6; south of Ogishke Muncie lake.
Ref. Annual Report, xv, pages 368, 372, 373, 397.

Meg. Coarse jointed, massive, porphyritic.

Mic. The much decayed feldspars are crowded with *zoisite*, *calcite* and other impurities. The pyroxene element is changed to *hornblende*, about which are gathered *hematite* and more or less *leucoxene*, the latter also being in other parts of the slide. Two crystals of *apatite* of the first generation also are conspicuous. One section.

Age. Archean (Keewatin).

Remark. This rock was probably originally a massive diabase with ophitic structure. N. H. W.

No. 1079. Conglomerate. *(Matrix of the pebbles.)*

Southern portion of sec. 23, T. 65-6; one-third of a mile north of the shore of Ogishke Muncie lake.
Ref. Annual Report, xv, pages 374, 397.

Meg. Matrix of the Ogishke conglomerate.

Mic. The rock consists, besides the finest matrix, of the following pebbles: *quartz;* diabase, both fine and coarser, particularly the former; *hornblende* crystals; *feldspar* crystals, which have the striking multiple twinning of those in rock No. 1061, at Kekequabic lake and in the porphyrel of Zeta lake; fine-grained rock like the matrix of the crystals of the Kekequabic Lake rocks, numerous; quartzyte, in which several orientations are in one pebble. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1079A: Pebble *(from No. 1079).*

Same place as No. 1079, *i. e.*, one-third of a mile north of Ogishke Muncie lake, sec. 23, T. 65–6.
Ref. Annual Report, xv, pages 375, 397.

Meg. Gray, fine-grained pebble.

Mic. The section shows a rock in all respects like the porphyry at the narrows of Kekequabic lake, and like the pebbles in that porphyry, having along with crystals of *feldspar* and altered *augite*, some large *quartzes.* These lie isolated in a very fine matrix of feldspar and quartz, in which still are seen some finer fragments of the same kind of crystals.

A section of another pebble from the same shows essentially the same kind of rock, but in this the matrix is considerably coarser, and more *calcite* is disseminated. The feldspars show their original zoning, but the *hornblendes* are not apparently of two periods of growth, but are much chloritized. Two sections.

Age. Archean (Upper Keewatin). N. H. W.

No. 1080. Conglomerate. *("Porphyritic.")*

Northeast corner of S. E. ¼ sec. 22, T. 65–6, north of Ogishke Muncie lake.
Ref. Annual Report, xv, pages 375, 397.

Meg. Evidently a fragmental rock with scattered crystals of large size of some feldspar.

Mic. There is *jasper*, *quartz*, *hornblende*, *feldspar*, *diabase*, and many pebbles like the matrix of the Kekequabic lake porphyroids. These constitute the coarser elements, but they graduate in size downward into the matrix. The whole rock might be considered a product of destructive friction on rocks of the Kekequabic lake series (No. 1061), or a non-metamorphic conglomerate of the same kind and age. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1081. Flint. *(Black.)*

N. E. ¼ sec. 22, T. 65–6, north of Ogishke Muncie lake.
Ref. Annual Report, xv, pages 375, 397.

Meg. Black slate.

Mic. Very fine-grained mixture of angular *quartz* and *feldspar* and probably debris of ferromagnesian elements, with secondary generation of *quartz*, sometimes in small veins. In convergent light, and on lowering the lower nicol there come to sight many isolated fine granules of what appear to be *zoisite* or *epidote* and a network of what appears to be fine spicules and fragments of *actinolite*. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1082. Tuff. *(Hard, dense, dark.)*

Eighty rods northwest of the last.
Ref. Annual Report, xv, pages 375, 376, 397.

Meg. Thicker bedded and arenaceous, sometimes greenish.

Mic. There are but few grains of *quartz* in the slide, but there are many fragments of *hornblende* and of *feldspar*, as well as some pebbles of rocks in which these crystals appear. The whole rock appears to be a volcanic tuff or a debris from quartz-porphyry and other Lower Keewatin rocks. It is similar to the rock No. 1080, but finer grained. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1083. Slate. *(Green-black, flinty.)*

From the hill, same locality.
Ref. Annual Report, xv, pages 375, 397.

Meg. Resembles a fine, flinty basalt, intersecting No. 1082.

Mic. The slide consists largely of *chlorite*, spicules of *actinolite*, feldspar, and roundish scattered grains, apparently of *epidote*, which are sometimes grouped into grains of larger size. These larger grains have a high single and also double refraction. There is a small amount of fine *quartz* in angular grains. One section.

Age. Archean (Upper Keewatin).

Remark. This rock is evidently a clastic one. N. H. W.

No. 1084. Conglomerate. *(Fine.)*

Sec. 22, T. 65-6. Same locality as No. 1082.
Ref. Annual Report, xv, pages 375, 397.

Meg. Fragmental rock from the dark-green beds represented by No. 1082.

Mic. Highly angular, gritty, with *quartz* and feldspar. The rock is a fair sample of the finer portions of the Ogishke conglomerate. There are many fine-grained fragments, apparently of the matrix of a quartz-porphyry and of *feldspar* and of *hornblende*. Some parts appear to be wholly micro-granulitized feldspars. It is apparent that the elements of this rock were much decayed before they entered into the constitution of a rock mass, but were not long exposed to sedimentary attrition. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1085. Conglomerate.

West end of Little Reynard lake, near the water; sec. 26, T. 65-6.
Ref. Annual Report, xv, pages 375, 397.

Meg. Evidently a coarse fragmental.

Mic. The slide is quite varied in its aspects. With conspicuous angular and subrounded *quartz* grains are many pebbles of a very fine-grained earlier fragmental rock, of old, now much decayed, twinned *feldspars*, and apparently of an older diabasic rock (judging from a suggestion of the ophitic structure still remaining). These are embraced in a greenish, finer matrix which is debris probably from some basic rock, the whole liberally sprinkled with *calcite* and a little *pyrite*. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1086. Slate. *(Black.)*

Near the same locality as No. 1085.
Ref. Annual Report, xv, pages 376, 397.

Meg. A very fine-grained, siliceous, black slate. No section.

Age. Archean (Keewatin). U. S. G.

No. 1087. Breccia.

Portage from Fox to Ash lake. The specimen came from near the southwest corner of sec. 25, T. 65-6 W.
Ref. Annual Report, xv, pages 377, 397.

Meg. A breccia of fine-grained, gray, siliceous slate and a coarser, gritty rock, the latter including fragments of the former. No section.

Age. Archean (Keewatin). U. S. G.

No. 1088. Biotite Schist *(with quartz).*

North shore of Gabemichigama lake. From an island at the entrance to the bay running northeast; S. W. ¼ sec. 29, T. 65-5.
Ref. Annual Report, xv, pages 379, 397; Annual Report, xxi, page 147.

Meg. Quartzitic slate, having a columnar aspect.

Mic. *Biotite* is very conspicuous, also angular *quartzes.* These lie in a finer matrix of quartz grains which also has some of striated *feldspar.* The quartz is secondary to the biotite, and partially incloses it poikilitically, having been entirely recrystallized. One section.

Age. Archean (Keewatin). N. H. W.

No. 1089. Biotite Schist *(with actinolite).*

North side of the long point, S. W. ¼ sec. 32, T. 65-5, Gabemichigama lake.
Ref. Annual Report, xv, pages 379, 380, 397; Annual Report, xxi, page 147.

Meg. Siliceous, fine grained, rather dark, in heavy layers.

Mic. In a fine background of secondary granular *quartz* are numerous *biotite* leaves, and a debris from basic rock consisting now in part of *actinolite* in fibres and occasionally in bundles of fibres, but most abundantly of scattered granular or globular particles, which are also embraced in the enlargements of the quartz. In the form of grains and minute particles this element mingles widely with the quartzose matrix and is evidently some form of *pyroxene.* One (thick) section.

Age. Archean (Keewatin). N. H. W.

No. 1090. Biotite Gneiss *(or schist, with cordierite).*

South shore of the same long point, Gabemichigama lake.
Ref. Annual Report, xv, pages 379, 380, 397; Annual Report, xxi, page 148.

Meg. Siliceous, gneissic, with evident biotite.

Mic. This rock is like the last, but is coarser and has a monoclinic *pyroxene.* The secondary *quartzes* form large crystals that embrace the earlier grains of *cordierite* and this regenerated ferro-magnesian debris poikilitically. Many of the glassy grains thus embraced are apparently of *oligoclase-andesine.* They not only show a fine albite twinning, but in a favorable section showing n_p perpendicular the extinction on the twinning trace was 70°. This is not conclusive, but by making the Becke test for comparative refraction it is found that these earlier glassy grains are uniformly less refractive than the quartz; many of them are certainly of cordierite. Compare Nos. 1350 and 1351. One section.

Age. Archean (Keewatin).

Remark. In another section of this rock the recrystallization is more advanced, the grains are larger and interlocking more like the structure of a crystalline massif. But as the rocks of this point are known to be clastics affected by the gabbro, this furnishes an instructive instance of the manner of formation of gneiss from clastic rock.

The rocks of this point received detailed examination in the field, and are referred to again under Nos. 1350 and 1351. See also rocks Nos. 767, 768, 983.

N. H. W.

No. 1091. Biotite Gneiss.

Same locality. Northwest portion of the S. W. ¼ sec. 32, T. 65–5, Gabemichigama lake.
Ref. Annual Report, xv, pages 380, 397; Annual Report, xxi, page 148.

Meg. The same kind of rock, but without apparent bedding or gneissic structure.

Mic. The same interlocking fine secondary quartz and feldspar as groundmass, is thickly and uniformly sprinkled with biotite. N. H. W.

No. 1092. Biotite Gneiss *(with cordierite)*.

Near the same place as the last, northwest corner S. W. ¼ sec. 32, T. 65–5.
Ref. Annual Report, xv, pages 380, 397.

Meg. Stratified gneissic rock. Compare No. 1350.

Mic. The rock, consisting entirely of secondary products, is still entirely crystalline. The most abundant element is perhaps the cordierite. This *cordierite* sometimes wholly surrounds small *pyroxene* grains which are nearly round. *Quartz* is less common, but still there are some large grains, and these are spread amongst the other minerals so as to involve them poikilitically, *i. e.*, the small *cordierites*, the pyroxenes, the biotite, the last also embracing the small pyroxenes.

The pyroxenes present a singular feature; they embrace sometimes a number of smaller globular pyroxenes, of differing orientation, and when these are numerous the general extinction is imperfect, and the whole grain appears to be made up of a grouping of smaller individuals. The consequence is that there is no complete extinction, and at the same time the cleavages are not evident. This phenomenon has to be explained in the same manner as *quartz-globulaire* has been explained by Fouqué, and similarly to the *siderite-globulaire* already noted in this work, viz.: that these infant globules represent the commencement of aggregation into crystals, but never acquired definite crystal outlines. One section.

Age. Archean (Keewatin). N. H. W.

No. 1093. Tuff. *(Green schist.)*

Southeast side of sec. 29, T. 65-6. Point in Kekequabic lake.
Ref. Annual Report, xv, pages 369, 397.

Meg. Greenish gray, nearly homogeneous, basaltiform.

Mic. Fragmental debris, consisting very largely of *hornblende* and *feldspar*, with a little angular *quartz* in a matrix of finer materials of the same, with a few grains and groups of *epidote*. The last is also quite abundant in the form a finer powder in the matrix, but rarely being coarse enough to show its polarization colors. There is a large amount of very fine isotropic substance, apparently of *chlorite*. One section.

Age. Archean (Keewatin).

Remark. The hornblendes do not show secondary growths. N. H. W.

No. 1094. Esterellyte (?) *(or Dacyte)*.

At the corner of secs. 29, 30, 31, 32, T. 65-6, Kekequabic lake.
Ref. Annual Report, xv, pages 368, 397; Annual Report, xvi, page 100; Annual Report, xvii, pages 197, 205; Bulletin vi, pages 41, 422; see, also, Annual Report, xxi, pages 41-49.

Meg. A hard, gray, porphyroidal rock, not evidently bedded or banded. Compare Nos. 1061, 1399.

Mic. Similar to some already described at Kekequabic lake. Extinction on feldspar 28° on n_g, acute bisectrix, indicates *labradorite*. On another grain extinction on n_g is 22°, indicating *labradorite* and on another 29°, indicating the same. There is also some *microcline*, at least a microcline twinning. The larger crystals of the labradorite are zoned and composed of different species. Sometimes the fresh central area extinguishes with the external zone, the acute bisectrix being n_g, at an angle of 9°, indicating *andesine*. Sometimes two feldspars are minutely interleaved like *microperthite*, the interstructure being parallel with the exterior of the crystal, as shown by the adjoining sketch, which shows a section nearly parallel to the brachypinacoid. These feldspars are also twinned in a complex manner. They sometimes include little crystals of *augite*, which are also more abundant in the surrounding rock, and are of considerable size, occasionally breaking the boundaries of the feldspars. These are fresh and idiomorphic or fragments of idiomorphic crystals. Scattered through the finer matrix are also numerous *actinolite* spicules, but these have no apparent connection with the augites. In this rock is also some secondary *quartz*, some *sphene* and some *apatite*. Two sections.

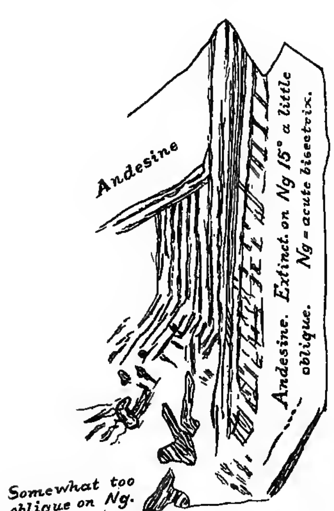


FIG. 41. TWINNED AND ZONED FELDSPAR IN ROCK NO. 1094.

Remark. That these augites and labradorites did not grow up together in the place where they are now found, is evident from the fact that their boundaries rarely interlock. Yet, that they grew together in the same rock, in same place, is evident from the inclusion of minute augites occasionally in the feldspars. That they are both out of their native places is further evident from the nature of the surrounding matrix, which consists of debris of actinolite and of secondary quartz, combined with fragmental stuff largely made up of feldspathic and augite grains. Such feldspars, holding augite in the same manner, are seen also in the porphyrel of Zeta lake, which is plainly composed of clastic materials, and is believed to be a less metamorphic analogue of this rock.

The following account by Dr. Grant, of the augite of this rock, No. 1094, which is the same as No. 86G, is taken from the Twenty-First Annual Report, pages 45–48.

"The *augite* occurs in short, stout prisms, whose length is half a millimeter or less; rarely, larger crystals, one to three millimeters in length, are seen. The crystals are generally completely idiomorphic, but occasionally the terminal planes are lacking, or are very poorly developed. The prismatic planes are the unit prism, the orthopinacoid and the clinopinacoid. The terminal faces, which are usually present, are the basal plane and the orthodone $P\bar{\infty}$ while the unit pyramid and a clinodome can sometimes be recognized, but usually there is a tendency to a rounding off of the edges of the basal plane and the orthodome $P\bar{\infty}$. The cleavage is well developed in thin sections and parting is usually not seen, but in one case (see figure 43) it is quite noticeable. An attempt was made to measure the angles on some of the larger augite crystals detached from the rock, but the faces gave such imperfect reflections that no satisfactory results were obtained.

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

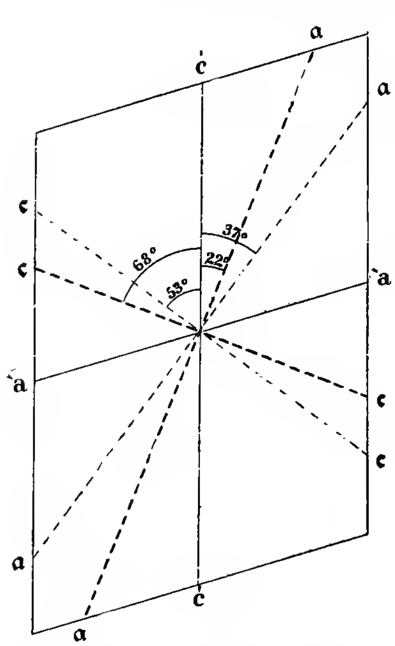


FIG. 42. DIAGRAM SHOWING THE RELATIVE POSITIONS OF THE CRYSTALLOGRAPHIC AND OPTICAL AXES IN THE GREEN AND COLORLESS AUGITE.

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

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

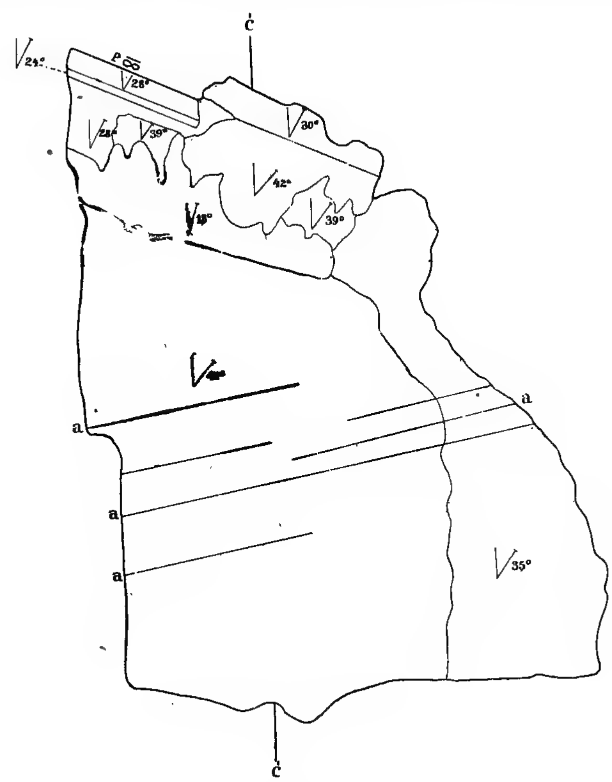


FIG. 43. SECTION OF AUGITE CRYSTAL SHOWING AREAS OF DIFFERENT OPTICAL ORIENTATION.

"The extinction angle of the colorless augite in sections parallel to the clinopinacoid runs as low as 37°, although usually higher than this; this is an angle of 53° as the extinction of augite is usually measured, *i. e.*, $\mathfrak{c}$ to c in obtuse angle b. In the green crystals and rims $\mathfrak{a}$ is inclined about 22° to c, but in one section it is as low as 18°. The positions of the axes of elasticity with reference to the crystallographic axes are shown in the accompanying figure (figure 42); the axes of elasticity of the colorless variety being represented by the lighter dotted lines.

"While in the zonal crystals there are usually only two parts, which are of different optical orientation, in a few there are more than two such areas. To illustrate parallel growths of this kind, the above figure is introduced. It shows part of a large crystal of augite cut parallel to the clinopinacoid. The extinction and outlines of the different parts are represented rather diagrammatically, as the different zones are not always separated by a sharp line. The lines *a a* represent the parting parallel to the basal plane. The extinction angles given are those of $\mathfrak{a}$ against *c*. The large central part of the crystal is colorless and the rest is greenish; the small irregular area with an extinction of 18° is yellowish green and distinctly pleochroic.

"A typical fresh specimen of the porphyritic granite (No. 86G) was powdered and the augite separated and analyzed. This augite is fresh and unaltered and the powder used (which has a higher specific gravity than 3) is quite pure, as in this specimen of the granite the only other minerals present were feldspar and quartz with a few minute fibres of secondary hornblende. The analysis is here given:

Analysis of augite.

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

"Assuming that this represents an isomorphous mixture of the diopside, heddenbergite, acmite and fassaite molecules and calculating their relative proportions, we get approximately the following result:

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

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

An analysis of the whole rock gave the following results:

SiO_2	67.42
Al_2O_3	15.88
Fe_2O_3	1.37
FeO	1.14
MnO	trace
CaO	3.49
MgO	1.43
K_2O	2.65
Na_2O	6.42
P_2O_5	0.07
H_2O	0.05
Total,	99.92

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

Age. Intrusion in the Upper Keewatin.

Remark. The name of this rock was given by M. A. Michel Lévy to the blue porphyry of Esterel in 1897,* a laccolitic and intrusive rock of southern France penetrating Permian strata, which he shows is perfectly analogous to the laccoliths of the Henry mountains. The chief chemical difference between this rock and that of Esterel consists in the somewhat greater percentages of silica and of soda in this. This high percentage of soda is in harmony with the aegirite nature of the pyroxene.

N. H. W.

No. 1095. Tuff. *(Porodyte?)*

Mallmann's peak, S. E. ¼ sec. 30, T. 65-6; Kekequabic lake.
Ref. Annual Report, xv, pages 368, 397.

Meg. Banded graywacke and slate.

Mic. The grains are angular, consisting of *quartz* and *feldspar*, embraced in an abundant matrix of prevailingly green elements. There are also pebbles which were probably originally glassy *(zirkelyte)*, but now are dark constantly between the nicols or are sprinkled sparsely with polarizing specks. This substance, in finer condition, also constitutes much of the surrounding matrix. Some of these pebbles are black, with fine dust of *magnetite*. A little *pyrite* is scattered through the slide. One section.

Age. Archean (Keewatin). N. H. W.

No. 1096. Diabase.

From a dike making a couple of islands in Kekequabic lake, south of Mallmann's peak, N. E. ¼ sec. 31, T. 65-6.
Ref. Annual Report, xv, pages 368, 398; Annual Report, xxi, page 29.

Meg. Dark, diabasic rock, of medium grain.

Mic. An ordinary diabase, which, however, has been subjected to some dynamic stress, as the pyroxenic element, which appears in the main to be still *augite* and is ophitic toward the feldspars, is broken into several fragments (each crystal) which cause a shifting extinction to pass over the crystal. The feldspars are all more or less clouded by *zoisite* and by *mica*. The rock has also some original crystals of *magnetite* and some secondary *actinolite* and *pennine*. One section.

Age. Dike cutting the Archean. N. H. W.

No. 1097. Green Schist.

S. E. ¼ sec. 30, T. 65-6 W. South shore of Kekequabic lake.
Ref. Annual Report, xv, pages 368, 398.

Meg. A rather soft, green schist, similar to many others in the vicinity. Evidently consisting largely of hornblende. In the field this rock shows contorted sedimentary structure. No section.

Age. Archean (Keewatin). U. S. G.

*Mémoire sur le porphyre bleu de l'Esterel. *Bull. Ser. Carte Geol. France No. 57*, tome ix, 1897-1898, Paris.

No. 1098. Green Schist.

N. W. ¼ sec. 31, T. 65–6, Kekequabic lake.
Ref. Annual Report, xv, pages 367, 368, 398; Annual Report, xvii, pages 197, 206.

Meg. "Conglomeratic, chloritic schist; phase of No. 1060."

Mic. There are fine fragments of *actinolite* and a few of *feldspar* distributed in a very fine pulpy matrix whose constituents cannot easily be differentiated, but which is partly actinolitic, but largely consists of a dirty, yellowish, fine mesh, which is almost wholly dark between the nicols, but which is probably in part chloritic and partly actinolitic, and at first zirkelyte. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1099. Tuff.

Portage trail from Kekequabic lake northward. Sec. 34, T. 65–7.
Ref. Annual Report, xv, pages 366, 398.

Meg. Hornblendic and conglomeratic, sometimes gneissic.

Mic. The fragmental hornblendes are generally free from secondary enlargements, which, in the form of spicules of *actinolite* have been disseminated throughout the matrix, but in some cases these secondary attachments are still in their native places. Some of the feldspars are also zoned. These lie in the usual fine fragmental matrix. In one section the elements are all much finer, and much calcite has been generated. Two sections.

Age. Archean (Upper Keewatin). N. H. W.

No. 1100. Granite.

Most westerly island in Kekequabic lake, sec. 3, T. 64–7.
Ref. Annual Report, xv, pages 361, 362, 398.

Meg. Reddish syenitic rock.

Mic. This rock is like those already mentioned (Nos. 1044 and 1045), made up largely of a recomposed debris of coarse, much twinned and zoned *feldspars,* lying in a matrix, now recrystallized, composed of secondary *feldspars, quartz, calcite* and *actinolite,* with scattering *magnetite* powder. One section.

Age. Archean (Keewatin).

Remark. This rock is a special condition of the prevailing tuffs of the region, due to greater effect of a regional metamorphism probably earlier than the advent of the gabbro. It differs from the tuffs in having a coarser interlocked matrix of quartz and feldspar, and in the manner in which the old feldspars are interlocked about their margins with the surrounding matrix by secondary enlargements.

N. H. W.

No. 1101. Granite.

From the north side of the same island, Kekequabic lake.
Ref. Annual Report, xv, pages 361, 362, 398.

Meg. Similar to the last, but greenish.

Mic. This rock, like the last, contains numerous old *feldspars* much twinned, with ragged edges, eaten into by a secondary micro-granulitic development of fresh *quartz* and feldspars. Some of the old feldspars are almost entirely replaced by this new generation. The *hornblende* is somewhat brown in pleochroism, parallel to n_m, and bluish parallel to n_g. The rock also has a few grains of *sphene* and scattered *magnetite*, and also *pyroxene* and *calcite*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1102. Granite.

West end of Animikie island in Kekequabic lake. S. W. ¼ N. E. ¼ sec. 3, T. 64–7 W.
Ref. Annual Report, xv, pages 362, 398.

Meg. "Greenish syenyte identical with No. 1101." No specimen found. No section.

Age. Archean (Keewatin). U. S. G.

No. 1103. Granite.

Northwest corner of Animikie island in Kekequabic lake. S. W. ¼ S. W. ¼ sec. 3, T. 64–7 W.
Ref. Annual Report, xv, pages 362, 398.

Meg. A reddish and a gray specimen, the former quite similar to Nos. 1101 and 1102. In one place a breccia is apparent, the gray holding fragments of the red. No section.

Age. Archean (Keewatin). U. S. G.

No. 1104. Tuff. *(Subgranitic.)*

East end of the largest or Animikie island, Kekequabic lake.
Ref. Annual Report, xv, pages 362, 398.

Meg. Green and diabasic in aspect, rather fine grained.

Mic. This fine-grained rock contains numerous fragments of feldspar, most of them very small and apparently of secondary date, but some of them old; *hornblende* in subordinate amount, also in mesh-like arrangement, and *biotite*. The last occurs both in the fine interlocked groundmass and in the body of the larger grains of feldspar. The slide also contains patches of rock, which varies from the rock of the slide, by being finer grained, or free from hornblende, but micro-granulitic with feldspar. Sphene and magnetite as in No. 1101. One section.

Age. Archean (Keewatin). N. H. W.

No. 1105. Esterellyte *(or Dacyte)*.

From the north side of the little island northeast of Animikie island, sec. 2, T. 64–7, Kekequabic lake.
Ref. Annual Report, xv, pages 363, 398; Annual Report, xvi, page 104.

Meg. Apparently porphyritic, siliceous.

Mic. This rock consists very largely of secondary *quartz* in interlocking growths which surround the old *feldspars*, which are much twinned and also much altered. In this interlocking growth are also irregular, apparently fragmental masses of *augite* and a few of *sphene*, as well as a few spicules of green *hornblende*. The feldspars are strikingly zoned, and are intergrown, apparently along the easy cleavages, in the manner of a microperthite, by another feldspar of later date, this later growth being somewhat interlocked about the margins in the secondary quartz. In this rock some of the small augite crystals are entirely included in the old feldspars. The same is true of some of the sphenes. One section.

Age. Archean (Keewatin). N. H. W.

Remark. This rock is closely similar to No. 551G, which is a part of this same granite mass. No. 551G is from the south shore of Kekequabic lake in S. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$ sec. 3, T. 64-7 W.

An analysis of the whole rock is as follows:

SiO_2	66.84
Al_2O_3	18.22
Fe_2O_3	2.27
FeO	0.20
CaO	3.31
MgO	0.81
K_2O	2.80
Na_2O	5.14
P_2O_5	trace
H_2O	0.46
Total	100.05

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

Analysis of feldspar.

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

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

No. 1106. Syenyte. (*Augitic, Esterellyte.*)

From the same little island as the last, north side.
Ref. Annual Report, xv, pages 363, 398. Compare No. 574G.

Meg. Porphyritic, similar to the last.

Mic. Has a great abundance of *augite*, considerable *biotite*, *sphene*, and large *apatites*. In this slide, where the augites are numerous, not only are some of the small ones entirely enclosed in the old feldspars, but several of the larger augites are seen to break the feldspar boundaries in a poikilitic manner, and the biotite does the same, while the biotites are pierced by spicules of *actinolite*, and broken by the augite. One section.

Age. Archean (Keewatin). N. H. W.

Remark. This rock represents the "poikilitic phase" of the granite as described by Grant in the Twenty-first Annual Report, page 50 (compare No. 574G). While the rocks Nos. 1105 and 1106 have certain characters that show them closely related petrographically, they are seen in the field to be one intrusive in the other, as thus described in the Twentieth Annual Report, page 74:

> There is an island in the N. W. ¼ N. W. ¼ sec. 2, T. 64–7, which is made up mostly of the pyroxene granite (No. 573G); this varies somewhat in grain, but none was seen as fine as No. 571G; it is noticeably porphyritic with reddish feldspars. On the west side of the island near the north end is a rock with a green aphanitic groundmass in which are numerous glistening biotite scales (No. 574G). This rock is seen in contact with the granite; the contact line is sharp and distinct. The green rock is cut by many vein-like forms of a purple rock which is seen to be part of the granite, but they were not actually traced into the granite. No. 575G shows this rock in contact with the green rock. On a microscopic examination No. 575G is seen to be part of the granite The two rocks were not apparently changed near the contact. Many angular and rounded fragments of the green rock are seen in the granite and a few fragments, or what appear to be such, of the latter are seen in the green rock. The evidence of this exposure points to the more recent age of the granite.

The rocks about Kekequabic lake can be divided petrographically into three groups, as follows: Group I, Nos. 1061, 1094, 1105, which are distinctly porphyritic with augite (and hornblende) and feldspar. These are at the narrows of the lake and on the little island northeast of Animikie island. There is reason to believe, contrary to the opinion of the writer when the field observations were made, that this is an igneous rock in its present structural relations, and that it originally existed in other regions adjacent. It is probably a phase of the granite represented by the first numbers of group II, below, both being intrusive in the green schists of Kekequabic lake, and into the crystalline conditions of that green schist.

The second group includes Nos. 1044, 1045, 1046, 1051, 1052, 1100, 1101, 1104, 1106. These are rather granitic in texture, and, judging from their geographic distribution, which is nearest the strike of the gabbro, as well as from their petrographic features, they may be referred to a recrystallization of older clastics more or less mingled with volcanic detritus, perhaps at the time of the gabbro revolution. These may again be separated into two sub-groups by excluding Nos. 1101, 1104 and 1106, which are green with much hornblende.

The third group is non-crystalline debris, or less crystalline than the last, and includes the following: Nos. 1047, 1048, 1049, 1050, 1055, 1057, 1058, 1059, 1060, 1093, 1098 and 1099.

The third group becomes more and more coarse and even conglomeratic toward the east, and cannot be distinguished petrographically from the Ogishke(?) conglomerate, as represented by the following numbers: 1062, 1063, 1064, 1065, 1066, 1080, 1095. N. H. W.

No. 1107. Flint.

West side of sec. 27, T. 65–7, on Knife lake, north from the portage landing from Kekequabic lake.
Ref. Annual Report, xv, pages 381, 398.

Meg. Purplish to black, weathering light colored.

Mic. This is apparently a finer debris of the same kind as the tuffs about Kekequabic lake, but probably of older date. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1108. Mica Schist and Granite.

Basswood lake, at the west end of the portage near the centre of sec. 6, T. 64–10 W.
Ref. Annual Report, xv, pages 356, 398.

Meg. A fine-grained, dark, compact, biotite schist cut by a vein about an inch in width, of medium-grained, pinkish, muscovite granite. No. section.

Age. Archean. U. S. G.

No. 1109. Quartz–Feldspar Schist.

At the portage from Newton lake to Fall lake.
Ref. Annual Report, xv, pages 356, 398; Annual Report, xvii, pages 198, 206.

Meg. "Sericitic" schist.

Mic. There is but little *sericite* in the slide, but there is a very finely granular background of secondary *quartz* and *feldspar*, in which are very sparsely distributed larger grains of *quartz*, *actinolite* and areas of *calcite*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1110. Granite.

From the island in White Iron lake, lying in sec. 33, T. 63–11, and sec. 5, T. 62–11.
Ref. Annual Report, xv, pages 330, 398.

Meg. Quartzose granite, rather coarse.

Mic. A finely striated feldspar has an extinction on n_p of 81°, a feldspar between andesine oligoclase and *oligoclase*, some have no twinning, *orthoclase*, and some have the quadrillage of *microcline*. The ferromagnesian mineral is *hornblende*. There are a few grains of *sphene*. In some of the feldspars is much *zoisite* in rather coarse crystalline grains. One section.

Age. Archean granite. N. H. W.

No. 1115. Actinolite Schist.

Near the north end of White Iron lake.
Ref. Annual Report, xv, pages 330, 398; Bulletin vi, page 8.

Meg. Schistose.

Mic. The section consists almost wholly of a fine interlocking background of *quartz*, or quartz and *feldspar*, in which are many *actinolite* fibres arranged mainly in one direction, some *magnetite* with a very little *garnet*. One section.

Age. Archean (Keewatin).

Remark. The foregoing schists stand nearly vertical, forming a bluff at the outlet of the lake which rises about 100 feet, and has been explored for iron. N. H. W.

No. 1116. Granite.

East shore of White Iron lake at a distance from contact with the schists.
Ref. Annual Report, xv, pages 330, 398.

Meg. Granite.

Mic. The feldspar (a fresh grain) cut perpendicular to n_p in the acute axial angle has extinction on a twinning striation at 88°, indicating *oligoclase*. Another section, having n_g in the acute angle of the optic axes has extinction on n_g of 15°, which falls between *albite* and *oligoclase-albite*. Some grains show the peculiar striation of *microcline*. There is also in the rock a series of older, much decayed feldspars which are frequently zoned. The *hornblende* of the rock is almost converted to *chlorite*. There is comparatively little *quartz*. One section.

Age. Archean granite. N. H. W.

No. 1117. Granite.

North end of White Iron lake, near junction with the schists.
Ref. Annual Report, xv, pages 331, 399.

Meg. Rather quartzose and fine grained.

Mic. The rock has much secondary quartz and secondary feldspars, the latter both as zoning about an older feldspar and as separate small grains, which latter are in part of *microcline*. There is a scant sprinkling of *biotite*, a little rusted *garnet* and a few crystals of *apatite*. One section.

Age. Archean granite. N. H. W.

No. 1118. Granite and Schist. *(Contact.)*

North end of White Iron lake; junction specimen.
Ref. Annual Report, xv, pages 331, 399.

Meg. Granite in immediate contact on the schists.

Mic. In the granite part of the slide is very much *quartz* in its usual secondary form, with a slight tendency to micropegmatitic intergrowth in the *feldspar*, of which some of the larger grains are of *microcline*, in which the peculiar and characteristic quadrillage is seen frequently in only a portion of the section, as if it were due to some secondary cause. There is also a little *biotite* and apparently of *garnet*, but it is remarkably free from the dark minerals. The schist side of the slide is marked by the presence of much *actinolite*, with secondary feldspar and quartz. There are also scattered grains of a highly polarizing monoclinic mineral, with frequent parallel extinction, colorless in common light, in prevailingly sub-quadratic sections, which is more fully described under No. 1123, and is probably *epidote*. One section.

Age. Archean granite. N. H. W.

No. 1123. Schist. (*Epidotic.*)

The same schist, more indurated, from a point lower down the cliff.
Ref. Annual Report, xv, pages 331, 399; Bulletin vi, page 8.

Meg. Actinolitic.

Mic. *Andesine-oligoclase* shows a section perpendicular to n_p in the broader bands, and has an extinction of 72°, and an angle between the macles of albite and of percline(?) in the same section of 72° 30′. This may be, however, due to a microperthitic growth, parallel to 001. The rock has some secondary *quartz* which embraces the other minerals and occasionally surrounds *cordierite*. There is a light green *actinolite* in considerable amount.

Epidote is rather abundant, shown by its high refraction and double refraction, and the position of the optic plane perpendicular to the easy cleavage in sections in the zone of symmetry. Many of the cross sections also have a parti-colored polarization, but a light yellow color in natural light. The mineral has a higher double refraction than actinolite, and also higher single refraction. It occurs in small scattered globular and angular grains which are fresh, evidently of secondary origin. This mineral serves a leading rôle in giving green color to the rock. It frequently shows its own crystal boundaries about a half or more of the individual grains, and it has numerous globular inclusions which give it a strong resemblance to the diopside in the metamorphic schists and gneiss of the long point in the northeastern part of Gabemichigama lake. One section.

Age. Archean (Keewatin).

Remark. If, as supposed when the specimens were gathered, this is a part of the prevalent green schists of the region, this greater crystallization is to be attributed to the action of the great granitic mass which is intrusive in the immediate vicinity.

N. H. W.

No. 1124. Actinolite Schist.

Same place as the last.
Ref. Annual Report, xv, pages 331, 399; Bulletin vi, page 8.

Meg. Somewhat more schistose than No. 1123.

Mic. This is similar to No. 1123, but contains more *actinolite*, with apparently one or two grains of *sphene*, and considerable *biotite*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1128. Green Schist. *(Regenerated.)*

East shore of White Iron lake, N. W. ¼ S. E. ¼ sec. 6, T. 62–11. Cut by intrusive granite.
Ref. Annual Report, xv, pages 331, 399; Annual Report, xvii, pages 198, 208.

Meg. Coarse-grained, crystalline, fresh rock, of dark color.

Mic. The rock is wholly crystalline, in a secondary sense, appearing like a massive rock, and furnishes a fine instance of the effect of metamorphism on the green schists when carried to the extreme. It consists of *hornblende, biotite, microcline* and a triclinic finely twinned feldspar which is probably *oligoclase*, and the same yellow mineral as mentioned in No. 1123, *i. e., epidote.* Scattered throughout the slide, and sometimes clustered, are also numerous globular grains of some pyroxene, perhaps *diopside.* These minerals, excepting the epidote and pyroxene, are interlocked in a truly massive or granitic manner. The diopside(?) is more isolated, yet is sometimes developed into larger crystals. The fresh feldspars are so glassy that they appear like quartz, but so far as tested they all give a biaxial figure in convergent light. The biotite and hornblende are also conspicuously ingrown in a micropegmatitic manner, and in other places the hornblende embraces the biotite poikilitically. One section.

Age. Archean (Keewatin recrystallized).

Remark. It seems impossible to give a current name to this rock. It perhaps could be called amphibolyte, but is too nearly a massive rock, and it has too much of other minerals for that. Still, it has the same origin as many amphibolytes. It might be designated a biotite-hornblende-pyroxene-plagioclase gneiss, but such would hardly be a name. It is rather a description; and, further, the rock is not distinctly gneissic. Perhaps the term tonalyte is appropriate, or mica-dioryte.

N. H. W.

No. 1129. Granite.

Same place as No. 1128, and cutting No. 1128.
Ref. Annual Report, xv, pages 331, 399; Annual Report, xvii, pages 198, 208.

Meg. Granitic.

Mic. *Quartz, microcline, oligoclase, hornblende* make the bulk of this rock, but there are scattering grains of *sphene*, the last being included in the hornblendes and in the feldspars. Many of the large feldspars are much altered at their centres with interpositions of *muscovite* and of *kaolin(?)* and some are wholly changed. In others there is a micro-intergrowth of another feldspar in the manner of *microperthite.* One section.

Age. Archean granite. N. H. W.

No. 1132. Amphibolyte.

South of the meander line between secs. 6 and 7, T. 62–11, White Iron lake.
Ref. Annual Report, xv, pages 331, 399; Annual Report, xvii, pages 198, 208.

Meg. Hornblendic and gneissic.

Mic. This rock, microscopically, is like No. 1128. It is wholly crystalline and granitic in structure. *Hornblende* constitutes somewhat more than one-half of the mass. One section.

Age. Archean (changed Keewatin). N. H. W.

No. 1133. Micro-Granite. *(Aplyte.)*

Meander line between secs. 6 and 7, T. 62-11, White Iron lake.
Ref. Annual Report, xv, pages 331, 399.

Meg. Fine grained, granitic. From dikes cutting granite.

Mic. *Quartz, microcline, oligoclase* in rather fine, interlocking allotriomorphic grains make up the bulk of this rock, but there is also a little *hornblende*, *sphene* and *epidote*. One section.

Age. Archean. N. H. W.

No. 1134. Amphibolyte. *(Micaceous.)*

Lake shore in sec. 12, T. 62-12, White Iron lake.
Ref. Annual Report, xv, pages 331, 338, 399; Annual Report, xvii, pages 198, 207.

Meg. Granitic, dark colored, cut by veins of granite.

Mic. *Hornblende* is the most conspicuous element, but shares the rock liberally with *biotite*. These constitute perhaps one-half of the rock, the rest being mainly of *feldspar*, but yet with a little *quartz* and a few scattered *sphenes*. One section.

Age. Archean (changed Keewatin).

Remark. This rock is petrographically like Nos. 1128 and 1132, and probably has the same origin. N. H. W.

No. 1135. Amphibolyte. *(Changed Keewatin.)*

From small dikes cutting the granite vein above mentioned.
Ref. Annual Report, xv, pages 331, 399.

Meg. Dark, hornblendic.

Mic. Similar to the last, but has no biotite and less hornblende, with evident epidote. One section.

Age. Archean (changed Keewatin). N. H. W.

No. 1136. Gabbro.

From a point about half a mile west of the line between sec. 31, T. 62-11, and sec. 6, T. 61-11, in town 61, Birch lake.
Ref. Annual Report, xv, pages 332, 399.

Meg. Gray, granitic in structure, with much feldspar.

Mic. Feldspar has extinction angle of 62° on n_p, and is hence *labradorite*. The *augite* is sometimes crowded with interlamellar inclusions. The *magnetite* is not unfrequently bordered by *biotite*. The *diallagic* augite was about cotemporary with some of the labradorites, cutting their borders, but being cut by others. *Olivine* is quite plentiful. One section.

Age. Cabotian. N. H. W.

NO. 1137. GABBRO.

From a point a short distance west of the meander stakes between secs. 24 and 25, T. 61–12, Birch lake. *Ref.* Annual Report, xv, pages 332, 399; Annual Report, xvii, pages 198, 207.

Meg. Fine-grained gabbro.

Mic. The *augite* is *diallagic*, and is also sometimes crowded with coarser interlamellar impurities, which, as in the last, do not coincide with the direction of the diallagic structure. *Olivine* is quite abundant. It was cotemporary with, or later than, either feldspar or augite. *Magnetite* is accompanied by *biotite*. The olivine is sometimes changed peripherally to *bowlingite(?)* and in the immediate vicinity is developed a finely radiated, rather highly doubly refracting lamello-fibrous mineral, which, with positive elongation, colorlessness in common light, seems to be a form of *tremolite*, but this is closely mingled with a light greenish fibrous mineral which has about the same structure, arranged frequently along the borders of the *tremolite* areas as if intimately related to the *tremolite*, and sometimes they intertwine or mingle. This is pleochroic and is evidently the remains of a green hornblende *(actinolite)* from which the other is derived. One section.

Age. Cabotian. N. H. W.

[NOTE. Nos. 1141 to 1263, inclusive, were collected outside the state of Minnesota and are not here described, excepting Nos. 1173, 1200 and 1203, which are described below. The field relations and preliminary designations of Nos. 1141 to 1263 are given in the Sixteenth Annual Report, pages 13–60, 114–119.]

NO. 1173. DIABASE.

Thessalon point, Canada. Original Huronian area.
Ref. Annual Report, xvi, page 18.

Meg. Schistose and slaty diabasic rock. Logan's "green chlorite slate."

Mic. The rock is composed of microlitic *feldspars*, lying in a matrix of alteration products, chief among which is *actinolite*, but in which also is *leucoxene*, *zoisite* and apparently *epidote*. One section.

Age. Keweenawan(?)

Remark. This is a part of the great greenstone or diabase seen a few miles further north and west, which is there later in date than the great basal quartzyte on which it lies, the quartzyte being considered of the age of the Potsdam at Potsdam, New York. N. H. W.

No. 1200. Gabbro.

Near Otter Tail P. O. (original Huronian region), Canada.
Ref. Annual Report, xvi, page 29.

Meg. Gray, medium grained, indefinite.

Mic. The rock has been much broken by dynamic movements, and the alteration of all the minerals is considerable. Particularly has *zoisite* been developed, indicated by its high refractive index, its parallel extinction and its blue color between the nicols. Much *pyroxene* is evident, but no olivine, while the feldspar is unidentifiable. There are small blades that appear to be of *actinolite*. One poor section.

Age. Cabotian. N. H. W.

No. 1203. Gabbro.

About N. E. ¼ sec. 23, Plummer (original Huronian area), Canada.
Ref. Annual Report, xvi, page 29.

Meg. Similar to No. 1200.

Mic. Less broken than No. 1200. There is in this rock much *magnetite*, some *sphene*, *hornblende*, *chlorite* and spicular *apatite*. The green areas which seem to be determined in outline by some earlier generation of a mineral now wholly changed, show probably old *olivines*, and others *augite*. One (thick) section.

Age. Cabotian. N. H. W.

No. 1264. Basalt.

Rove Lake road, north of Grand Marais, near the south foot of Pine mountain.
Ref. Annual Report, xvi, pages 61, 119.

Mic. The rock is porphyritic with fine *feldspars* that lie numerously in an ophitic relation in the *augite*. There is developed considerable fine *actinolite*. The augite is fresh, while the feldspars are much rotted. In crystallizing, the augites apparently enclosed much of the magma glass in places, and this is now marked by the sprinkling of *magnetite* grains in the augite crystals, but in other cases much of the zirkelyte of the rock resulted simply from the condensation of the magma without crystallization, and such portions are now thickly sprinkled with fine magnetite particles. Between the nicols the rock in general is also much darkened, apparently by the prevalence of fine *zoisite* particles with their high refractive index, and by the generation of *chloritic* substance. Two sections.

Age. Keweenawan.

Remark. There seems to have been a long time (or a short period of great activity) between the formation of the feldspars and the final consolidation of the rock, the latter being but shortly after or contemporary with the formation of the augites. During this intervening period not only were the olivines wholly lost by resorption, but the feldspars were much affected by the introduction of many microlitic impurities. N. H. W.

No. 1265. Granite. *(Red.)*

Brulé mountains, north from Pine mountain.
Ref. Annual Report, xv, pages 62, 119.

Meg. "Red rock."

Mic. Consists chiefly of reddened feldspars, dimmed by much impurity and by general decay. Some can be seen, however, to be twinned on the albite plan. In some small angular spaces *quartz* is generated. There is a little *magnetite*, some *hornblende* and apparently *pyroxene*, and some red crystals of *hematite(?)* Two sections.

Age. Cabotian.

Remark. It is evident, in one slide, that the extinction in the quartz grains governs that in the surrounding feldspars, which are permeated by it, and which give place to it sometimes in the manner of a micro-pegmatyte. N. H. W.

No. 1265A. Porphyryte (?)

On the Grand Marais and Rove Lake wagon road; probably near the crossing of the North Brulé river, which is in the N. W. ¼ sec. 32, T. 64-1 E. From a boulder.
Ref. Annual Report, xvi, page 63.

Meg. The rock has a very fine-grained, brownish-gray groundmass, in which are numerous large, tabular, red, porphyritic crystals of feldspar, some of which are an inch across. There are also areas, apparently amygdaloidal, which are filled with a yellow mineral, probably epidote; also similar areas filled with a soft, dark-green mineral, probably chlorite. No section.

Age. Cabotian. U. S. G.

No. 1269. Gabbro. *(Weathered.)*

North side of sec. 19, T. 64-1 E.
Ref. Annual Report, xvi, pages 64, 66, 119.

Meg. Dark, coarse grained.

Mic. The ophitic structure is still evident, although the *augite* is now transformed largely into a dull-gray substance which in the centres and other parts of the augite masses extinguishes in alternation with the rest. The rock contains, along with the evident plagioclases, considerable amounts of *magnetite*, of *apatite* and of a dull yellowish chloritic substance, the result of alteration, probably of *olivine* and of the augite. One section.

Age. Cabotian. N. H. W.

No. 1273. Diabase.

Just west of the rapids going out of North lake.
Ref. Annual Report, xvi, pages 65, 119.

Meg. Dense, trap-like rock.

Mic. Ophitic, and finely holocrystalline, with secondary *calcite.* The rock contains a few spots, occupied by a greenish-yellow felted substance, which are not areas of magma glass, but amygdules or pseudamygdules filled subsequent to the consolidation. The *augite* is in rather fine particles, but sometimes is cut by the *feldspars* which are wholly microlitic. One section.

Age. One of the Logan sills of the Animikie. N. H. W.

No. 1275. Gabbro.

A mile west of the entrance of the river to Gunflint lake, north shore.
Ref. Annual Report, xvi, pages 65, 66, 119.

Meg. Rather medium-grained gabbro.

Mic. The striking feature in this rock is that the formation of the *feldspars* preceded that of the *olivine,* there being an ophitic relation between them like that characteristic of augite and feldspar in diabase. The feldspar is *labradorite-bytownite* as shown by extinction of 28° on a section exactly perpendicular to n_g as the acute bisectrix. The *augite,* which is purplish, is also ophitic toward the feldspars. While this is the general rule, there are still instances in which all three of these minerals appear to have formed nearly cotemporaneously, since these relations are reversed, and augite and olivine crowd upon the boundaries of the labradorite-bytownite. One section.

Age. Cabotian.

Remark. It is but rare that this ophitic relation between the olivine and the feldspars in the gabbro is met with. Compare Nos. 757 and 1842, where it is also mentioned. N. H. W.

No. 1276. Taconyte.

North shore of Gunflint lake.
Ref. Annual Report, xvi, pages 66, 119.

Meg. Immediately overlain by gabbro (No. 1275).

Mic. The green glauconitic grains are rounded and at their centres are crystallized into minute *actinolites,* which also is somewhat distributed elsewhere. These green bodies lie in the midst of interlocking fresh secondary grains of *quartz,* which also permeates the green masses in still finer granules. Sometimes a little *magnetite* in fine powder is scattered through the green substance, but generally not. So far as can be determined the green substance is perfectly amorphous. One section.

Age. Animikie. N. H. W.

No. 1277. Flint.

North shore of Gunflint lake (Canada).
Ref. Annual Report, xvi, pages 66, 119; Annual Report, xviii, pages 34, 62; Bulletin vi, pages 114, 123, 422.

Meg. "Composed of pieces and granules of a dark-gray, aphanitic rock, varying in size from that of a pinhead to peas or larger, closely compacted together; * * * the general aspect being that of a dark, basic, dense diabase, specked with minute white spots."

Mic. Consists essentially of excessively fine, interlocking grains of *quartz*, as in the last, with a slightly schistose distribution of a scant, dirty, green substance, which gives opacity to the rock, as well as a slightly gray color. Occasionally this green substance shows a sprinkling of *actinolite* fibres, and in other places it is stained by *hematite*. One section.

Age. Animikie.

Remark. Another section shows a non-schistose, even distribution of the finely globular green substance, with areas of *calcite*. This rock is apparently produced by a finer association of the elements found in No. 1276. N. H. W.

No. 1278. Feldspar Schist.

Mouth of the creek, east end of the long bay, north side of Gunflint lake (Canada).
Ref. Annual Report, xvi, pages 67, 119; Annual Report, xvii, pages 199, 202.

Meg. Schist, light green, fine grained, with pyrite.

Mic. The rock consists essentially of very fine angular grains of feldspar, lying in an abundant mesh of the well-known translucent, but nearly isotropic, chloritic substance, which results from alteration of ferro-magnesian minerals, whether in the massive rocks or in their detritus. This mesh has a prevalent elongation and structure in one direction. It has a few fibres that polarize distinctly, which may be of *actinolite* or *muscovite*, and much *calcite*, the latter being not infrequently aggregated in masses of considerable (microscopic) size.

The feldspar grains are in two conditions—whether two species it is impossible from this slide to determine. One sort is clear and fresh, though not glassy, giving the low gray colors of the first order in a section of the normal thinness, without visible impurities. The other sort is so crowded with minute grains and crystalliths that they are nearly as dark between the rotating nicols as the chloritic mesh. It is possible to explain this difference by assuming that the clouded feldspars are original fragmental grains lying still in the detritus in which they were deposited, and that the fresh feldspars are of secondary growth *in situ* under the action of metamorphic forces. As to shapes and sizes, these grains do not differ notably, and they are both slightly elongated, prevailingly with the schistosity. They all have a shadowy extinction, and this is noticeable in the fresh grains, because in the clouded grains the indefiniteness of extinction prevents observation on this point. As to relations of orientation, they do not seem to have any dependence, one on the other, as might be expected if the fresh grains were secondary developments in the vicinity of older grains. They are usually not in contact, but occasionally they are. It is to be inferred, hence, that if the fresh grains are of later date they are of a different species from the clouded grains. The fresh grains are themselves frequently in contact, but their orientations are different.

There is no quartz, but there are a few fine, black, opaque particles which are indeterminable, but which are not magnetite. One section.

Age. Archean (Keewatin).

Remark. This schist may consist of one feldspar and a lot of micro-granulated debris. This debris may have been originally largely feldspathic, or it may have been a volcanic glass. N. H. W.

No. 1279. Quartz-Porphyry. *(Sheared debris.)*

Associated with No. 1278. Compare No. 311.
Ref. Annual Report, xvi, pages 67, 119.

Meg. Coarser grained, sub-porphyritic, with pinkish feldspars.

Mic. In a fine, granular matrix of fresh feldspar and of quartz, lie many large crystals of *feldspar* and grains of *quartz*. This matrix is more angular than in the last, and, while belts of chloritic matter *(pennine)* cross it, yet the grains are not uniformly elongated. The quartzes have occasionally a hooked or serrated border and the hooks and teeth extinguish with the grain, but the common orientation does not extend beyond the ends of the hooks. Occasionally, but not commonly, these quartzes are broken, the parts still lying adjacent, with slightly differing orientations, and sometimes many small fragments are strung off one side of the principal mass. These large quartzes are not of vein formation, but have come from a quartz-porphyry, if not now in their native places, for they occasionally show the marginal embayments peculiar to such quartz. The feldspars are much twinned and much altered, being charged with micaceous scales, *calcite*, *epidote*, and with kaolinic impurities. They occasionally are also broken and deranged in orientation in a manner similar to that of the quartzes. They are also occasionally bordered by narrow rims of secondary growths, which are not clouded by the impurities seen in the body of the crystal. Extinction on n_p indicates *oligoclase* for the body of the crystal,* and there is no observable difference in extinction between it and that of the rims.

In the slide are several phenocrysts of *apatite* and spots that appear to be *leucoxene*. A considerable amount of the coloring matter, scant as it is, is of *biotite*, and a few small *sphenes* are scattered in the fine matrix. There is one grain in the slide which appears to have the form of a basal section of *augite*, and a portion of the grain polarizes like augite, the rest of the area being dark. One section.

*The actual extinction angle read on an albite twinning line on n_p is 4°, but as Fouqué does not give so small an angle on n_p in any feldspar, this is taken to be the supplement of the true angle given by him, which would therefore be 86°.

Age. Archean (Keewatin).

Remark. This rock has a petrographic relationship with the porphyritic rock at Kekequabic lake (Nos. 1061, 1094 and 1106), except that the augite, if it ever existed in considerable quantity, has been destroyed by the exigencies through which the rock has passed; and in that respect the relation seems to be nearer some of the conglomeratic debris less metamorphosed, seen east from Kekequabic lake. N. H. W.

No. 1280. Basalt.

North shore of Gunflint lake, interstratified with the schists (Canada).
Ref. Annual Report, xvi, pages 67, 119.

Meg. Having the appearance of a massive greenstone.

Mic. In an originally glassy matrix lie microlitic *feldspars* and spicules of *magnetite* of about cotemporary generation, the feldspars being generally a little earlier, but occasionally cut by the magnetites. The zirkelyte is now devitrified. It is filled with granular magnetite and pleochroic *biotite* and apparently globular *augite*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1281. Graywacke (?)

North shore of Gunflint lake (Canada).
Ref. Annual Report, xvi, pages 67, 69, 120.

Meg. Gray, compact, weathering reddish, with sedimentary bands.

Mic. This is a rock similar to the fine-grained matrix of No. 1279, but finer and less easily analyzed. There are fine mica scales everywhere in the rock, and these scales are also gathered abundantly in spots, giving a spotted aspect to the slide between crossed nicols. In some of the larger scales a pleochroism is visible. Hence the mica is probably *biotite*. Some particles of *sphene* and groups of dark *leucoxene* are identifiable. But the greater portion of the rock consists of fine angular feldspars, which are fresh, and equally fine quartzes. One section.

Age. Archean (Keewatin). N. H. W.

No. 1282. Graywacke. *(Sheared.)*

North side of Gunflint lake (Canada).
Ref. Annual Report, xvi, pages 68, 120; Annual Report, xvii, pages 199, 202.

Meg. Gray, gneissoid, slightly porphyritic.

Mic. Like the last, excepting the presence of gneissoid structure and much *calcite*, with some *quartz*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1283. Quartz-Porphyry. *(Schistose debris.)*

Bluff, north shore of Gunflint lake (Canada).
Ref. Annual Report, xvi, pages 68, 120; Annual Report, xvii, pages 199, 202.

Meg. Porphyritic aspect, with a little pyrite. Compare No. 311.

Mic. This rock is quite like No. 1279, but coarser, and the full description need not be repeated. The slide, however, shows no large quartzes, and the mica scales are more abundant. One section.

Age. Archean (Keewatin).

Remark. On the weathered surface the white porphyritic feldspars stand out prominently and are larger and more numerous than the quartzes. N. H. W.

No. 1284. Slate. *(Micaceous.)*

Interbedded with No. 1283; north shore of Gunflint lake (Canada).
Ref. Annual Report, xvi, pages 68, 120.

Meg. Fine, grayish, slaty.

Mic. *Mica* scales are distributed parallel with the slatiness. Hence the slide darkens noticeably four times in one revolution, like a zeolitic mineral. It contains, however, *calcite* and angular grains of *feldspar*, which do not usually darken parallel with the threads and the slatiness. N. H. W.

No. 1285. Argillyte.

Interbedded with No. 1283.
Ref. Annual Report, xvi, pages 68, 120.

Meg. No specimen found. No section.

Age. Archean (Keewatin). U. S. G.

No. 1286. Graywacke. *(Sheared.)*

Same rock as No. 1282 (Canada).
Ref. Annual Report, xvi, page 120.

Meg. Evident quartzes are visible in this rock, which is schistose.

Mic. While this is much like No. 1283, it differs from it in having much more general decay and less evidently a gneissic structure. Quartz is quite abundant in rounded and sub-angular grains. One section.

Age. Archean (Keewatin).

Remark. This is quite evidently a clastic rock, and its relations with No. 1283, as described in the field, so closely ally it with that rock that it is reasonable to call attention to the petrographic alliance of Nos. 1279 and 1283 with the pebbly and "porphyritic" portion of the Ogishke conglomerate seen intermediate between Ogishke, Muncie and Kekequabic lakes, in which the "porphyritic" feldspars are evidently derived as detritus from some earlier quartz-porphyry.

No. 1287. Muscovadyte.

Mayhew iron location, Mayhew lake. Compare Nos. 694–700.
Ref. Annual Report, xvi, pages 78, 120.

Meg. The gray rock "on which the gabbro lies unconformably."

Mic. *Feldspar* and *diallage* practically compose this rock, rather evenly and finely granular, and cotemporary in origin. It is but rarely that can be seen a feldspar encroaching on the boundary of a diallage. Yet occasionally a very small round feldspar is wholly embraced in a diallage, and, *vice versa,* small diallages are in the feldspars. The diallage shows an interesting instance of basal twinning. Several lamellæ are visible crossing the grain. Generally the diallagic lamination parallel to 100 and this twinning are visible only in separate grains, giving, on first view, the impression of separate and distinct minerals, but on careful search it can be seen occasionally that they both occur in the same grain. They stand nearly at right angles to each other. The lamellation parallel to 100 is also affected by the interposition of some polarizing mineral, which renders the separation planes quite light when the lamellæ themselves are dark.

The last mineral to form was *magnetite,* which is scattered in round small grains sparsely, and in one instance in form of a large mass, which embraces small grains both of feldspar and of the pyroxene. One section.

Age. Cabotian (modified Keewatin).

Remark. This is evidently petrographically a portion of the gabbro, but has a bedding and dip resembling that of sedimentation. The reader may compare the chapter on structural geology for a discussion of the origin of the gabbro and of muscovadyte.

N. H. W.

No. 1288. Gabbro. *(Iron-bearing.)*

Near the same place as the last, but further west ; Mayhew lake.
Ref. Annual Report, xvi, page 120.

Meg. Dark and heavy with iron ore.

Mic. *Olivine, magnetite, plagioclase* essentially compose this rock. But there is frequently a rim of *brown hornblende* between the magnetite and the plagioclase. There seems to have been a powerful corrosion of the olivines and plagioclases, leaving only remnants of their former sizes, sharp and angular, crescent shaped or excavated in curvilinear contours, and the spaces filled by later *magnetite.* One section.

Remark. This is another instance of the later date of the iron ore in the gabbro rocks of the state. This subject is mentioned in connection with the description of the rocks at Duluth (No. 1, etc.). N. H. W.

No. 1289. Siderite *(in glassy matrix).*

Boulder of the gray rock belonging near the bottom of the Animikie.
Ref. Annual Report, xvi, page 120.

Meg. Gray, massive, finely crystalline, coated on weathered surfaces with a film of limonite, on the fractured surfaces with glistening cleavages.

Mic. The rock consists almost entirely of highly doubly refracting grains, which are seldom so crowded that they do not show a tendency to idiomorphic rhombic outlines, and which, in form and cleavage, as well as in comparative refractive index, are to be considered nearer *siderite* than calcite; and taken in connection with the rusty film that coats all weathered surfaces, there is no escape from calling them siderite. In all parts of the slide, and more abundantly in some than in others, the substance in which these rhombs lie is seen to be isotropic, though transparent, resembling *glass*. In high power of magnification and with strong light, there appear between crossed nicols dim, minute crystalliths whose forms cannot be made out any further than to determine that usually they show some elongation. They do not polarize in colors, but show only the lowest grays of the first order. One section.

Age. Bottom layers of the Animikie. N. H. W.

No. 1292. GABBRO. *(Iron-bearing.)*

Same as No. 1288.

Meg. With olivine.

Mic. *Brown hornblende* in considerable quantity separates the *magnetite* from the other minerals, whether *olivine* or *plagioclase*, and is sometimes surrounded by the magnetite. A little *augite* is in the slide. One section.

Age. Cabotian. N. H. W.

No. 1293. DIORYTE(?)

North shore of Iron lake. From a boulder.
Ref. Annual Report, xvi, pages 78, 120.

Meg. A dark crystalline rock composed mainly of hornblende and feldspar, with some biotite. The following description is from the Sixteenth Annual Report, page 78:

"Rock No. 1293 is from a boulder, north shore of Iron lake. The interesting feature in this boulder, which was rounded, and evidently far transported by drift agents, is that *it is made up of boulders*. Originally the mass measured three feet by two and one-half feet by four feet, and by the action of fire large slabs have been made to drop off. Otherwise no samples could have been obtained with any means which we could control. This is not only made up of boulders, but it is from the mica-hornblende schist or Vermilion group [Coutchiching], and shows that conglomerates there have been converted into crystalline rock. The small boulders are of greenstone, mica schist and changed greenstone. The matrix is granulyte or granite." No section.

Age. Archean. U. S. G.

No. 1294. TACONYTE.

On the town line (if extended into Canada) between T. 65-1 and T. 65-2 W., about half a mile from Gunflint lake.
Ref. Annual Report, xvi, pages 69, 120.

Meg. Appearing like a conglomerate, or breccia, ferruginous and somewhat crumbling.

Mic. The section consists of interlocking *quartz* grains of secondary origin, serving as matrix for rather large, pebbly and concretionary grains, which are stained with *hematite* or *limonite* scales and by darker concentric layers of the same, presenting pisolitic structure. The concentric structure pertains, however, only to the borders of these grains, their interior portions being amorphous, and supposed to have been originally of *glauconite*. One section.

Age. Animikie, lying below the limestone No. 1289—at least further north.

N. H. W.

No. 1295. Jaspilyte.

Same place as the last; portion of the same mass.
Ref. Annual Report, xvi, pages 69, 120; Bulletin vi, pages 115, 422.

Meg. Red and gray, flinty.

Mic. There are no round masses of the changed glauconite in this portion of the rock, but while the mass in general consists of the same interlocking, secondary quartz grains, the iron films, instead of being concretionary, are in parallel fine films nearly straight, lying in the body of the quartzitic mass. These give color to the rock. As these are wanting, and as the quartz becomes finer, so the rock approaches flint. Compare No. 1277. Two sections.

Age. Animikie. N. H. W.

No. 1296. Sericite Schist.

On a traverse made north from Gunflint lake, about half a mile west of the east end of the lake.
Ref. Annual Report, xvi, pages 69, 120.

Meg. A fine-grained, hard, siliceous, gray, roughly schistose rock, with minute scales of a mineral like sericite. No section.

Age. Archean (Keewatin). U. S. G.

No. 1297. Porphyrel. *(Schistose.)*

On the same line, north from Gunflint lake, in Canada, as Nos. 1294 and 1295.
Ref. Annual Report, xvi, pages 69, 120.

Meg. Porphyritic with feldspars. Compare Nos. 1279, 1283 and 311. A fine-grained, siliceous rock, gray or greenish gray, with some pyrite.

Mic. Large patches of *actinolite* are perhaps the most conspicuous element in this rock. They are light green in natural light, but show a slightly darker green when the polarizer only is used, and the fibres are brought into parallelism with its principal section. Smaller particles and single fibres are scattered through the slide.

Quartz is the next in importance. It is distributed everywhere in fine sub-angular, glassy, clear grains, forming the general matrix. These grains are generally not in contact, but are separated by another finer matrix which becomes visible on lowering the condenser in natural light, but which is translucent in general, and polarizes aggregately between crossed nicols, apparently a kind of *kaolin*. But these quartzes are sometimes larger and in contact. They then have more irregular shapes and more tortuous boundaries with respect to each other, and enclose partially some of the areas of kaolin. These larger areas in part break up into grains having separate orientation.

There are many roundish areas, occupied chiefly by the fine kaolinic substance, which extinguish as individuals, but which are filled with secondary substances, amongst which can be distinguished *calcite*, *quartz* of secondary origin, *muscovite* and zoisite.

Zoisite is also scattered throughout the slide. It is distinguished by its clear transparency and its high refraction, the latter property being brought out on lowering the condenser. Between crossed nicols also it is often blue (or gray). It is in the midst of the actinolite and sometimes occupies the central portion of the actinolite groups, but in general it is in fine isolated grains scattered through the kaolin, as well as in large cleaved but loosely aggregated masses.

Apatite is found in a few quite sizeable grains.

Biotite is rare, in very fine brown leaves, but more frequent in certain areas than in others.

Sphene is seen in a few isolated grains, some of them being quite large. Two sections examined.

Age. Archean (Keewatin).

Remark. This rock is one of those regenerated, sub-porphyritic clastics which, while revealing its originally fragmental condition, is yet a perfectly crystalline rock. It has the outward megascopic aspect of a fine-grained granite, and is light colored. The old feldspars are the most decayed portion of the rock, but they are now firm with the formation of innumerable grains of other feldspar, of quartz, of muscovite and of zoisite. The smaller clastic feldspars are micro-granulated and lost, but the largest are evident by the four extinctions that occur on rotation. Their borders are interhooked with the matrix by new feldspathic growths. The quartz is wholly secondary. N. H. W.

No. 1300. Hornblende Schist.

About three-fourths of a mile north of Gunflint lake; from the "black belt" in the Keewatin schists.
Ref. Annual Report, xvi, pages 69, 120.

Meg. Coarse hornblendic rock, associated with micaceous schist, lying in a rudely stratified belt in the green schists and other rocks that constitute the Keewatin north of Gunflint lake.

Mic. *Green hornblende* abundant. Two forms of *feldspar*, one in large grains, much altered, and the other fresh and glassy, evidently of later date. *Quartz* not abundant. *Diopside* common, but generally not in large masses. *Sphene*, *epidote*, *calcite*, *apatite*. One section.

Age. Archean (Keewatin).

Remark. If this were originally a basic intrusive rock, and were then sheared and altered by such action, it would perhaps have produced a rock like this. If it had been a coarse debris from basic rocks, produced by erosion, such as some parts of the Ogishke conglomerate, and had been sheared in the same way, it would probably also have produced such a rock. The diopside shows distinct cleavages parallel and perpendicular to the optic plain in a section perpendicular to an optic axis, being therefore the pinacoidal cleavages rather than the prismatic. N. H. W.

No. 1301. Granite.

At a point about a mile north of Gunflint lake, on the same town line.

Meg. An imperfect granite or gneiss.

Mic. The foregoing description of No. 1300 would also apply to this rock, only requiring less hornblende and more quartz. One section.

Age. Archean. N. H. W.

No. 1304. Feldspar Schist. *(Micaceous.)*

North from Gunflint lake, at the "black belt."
Ref. Annual Report, xvi, pages 70, 120.

Meg. Shows a blending of the characters of the mica schist and those of the regenerated porphyritic schist (porphyrel).

Making a closer inspection of the rocks of the Vermilion group (*i. e.*, the Coutchiching of Lawson) at this point, they are found to extend north and south about fifteen rods. There is certainly a conformable transition from the Keewatin to this, which is chiefly mica schist, at least superficially. At some depth within the rock perhaps there would be found a greater proportion of hornblende, since it seems that the mica results from the natural decay of the hornblende. The interbedded, light-colored rock is the gray "porphyritic" rock of the lake shore, but has some mica scales. It acts here much like the so called "dikes" of gneiss that are interstratified with the Vermilion group or mica schists north of Vermilion lake. It fades out by very slow transitions into the mica schist, and it also is replaced abruptly by it. It runs to needle-shaped points and vanishes conformably in the darker rock. If it is, hence, eruptive, then this porphyritic rock everywhere is eruptive, and also the schist into which it graduates at the lake shore. Rock No. 1304 shows a blending of the characters of the mica schist with those of the rock that shows the porphyritic characters. The belt from which this came is about ten inches wide, and such are numerous in the schists. Indeed, there can be seen almost every kind of transition and every direction of gradation between the schist, the hornblendic rock and the porphyritic and gneissic rock. They all occur as strings and as isolated portions in each of the others. There are belts of coarsely hornblendic rock that alternate several times in the mica schist, conformably with the strike, but the former are confused, lumpy and uncertain. They may have been basic eruptives in the sediments of the Keewatin at the time of their accumulation, and so spread out as sheets approximately conformable to the sediments.

The section foregoing was made on the town line extended north from the south side of the lake between T. 65-1 and T. 65-2 W.

Mic. *Green hornblende* and a little *biotite* give color to the rock. There is much secondary quartz and glassy feldspar and some larger feldspars that appear to be *orthoclase.* There are also much decayed feldspars, on one of which a determination by extinction on n_p in the acute angle of the optic plane indicates *andesine-oligoclase.* The glassy feldspars generally show no cleavage nor twinning, and therefore it is difficult to determine them specifically. It appears in some cases that an old feldspar furnished the nucleus on which the fresh feldspar grew. One section.

Age. Archean (Keewatin). N. H. W.

No. 1305. Diabase. *(Dense.)*

Gunflint lake, north shore.
Ref. Annual Report, xvi, pages 72, 120.

Meg. Associated with the rock which bears the rusty film seen on some of the rocks of the Animikie. Dark, fine, apparently embracing lumps of gray flinty taconyte, like No. 1307.

Mic. Microliths of *feldspar*, *augite* and of *magnetite*, very much as in the rock No. 1280, lie in a dim, slightly polarizing brown matrix which may have been at first of glass, but is now composed wholly of the above minerals. The little feldspars are frequently in couples, as if albite twins, but their extremities are not uniformly placed, one or the other projecting too far at one or at both ends. They are also sometimes separated by a portion of the surrounding semi-opaque matter, which is in general heavily charged with the magnetite rods. One section.

Age. Animikie.

Remark. This was apparently a surface extension of a basic igneous rock, involving the bottom beds of the Animikie. Its petrographic alliance with No. 1280, which is in the midst of the Keewatin schists, indicates that No. 1280 is really of the date of the sills of the Animikie. The banded structure presented by this slide is due to the concentration of the magnetite in some belts, compared with its scarcity in others. N. H. W.

No. 1306. Diabase. *(Dense and magnetited.)*

Same place and same rock mass, but from a specimen numbered 1305 and 1306, showing a gray film.
Ref. Annual Report, xvi, pages 72, 120; Bulletin vi, pages 121, 129, 422.

Meg. Heavy with magnetite.

Mic. In the midst of the opaque part of this slide are scattered minute light spicules, which can be nothing but *feldspars*, the same as those seen in No. 1305. The rest of the slide is gray and sub-transparent—apparently a glassy part, less ferruginous, and in this also can be seen the same feldspar microliths. One section.

Age. Animikie. N. H. W.

No. 1307. Taconyte. *(Sideritic.)*

Same place.
Ref. Annual Report, xvi, pages 72, 120; Bulletin vi, pages 121, 129, 422.

Meg. So-called limestone, of Gunflint lake.

Mic. The most of this slide is made up of *siderite* and *quartz*, the latter being of secondary origin, as shown by its interlocking borders. These are mingled throughout the slide rather uniformly, the siderite grains making roundish patches such as to suggest that it is the result of replacement of some earlier mineral which was granular.

In the siderite patches are other substances, and particularly *pyroxene*(?) which in occasional elongated grains has a transverse cleavage and parallel extinction, as if it were orthorhombic, while its high polarization is like *epidote*. Other grains show conclusively that this mineral is not orthorhombic. Its optic plane is perpendicular to the scant cleavage. It is scattered in finer particles throughout most of the siderite patches. At the same time there is much *magnetite* in form of a fine powder. These give the siderite patches, in common light, the form and manner of distribution of the glauconite (so called) of the rock taconyte, and the rock might be called taconyte, were it not that the patches are largely of siderite and epidote. One portion of the slide is free from epidote and iron oxide, and is then simply a sideritic taconyte, or "cherty carbonate." One section.

Age. Animikie (probably iron-bearing member).

Remark. This close association of basic igneous rock with the sideritic taconyte, well known about Gunflint lake, seems to link them in some measure in a common history or in a succession of chemical transformations having a common cause, and is quite significant. N. H. W.

No. 1308. Magnetite.

Near the north shore of Gunflint lake, about on sec. 13, T. 65-3 W., if the United States system of survey were extended to the Canadian shore.
Ref. Annual Report, xvi, pages 72, 73, 120; Bulletin vi, pages 117, 131, 422.

Meg. Fine-grained, compact, nearly pure magnetite. No section.

Age. Animikie (iron-bearing member). U. S. G.

No. 1309. Quartzyte and Muscovadyte.

East end of Gunflint lake.
Ref. Annual Report, xvi, pages 72, 73, 120; Bulletin vi, pages 117, 131, 422.

Meg. A condition of "muscovadyte," near contact with the gabbro.

Mic. Essentially quartzyte at the present time. The grains are of uniform size, wholly reformed, but without interlocking. They fit closely to each other, filling all the interstices, but do not interlock. They contain numerous globular inclusions which extinguish independently and which are always at or near the centre. They are separated from each other by a yellowish film which is chloritic or serpentinous, but occasionally this is replaced by iron ore, which spreads irregularly about the grains of quartz. When the iron increases thus the greenish-yellow substance also increases, and it then occasionally shows the polychroism of *actinolite*, into which secondary quartz sometimes has insinuated itself in the manner of a micropegmatyte. This change goes further, for in connection with the increased occurrence of magnetite and of actinolite is also considerable of the *epidote* mentioned in No. 1307 and of *augite*, the latter even forming large but much altered crystals, while a yellowish substance resembling *bowlingite* may be the residuum from olivine.

The foregoing describes one of the slides. Another slide, having the same number, has much less of quartz, or none, but granular *augite* and *feldspar*, with a liberal sprinkling of *magnetite*, compose the rock. Here frequently the finer magnetite grains are clustered near the centres of the feldspars. This is a typical muscovadyte. Two sections.

Age. The quartzyte is supposed to be of the age of the Animikie, and the other seems to be a part of the gabbro. The first section described shows a transition from the muscovadyte to quartzyte, in a manner represented by Bayley (Nineteenth Annual Report), which requires that both slides be referred to the gabbro.

[NOTE. In the light of the latest conclusions as to the nature and relations of the muscovadyte to the gabbro, such curious combinations as this are explained by referring both the quartzyte, the muscovadyte and the magnetite, with all their associations, primarily to the Keewatin, the quartzyte and magnetite appearing abundant when the Keewatin happened to contain a jaspilyte lode which suffered the metamorphosing action of the gabbro revolution, the normal gabbro itself being the last term in the series of rock genesis, formed by complete refusion where the original Keewatin contained no jaspilyte.] N. H. W.

NO. 1310. LIMESTONE *(with tuff?)*

North shore of Gunflint lake.
Ref. Annual Report, xvi, pages 72, 73, 121; Bulletin vi, pages 115, 121, 129, 130, 422.

Meg. Breccia of flint, etc., in limestone.

Mic. The sections consist of the well-known granular limestone, in the main, but contain chloritic and finely siliceous portions, evidently of foreign nature, which remain mainly dark between crossed nicols, and which, in one case, show a rhyolitic structure, with quartz and magnetite. It appears, therefore, possible, if not probable, that it is of the nature of a lapillus from an adjoining volcanic source. The rock also contains more *siderite* than *calcite*. Two sections.

Age. Animikie (probably the iron-bearing member).

Remark. In several instances it has been stated that there were evidences of local volcanic action in the rocks of the bottom of the Animikie in the vicinity of Gunflint lake and North lake, but in nothing has this been indicated more strongly than in this slide. From this it is reasonable to infer that the flinty, angular fragments which characterize this limestone in the vicinity of Gunflint lake are generally of the nature of devitrified volcanic glass.

Two additional sections were made of this breccia, cutting some of the siliceous masses, and the black strings, but showing nothing decisive as to the nature and origin of these inclusions. The siliceous masses are apparently not of clastic structure. Special conditions are responsible, apparently, for the carbonate of iron here, in the iron-bearing member, instead of the usual oxide. N. H. W.

No. 1311. Siderite *(with tuff)*.

North shore of Gunflint lake.
Ref. Annual Report, xvi, pages 73, 121.

Meg. Another stage of this rusting rock. (Compare No. 1289).

Mic. Mainly carbonate of iron, with some scattered dark patches, but not showing any new or even characteristic features, except the prevalence of granular crystals of siderite. The dark patches are presumed to be of rhyolitic origin, one being apparently of glass hardly devitrified. One section.

Age. Animikie. N. H. W.

No. 1312. Diabase.

At the narrows at the outlet of Gunflint lake.
Ref. Annual Report, xvi, page 121; Annual Report, xvii, pages 199, 204.

Meg. Black, heavy and close-jointed.

Mic. The diabasic structure is distinct, notwithstanding the fineness of grain, yet the shapes and the occasional breaking of the *feldspar* borders by *augite* show that the two minerals were nearly cotemporary in origin. Many conspicuous *magnetite* spicules pierce the other minerals, but less frequently the feldspars. The substance lying in the interstices of the feldspars and augites is greenish, sub-crystalline or micro-crystalline, and indistinct, and represents doubtless a devitrified portion of the glassy magma. One section.

Age. Sill in the Animikie. N. H. W.

No. 1313. Quartzyte. *(Ferriferous.)*

Near the narrows at the outlet of Gunflint lake, on the west side.
Ref. Annual Report, xvi, pages 73, 121.

Meg. Gray, siliceous and magnetited.

Mic. Mostly interlocking, secondary *quartz*, but with considerable *iron ore*, and a little of rusty fibrous *actinolite(?)* Another section having this number is quite different, consisting of very fine or flinty texture, and uniform grain; it is like the supposed nodule of glass in No. 1311, and probably was not correctly numbered. Two sections.

Age. Animikie.

Remark. The iron ore in this slide consists of both magnetite and siderite, and they present a structure that appears to be a remnant of an earlier taconitic origin. These ores are independent of each other. There is no sign that one was derived from the other, but they appear to have been about cotemporary in origin. The siderite is somewhat limonated, but that is due to recent exposure. N. H. W.

No. 1314. Diabase. *(Porphyritic.)*

Animikie bay, west end of Gunflint lake; also cut by the new railroad.
Ref. Annual Report, xvi, pages 78, 85, 121.

Meg. Diabase, having conspicuous feldspar crystals of porphyritic habit.

Mic. The section shows none of the large feldspars. It is in all respects similar to No. 1312, except that the elements are all coarser, and that through alteration much *actinolite* has been developed. One section.

Age. Sill in the Animikie. N. H. W.

No. 1316. Granite.

North side of Black Fly bay, at the outlet of Gunflint lake.
Ref. Annual Report, xvi, pages 73, 121; Annual Report, xvii, pages 199, 203.

Meg. Gneissic.

Mic. Much decayed, the feldspars being rendered almost non-transparent. Contains *quartz*, some *pennine*, *sphene* and probably *orthoclase* and *oligoclase.* One (thick) section.

Age. Archean. N. H. W.

No. 1317. Hornblende Schist.

Enclosed in No. 1316.
Ref. Annual Report, xvi, page 121.

Meg. A rather fine-grained rock, composed of hornblende and feldspar with a few large grains of quartz. No section.

Age. Archean. U. S. G.

No. 1318. Dioryte. *(Camptonyte?)*

At the first falls going north from the outlet of Gunflint lake.
Ref. Annual Report, xvi, page 121; Annual Report, xvii, page 199.

Meg. Darker portion of the gneiss, spreading irregularly, but in manner of a dike.

Mic. The rock is colored by *hornblende,* which is in distinct, well-cleaved crystals, as well as in form of an alteration product which is less doubly refractive, almost non-pleochroic and has an imperfect short fracture-cleavage parallel or nearly parallel with which extinction takes place, and is in general a fibro-scaly, dull-green substance which seems to agree physically with the descriptions of *uralite.* Fresh *actinolite* (or grünerite?) fibres pass through this substance, showing a fine twinning. This uralitic substance has n_p for acute bisectrix.

Epidote in considerable quantity is also present. The original feldspars are much altered and are indeterminable. They are rejuvenated by secondary growths which are fresh, and which are distributed irregularly through the old grains, and about their borders. With *pennine* in small amount, and some *calcite* and *quartz.* One section.

Age. Archean.

Remark. This rock is the same as No. 61G, described on pages 160, 161, Seventeenth Annual Report. It is in form of a dike, and cuts both granite and schist.

N. H. W.

No. 1319. Taconyte.

North side of the point that lies north of Animikie bay, Gunflint lake.
Ref. Annual Report, xvi, pages 77, 121. (Compare No. 437.)

Meg. Fine, siliceous.

Mic. Taconyte. The rock is mostly *quartz*, but it is stained with iron and other substances so as to show the peculiar globular structure of taconyte. These globules are not heavily charged with iron, but in the main are translucent, though sometimes entirely opaque. Some of the finest-grained ones, which suggest a possible derivation from devitrification of volcanic glass, are crowded with feathery tufts of fibres (or trichites?), which are exceedingly fine. It is evident, however, that these fibres are of later date than the deposition of these grains in this rock, since they extend beyond the borders of the grains into the surrounding interlocking matrix of quartz. If these grains are of original volcanic glass, their devitrification was probably effected about the time of the deposition of the interlocking quartz. One section.

Age. Animikie. N. H. W.

No. 1320. Taconyte. (*Banded.*)

A condition of No. 1319. (Compare No. 1277.)
Ref. Annual Report, xvi, pages 77, 121.

Meg. The rock appears "streamed." In the field said to be a condition of rock No. 1319.

Mic. The whole rock consists of quartz and *magnetite*, in a rhyolitic(?) structure, the magnetite being in cubes and the quartz in interlocked, very fine grains. The structure is the same as that of the rhyolitic fragment mentioned in No. 1310, but much coarser. One section.

Age. Animikie.

Remark. It is in keeping with the intimations that precede, that a rhyolitic rock should be found in place, and this may be that rock. It is at or near the bottom of the Animikie. This seems to be the rock that supplied the supposed grains of volcanic glass seen in No. 1319. N. H. W.

No. 1322. Quartzyte.

North side of the same point. In fallen, at least transported, masses; the original beds not seen.
Ref. Annual Report, xvi, pages 78, 85, 88, 121; Annual Report, xviii, page 62; Bulletin vi, pages 117, 422.

Meg. Granular, firm, gray quartzyte.

Mic. The forms of the original rounded grains are distinctly outlined by the curving bands of colored impurities, outside and inside of which extinction is simultaneous for the same grain. The secondary growths have formed an interlocking granular quartzyte. Besides the quartz grains there are a few of feldspar and one of flint, or devitrified rhyolite (No. 1277). There are also several that are perfectly isotropic, greenish gray in common light, but in convergent light on lowering the lower nicol there appears a mesh or maze of very fine spicules and crystalliths, which are also probably a result of devitrification. One section.

Age. Animikie.

Remark. This rock, although not seen *in situ*, is distinctly allied to the rock No. 1319, in containing, amongst a prevalent sand of round quartz grains, a few grains of devitrified glass, or aporhyolyte. There is here a strong suggestion that the pre-Animikie surface was covered, to a greater or less extent, by volcanic rocks which furnished this debris. These rounded pebbles of devitrified glass, although consisting now largely of fine secondary quartz, and in that respect resembling some parts of the taconyte of the Animikie, are free from iron. This slide is illustrated by figure 9, plate II.
N. H. W.

No. 1323. Diabase.

Top of the hill (or ridge running east and west) north of Animikie bay, Gunflint lake.
Ref. Annual Report, xvi, pages 78, 121.

Meg. Gabbro like, sometimes porphyritic like No. 1314.

Mic. The *magnetite*, which is in crystals and skeleton crystals, cuts the *augite*, and slightly the *feldspar*. The rock is weathered. Decay in patches in the feldspars has produced apparently a mica which is near *muscovite.* One section.

Age. Sill in the Animikie.
N. H. W.

No. 1324. Zirkelyte.

Near the diabase contact, near the top of the ridge north of Animikie bay, Gunflint lake; same place as the last. This underlies the diabase sill. Compare No. 1327.
Ref. Annual Report, xvi, pages 78, 121.

Meg. Flinty lower part of a diabase sill.

Mic. The slide consists entirely of the same fine-grained, flinty substance already mentioned, more or less clouded by magnetite and by belts of radiating trichites, the latter being in the main arranged along fissures, but sometimes disposed in radiating clusters in the mass of the rock. There is also another coarser crystallization, consisting of a highly doubly refracting mineral, apparently *pyroxene* or *actinolite*, which along a certain boundary is abruptly separated from the finer rock, but which in another part of the slide graduates into the finer, showing that they have a similar origin. These coarser crystalliths graduate into finer and finer needles, sometimes forming four-armed black crosses which polarize near the point of crossing, but which, where separated, can be seen to blend into the finer trichites and are lost in the finer mesh. This fine crystallization, whether polarizing or not, is embraced in a fine siliceous(?) granular background—the body of the so-called flint or zirkelyte. The most of the magnetite is found in borders along the belts of the coarser crystalliths above. One section.

Age. Animikie.

Remark. The slide does not fairly represent the rock having this number, but is evidently made from one of the thin, flinty lenticular parts embraced in No. 1324. The rock itself is coarser. N. H. W.

No. 1327. Quartzyte. *(Actinolitic?)*

Northwest corner of sec. 23, T. 65-4, west from Gunflint lake. (Compare No. 1324.)
Ref. Annual Report, xvi, pages 80, 121; Annual Report, xix, pages 194, 201.

Meg. Gray, quartzose, underlying a cherty magnetite.

Mic. The quartz is wholly secondary, so far as seen in the slide, with interlocking borders, the grains being sub-rounded. If ever this quartz was of clastic structure, it has lost it now, not even the boundaries of any original grains (except rarely and doubtfully) being preserved. It is permeated in a loose manner by conspicuous radiating rosettes of *actinolite*(?) fibres, each of the rosettes having about the size of the individual quartz grains, making a handsome and unusual appearance between the nicols. These fibres pierce the surrounding quartz in all directions. The rosettes are not promiscuously placed in the quartz, but are at the boundaries of the quartz. They have the appearance, as mentioned below, of having grown up from some other original substance which was a constituent of the rock before the metamorphism to which it has been subjected had acted upon it. The rock, indeed, was probably a taconyte. The quartz, as well as the original glauconite, if such were ever present, have been recrystallized simultaneously.

Mingled with the quartz, which shows no trace of rounded clastic boundaries, is a liberal ingredient of volcanic glass, largely devitrified. In this substance the actinolitic(?) rosettes take their source, radiating not only through the glass, but also into the quartz adjacent. Some portions of this volcanic glass do not contain these rosettes, but are charged with indefinite ultra-microscopic forms, which cannot be determined. This rock is a phase of the taconyte of the Animikie. It is illustrated by figure 10, plate II. One section.

Age. Animikie (iron-bearing member).

Remark. The appearance of this rock in thin section is similar to that of uxulianyte, which has tourmaline arranged in a stellate grouping, in quartz, but the fibres in this are finer. N. H. W.

No. 1328. Granite.

Bottom of the test pit in N. W. ¼ sec. 23, T. 65-4 W.
Ref. Annual Report, xvi, pages 80, 121.

Meg. There are three specimens of this rock. One is a pinkish granite with little hornblende (and biotite), and the others are much darker colored and much richer in hornblende. The excavation passed through the iron-bearing member of the Animikie and struck granite.

Age. Archean. U. S. G.

No. 1329. Diabase *(with olivine).*

About one-eighth of a mile west of the northeast corner of sec. 22, T. 65-4 W.
Ref. Annual Report, xvi, pages 81, 121; Annual Report, xix, pages 195, 201.

Meg. An ordinary diabase, looking like the diabase of the Logan sills in the adjoining Animikie strata. No section.

Mic. W. S. Bayley's description of this rock is as follows:*

"This specimen is a sample of a great dyke that cuts the gneiss underlying the rocks above mentioned. No. 1329 does not correctly represent the dyke, but it is the only sample that has been furnished. It is a very coarse-grained olivine-diabase, with long, lath-shaped crystals of a plagioclase near andesine, large grains of light-colored olivine, and interstitial, allotriomorphic, dark pink, slightly pleochroic augite, with much irregular magnetite in and around the augite. This last named mineral is quite fresh, except in small areas immediately next to feldspars, where it is slightly chloritized. The rock resembles very strongly the substance of the great dykes everywhere cutting the Animikie in the lake Superior region."

Age. Probably Cabotian dike cutting Nos. 1330 and 1331. U. S. G.

No. 1330. Amphibolyte.

Near the quarter post between secs. 20 and 21, T. 65-4, west of Gunflint lake.
Ref. Annual Report, xvi, pages 82, 83, 121.

Meg. Greenstone, harsh, firm, hornblendic.

Mic. The rock consists almost exclusively of well crystallized hornblende, with the angle $c \wedge c$ (maximum) measured on 010 at 20°. It has n_p as the acute bisectrix. There is, however, a sprinkling of magnetite throughout some of the larger grains. One section.

Age. Archean (Keewatin). N. H. W.

No. 1331. Amphibolyte.

From the same place as No. 1330.
Ref. Annual Report, xvi, pages 82, 121.

Meg. Green schist, schisted condition of No. 1330.

Mic. Like the last, but finer and containing a considerable feldspar. There are also isotropic, brown areas *(biotite)* elongated with the structure, in which appear small biotite scales. One section.

Age. Archean (Keewatin). N. H. W.

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* *Nineteenth Annual Report*, p. 195.

No. 1334. Greenstone. *(Muscovadyte.)*

Most southerly exposed part of the same greenstone as No. 1333. In a ridge thirty rods south of Nos. 1330–1332, but from its most southerly exposed portion.

Ref. Annual Report, xvi, pages 83, 84, 121; Annual Report, xix, pages 195-197, 199–203.

Meg. Greenstone.

Mic. Pyroxene *(augite)* in globular and angular grains, and in ragged masses, with *plagioclase* and a little *magnetite*. The feldspars are crowded with inclusions. *Leucoxene* is common in rather dark grains. One section.

Age. Archean (Keewatin metamorphosed).

Remark. This rock in its internal structure illustrates the familiar fact that minerals in incipiency under metamorphism assume globular forms at first. These augitic grains are identical with those seen in the pyroxenic gneisses in the long point (Muscovado point) at the northeastern side of Gabemichigama lake, and at other places mentioned, and they are in all cases to be attributed to the general metamorphosing effect of the gabbro revolution on the clastic greenstones of the Archean. Mr. Bayley argued that this rock is degenerated or crushed gabbro (Nineteenth Annual Report, pages 196, 197). He apprehended its petrographic alliance with the normal gabbro, but put it at the wrong end of the series of change. It is at the incipiency of gabbro rather than at its degeneracy. It is at its cradle rather than at its grave. It was a clastic greenstone originally. It is now a metamorphic rock. The normal gabbro occurs but few rods south of this rock. N. H. W.

No. 1335. Greenstone. *(Muscovadyte.)*

Rock of the hill north of Chub (Akeley) lake.

Ref. Annual Report, xvi, pages 83-85, 87, 95, 98, 121; Annual Report, xix, pages 195-197, 199–201, 203.

Meg. A rather indefinite, greenish rock.

Mic. *Hornblende* and *plagioclase* feldspar, in imperfect, fine, granular association, compose this rock. It has also a globular pyroxene (probably *diopside* or incipient *augite*) rather thickly scattered throughout the slide. This is in globular grains and in groupings of grains and frequently small globular pyroxenes are enclosed in the larger. With a little biotite that composes the rock. One section.

Age. Archean (Keewatin).

Remark. It is reasonable to assume that this rock was also originally a basic clastic of the greenstone kind. It approaches muscovadyte in its present condition, and as Bayley states might be styled a granulitic gabbro. N. H. W.

No. 1336. Peridotyte *(with fayalite)*.

From an excavation at Chub (Akeley) lake, for ore. This lies on the greenstone No. 1335, dipping southward under Chub lake. It is closely associated with the iron ore, and is, indeed, a part of the ore of the locality, varying to quartzyte.

Ref. Annual Report, xvi, pages 83, 84; Annual Report, xix, pages 195, 197, 198. 201, 203, 204.

Meg. Heavy with magnetite, but fresh.

Mic. The rock consists essentially of olivine and augite, with a few scattered grains of plagioclase and a notable amount of *magnetite.*

The *augite* embraces the other minerals poikilitically, but it is not a common mineral although it exists in some large grains.*

The appearance of the olivine suggests at once the occurrence of hypersthene, because it is conspicuously cleaved and frequently presents parallel extinction. But a closer examination shows that the grains cleaved and not cleaved have the same index of refraction, and a very high double refraction, even higher than ordinary olivine. Sections that show the highest colors are the most distinctly cleaved, and those that show no regular cleavage exhibit a bisectrix n_p, the axial angle being rather small. This form of olivine has the special name *fayalite.*

One or two small grains of *labradorite(?)* serve to show the thinness of the slide, and hence to furnish an estimate of the double refraction of the fayalite.

Some reddish yellow portions are apparently *bowlingite.* They are nearly dark between the nicols.

Age. Cabotian (modified jaspilitic Keewatin).

Remark. This form of peridotyte might take the name of *picryte* or cumberlandyte. This rock is illustrated by figure 11, plate II. N. H. W.

No. 1338. QUARTZYTE. *(Gray.)*

Associated with the ore No. 1336.
Ref. Annual Report, xvi, pages 85, 121; Bulletin vi, pages 118, 127, 422.

Meg. Compact, vitreous, with magnetite.

Mic. *Quartz,* with some *augite* and *magnetite.* One (thick) section.

Age. Pewabic (modified jaspilyte of the Keewatin). N. H. W.

No. 1339. QUARTZYTE. *(Pyroxenic.)*

Chub lake. Pyroxenic portions of the strata associated with the ore.
Ref. Annual Report, xvi, pages 85, 121; Bulletin vi, pages 118, 127, 422.

Meg. Dark with pyroxene.

Mic. The rock is about equally divided between quartz and diallagic *augite.* From the latter many minute fibres of *actinolite(?)* radiate into the quartz, along the margins where the quartz and augite unite. In another section some distinct form of *amphibole* is developed, twinned like *grünerite.* So far as can be seen the quartz with its numerous inclusions is latest in origin. Magnetite grains are in both quartz and augite. Four sections.

Age. Pewabic quartzyte (modified jaspilyte of the Keewatin). N. H. W.

*This mineral has a higher refractive index than the olivine, which it surrounds, and hence cannot be hornblende, as identified by Bayley (Nintеenth Annual Report, p. 197, fig. 3), and it cannot be hypersthene, since it is not perceptibly pleochroic, and has not parallel extinction in sections cut in the zone 001 : 100. Bayley's figure, however, does not agree with his descriptive text, where this mineral is described as augite.

No. 1340. Quartzyte (*with diallage*).

One-eighth of a mile west of the ore pits (No. 1336) at Chub lake.

Ref. Annual Report, xvi, pages 85, 122; Annual Report, xvii, pages 199, 203; Annual Report, xviii, page 62; Annual Report, xix, pages 198, 199, 201, 203.

Meg. Purplish-gray, vitreous, with magnetite.

Mic. The *magnetite* is in the main at the borders of the *quartz* grains, which are rounded, closely compacted and adjusted at their margins, but not interlocked, yet embraces frequently small, round magnetites. A few grains of *diallage*, with *enstatite* in the parting planes parallel to 100, are in like manner crowded amongst the quartzes, generally giving place to the forms of the quartz, but sometimes independent of the quartz. In the former are small globular inclusions of pyroxene and of magnetite. It is only the generally rounded shapes of the quartz grains and their uniformity of size that can be considered perhaps an indication of their earlier clastic origin, for at present the original outlines are lost, if they ever had any others. The three principal minerals—quartz, magnetite and diallage—mutually enclose small globular individuals of the others. One section.

Age. Pewabic (modified jaspilyte of the Keewatin). N. H. W.

No. 1341. Gabbro. (*Muscovadyte.*)

Near the top of the quartzyte ridge visible on the north side, a sill, one-fourth of a mile west of the ore pits (No. 1336), Chub lake.

Ref. Annual Report, xvi, pages 85, 122; Annual Report, xix, pages 198, 201, 203.

Meg. Granular, gray, magnetited.

Mic. Prof. W. S. Bayley's description of this rock is as follows:

"The gabbro interbedded with the crystallized quartzyte is in an intermediate phase between the coarse grained normal olivine gabbros and the granulitic varieties, in which the pyroxene occurs in small rounded grains. The olivine is in the ordinary form. The plagioclase is in irregular grains, with a tendency to the lath-shaped forms of diabasic feldspar. Its gabbroitic character is evinced in the abundance of dust-like particles scattered through it, and especially by their thick accumulation toward the centres of all grains. The pyroxene is a light colored augite, thickly crowded with magnetite grains, small masses of limonite and tiny plates of brown biotite. Some of the augite is in ophitic plates between the feldspars, but most of it is in little rounded grains. The magnetite, nearly all of which is secondary, is thickly strewn through the section in long irregular grains in and between the other constituents, especially the augite and olivine, and in tiny rounded grains in the augite and the plagioclase."

In the light of previous descriptions and interpretations, this rock is a secondary one. The above description would apply to many muscovadytes or regenerated greenstones. The bed from which the rock came is hence to be regarded as originally a layer of basic sediments interstratified in the jaspilyte, and not as an intrusive of the nature of the Logan sills of the Animikie. The general globular forms of the minerals show the incompleteness of the fusion, and the occasional ophitic growths of the augite show what would have been the rock had the recrystallization been unimpeded. This interstratification of basic and acid sediments in the iron lodes of the Keewatin is illustrated by figures 1 and 2, page 48, of Bulletin vi. One section examined.

Age. Cabotian muscovadyte (modified Keewatin). N. H. W.

No. 1343. Quartzyte *(with fayalite, etc.; peridotyte).*

Sec. 25, T. 65–5, north of Flying Cloud lake.
Ref. Annual Report, xvi, pages 87, 88, 122; Annual Report, xix, pages 199, 201, 204.

Meg. Quartz, with ferro-magnesian minerals.

Mic. This is somewhat like No. 1340, but is in general coarser grained. It has *augite* (diallagic), *grünerite, fayalite.* The *quartz* holds many globular inclusions of the other minerals. Such small globules are also disseminated in the olivine and in the hypersthene. The minerals are all fresh and perfectly intact as to chemical perfection, with abrupt boundaries but rounded outlines. There is a little also of the orange-yellow mineral resembling what has been mentioned as *bowlingite.* One section.

Age. Pewabic (modified jaspilyte of the Keewatin).

Remark. This is a remarkable rock, and is worthy of a special name, but the horizon containing it does not always show all these minerals. It is stratigraphically in the place of some jaspilyte rocks. The question that arises as to its origin can be stated thus: Is it the result of silicification of the gabbro, or is it the result of the metamorphism of the jaspilyte? (See Part III.) If there be no irregularities in the structure, the horizontal distance north and south over which it is exposed, would give it a thickness of 300 to 500 feet, including interbedding gabbro. N. H. W.

No. 1344. Gabbro *(with biotite).*

Sec. 25, T. 65–5. Interbedded in No. 1343.
Ref. Annual Report, xvi, pages 87, 88, 122.

Meg. Granular, like muscovadyte. Interbedded in No. 1343; eight feet thick.

Mic. *Plagioclase, olivine, augite, biotite, magnetite.* In the augite and in the olivine are numerous globular inclusions, and these are occasionally seen in the plagioclase. See the description of Nos. 1341 and 1365. One (thick) section.

Age. Cabotian (regenerated Keewatin). N. H. W.

No. 1345. Muscovadyte. *(Dioritic.)*

From a hill south of Bingoschick lake, north from the last.
Ref. Annual Report, xvi, pages 87–89, 94, 98, 122; Annual Report, xix, pages 199–201.

Meg. The same indefinite greenstone as No. 1335, forming a continuous prominent east and west range, underlying the ferruginous quartzyte above.

Mic. *Plagioclase, hornblende,* a little *biotite* and a little globular *augite* make up this rock. These all (except the hornblende) are in roundish or globular form and are frequently included in the large hornblendes. The plagioclase is *labradorite.* One section.

Age. Keewatin (regenerated basic clastic). N. H. W.

No. 1347. Muscovadyte.

North shore of Muscovado lake, sec. 36, T. 65-5.
Ref. Annual Report, xvi, pages 88, 89, 122; Annual Report, xix, pages 199-201. (Compare No. 2197.)

Meg. Granular gabbro.

Mic. The rock is characterized by a uniformly granular and globular condition of all the minerals, which are those characteristic of granulitic gabbro. The *feldspars* sometimes contain small rounded *augites* and *magnetites* poikilitically, and the augites hold the magnetites in the same way. One (thick) section.

Age. Cabotian (regenerated fragmental Keewatin). N. H. W.

No. 1348. Labradoryte. *(Anorthosyte.)*

North part of sec. 11, T. 64-5, south side of Bashitanequeb lake. Forms an elevated bluff.
Ref. Annual Report, xvi, pages 89, 122.

Meg. Like the well-known "feldspar rock."

Mic. The rock consists almost entirely of labradorite, whose extinction angle on 010 is 22°; but there is a little *magnetite,* about which, on its borders, is a little *brown* biotite. There are also a few small, straggling shreds of *augite.* Several larger grains of augite are alternately twinned with *bronzite(?)* in narrow bands. One section.

Age. Cabotian. N. H. W.

No. 1350. Biotite Gneiss.

North side of the point, sec. 32, T. 65-5, Gabemichigama lake.
Ref. Annual Report, xvi, pages 89, 122; Annual Report, xxi, page 148.

Meg. Apparently finely fragmental, a condition of the rock which lies below the gabbro. (See Nos. 1089-1092 and 1777.)

Mic. Granular, consisting of *plagioclase, diopside, biotite, quartz, magnetite.* One (thick) section.

Age. Keewatin (changed). N. H. W.

No. 1351. Slate.

S. W. ¼ sec. 29, T. 65-5. North of Gabemichigama lake.
Ref. Annual Report, xvi, pages 89, 122.

Meg. Fine, fragmental, sedimentary, highly tilted (45°) toward the northeast.

Mic. This slate is made up of a fine clastic dust of *hornblende, biotite, feldspar* and *quartz*, colored, also, in part, apparently, by *leucoxene,* the quartz being rather rare. One section.

Age. Probably Upper Keewatin. N. H. W.

NO. 1352. SLATE.

Same place as the last; same rock.
Ref. Annual Report, xvi, pages 90, 122.

Meg. Coarser slate.

Mic. It is apparent that the *quartzes* and the *feldspars* have been enlarged by later growth, as they extend in small hooked projections into the surrounding matrix with the same orientation, embracing the *biotite* leaves and the *actinolite* spicules. It is noticeable that numerous microgranulitic inclusions have a tendency to a globular outline, some of which are also of devitrified glass. Some glassy feldspars are entirely developed new and some old ones are clouded. Sometimes the biotite is clustered about a *magnetite* grain. The biotite is frequently pierced by spicules of *actinolite.* One section.

Age. Probably Upper Keewatin. N. H. W.

NO. 1353. GRIT. *(Gray.)*

Same place as the last; same rock mass.
Ref. Annual Report, xvi, pages 90, 122.

Meg. Coarser slate, a gray grit, with quartz grains.

Mic. This is a more freshly and coarsely fragmental rock than the last. There were sizable grains of *feldspar*, *quartz* and of *hornblende*, with a great amount of finer debris concerned in the original composition. There is no apparent recomposition, but a degradation visible in the present condition of these grains. There was also apparently a porphyritic or trachitic zirkelyte which furnished pebbles as a debris for the constitution of this rock. Such fine pieces are now nearly isotropic, but sometimes embrace the forms of small crystals which are shown by the predominance of doubly polarizing fine minerals over spaces having geometric forms. These supposed zirkelyte pebbles have prevailingly rounded outlines and are sprinkled with fine dust which appears to be of the same nature as the coloring matter of the rock in general. One section.

Age. Probably Upper Keewatin. N. H. W.

NO. 1354. SLATE.

A little south of the centre of sec. 29, T. 65-5.
Ref. Annual Report, xvi, pages 90, 122.

Meg. Samples of the same rock, one coarser than the other.

Mic. The coarser-grained rock is identical with the last. The original *feldspars* were coarsely twinned and the *quartzes* appear to have been derived from an eruptive rock.

The finer rock (which is very fine) is dark with all the colored minerals, particularly with *biotite.* There are spots in the slide where these biotite scales are prevailingly set edgewise across the section. Then by their greater polarization colors they give the whole slide a spotted aspect, which is increased by the occurrence of actinolite in the same areas. Two sections.

Age. Probably Upper Keewatin. N. H. W.

No. 1356. Conglomerate.

At about the centre of the N. E. ¼ sec. 31, T. 65–5.
Ref. Annual Report, xvi, pages 91, 122.

Meg. Supposed to be a portion of the Ogishke conglomerate when collected.

Mic. The rock is undoubtedly a part of the Ogishke conglomerate, having the peculiar twinned feldspars and parts of their matrix, like the Kekequabic porphyry. Compare Nos. 1062-1066, 1080, 1095. One section.

Age. Keewatin (Ogishke). N. H. W.

No. 1357. Actinolite Schist.

A little northeast from the last.
Ref. Annual Report, xvi, pages 91, 122.

Meg. Fine grained, grayish green.

Mic. The rock consists very largely of fine spicules of *actinolite,* which are rarely in union, but lie criss-cross in a mesh, with minute *feldspar* and *quartz* grains between. One section.

Age. Keewatin (Ogishke). N. H. W.

No. 1358. Graywacke.

South shore of Gabemichigama lake, near the southeast corner of sec. 31, T. 65–5 W.
Ref. Annual Report, xvi, pages 91, 122.

Meg. A fine-grained, compact, siliceous graywacke or quartzyte. No section.

Age. Archean (Keewatin). U. S. G.

No. 1359. Quartzyte (?)

Near the same place; probably a little southwest.
Ref. Annual Report, xvi, pages 91, 122.

Meg. A rather fine-grained, granular, yellowish rock. The hand sample shows large reflecting cleavage faces of some mineral, perhaps biotite, which includes poikilitically the smaller grains of the rock.

Age. Archean (Keewatin). U. S. G.

No. 1360. Gabbro.

South side of Gabemichigama lake; probably in N.E. ¼ sec. 6, T. 64-5 W.
Ref. Annual Report, xvi, pages 92, 122.

Meg. The ordinary gabbro, somewhat decayed and coated with a green mineral, probably *malachite.* No section.

Age. Cabotian. U. S. G.

No. 1361. Diabase.

About on the town line between T. 64-5 and T. 64-6 W., south side of Gabemichigama lake. A basaltic dike at the shore.
Ref. Annual Report, xvi, pages 92, 122.

Meg. Heavy and firm, dark, medium grained.

Mic. Although the ophitic structure is evident, still there were many of the *augites* which were as early in origin as the *feldspars.* These are small and roundish. The later ones are frequently interlaminated with the feldspars, which, in a few cases, have taken fantastic shapes, with spreading, recurving branches like a rigid wand. The augites also embrace much of the glassy magma, now charged with magnetite particles. One section.

Age. Dike in the Keewatin. N. H. W.

No. 1362. Muscovadyte *(with quartz, etc.)*

From near the top of the irony bluff south side of Gabemichigama lake.
Ref. Annual Report, xvi, pages 92, 122.

Meg. Dark, heavy with iron ore, crumbling.

Mic. *Hypersthene, magnetite, quartz* make up this slide in the order named, quartz being about one-fifth of the whole, the hypersthene embracing the other minerals poikilitically, and being sometimes stained with hematite. One (thick) section.

Age. Cabotian (changed Keewatin). N. H. W.

No. 1364. Quartzyte *(with hypersthene, etc.)*

Near the bottom of the quartzyte bluff, south side of Gabemichigama lake.
Ref. Annual Report, xvi, pages 92, 122. Compare No. 118E.

Mic. *Quartz, hypersthene, magnetite, diallage* compose this rock, about four-fifths being quartz. In the quartz are numerous small inclusions, generally grouped near the centres of the grains. Finer inclusions run in lines across the quartzes. The hypersthene sometimes embraces all the other minerals poikilitically, forming plates of considerable size, in the manner of augite in a diabase, and also encloses globular grains of diallage and apparently of olivine. Two sections.

Age. Pewabic (changed jaspilyte of the Keewatin).

Remark. Considering only the evidence of the slides Nos. 1362 and 1364, it appears that the bottom of the quartzyte bluff is less pyroxenic than the top. That signifies that at this place there is a gradation increasing toward the gabbro, and warrants the hypothesis that the pyroxenic element depends on the proximity of the gabbro. It would then be left to inquire, on the hypothesis that the Pewabic was a pure quartzyte originally, whether that difference is due to infiltration of hypersthene, etc., into the quartzyte, or the infiltration of quartz into the base of the gabbro, accompanied by an alteration of its ferromagnesian minerals, and especially of augite, into hypersthene, and the entire loss of the feldspars. But as the Pewabic quartzyte is only a changed jaspilyte varying to muscovadyte, it must have contained originally more or less greenstone debris capable of giving origin to all these ferromagnesian minerals *in situ*. N. H. W.

No. 1365. Peridotyte.

A little northeast from the "narrows" of Gabemichigama lake, on the south shore.
Ref. Annual Report, xvi, pages 93, 123.

Meg. Heavy, banded, a part of the "olivinitic iron ore."

Mic. This rock consists almost wholly of olivine *(fayalite)*, with a little *hypersthene* and *magnetite*. There is also a little *grünerite*, distinguished by its multiple twinning, its higher refraction (tested by the Becke method) and its higher double refraction. The surface roughness of the grünerite is visibly less than that of the olivine, which it pierces, and than the hypersthene, yet the fine Becke line always moves toward the grünerite on raising the objective.

Examining another slide, it appears that there is a little *quartz* in this rock. It is in round grains in the hypersthene, or indents its borders. Two sections.

Age. Cabotian (changed Keewatin). N. H. W.

No. 1366. Gabbro. *(Muscovadyte.)*

At the narrows of Gabemichigama lake. Embraced in the Pewabic quartzyte No. 1364. Compare Nos. 1341 and 1344.
Ref. Annual Report, xvi, pages 93, 123.

Meg. Fine-grained gabbro.

Mic. *Plagioclase*, *augite*, olivine, *magnetite* are the essentials in this slide, without an ophitic structure in the main; some of the augites are small, rounded, and apparently as early as the feldspar. The magnetite is in rounded masses, and in larger branching parts, frequently embracing parts of the augite. The feldspar is generally clouded with a dust of minute crystalliths which it is impossible to determine, but which is in part apparently pyroxene and *biotite*. The latter also appears in larger masses independent of the feldspar. One section.

Age. Originally a layer in the jaspilyte of the Keewatin (now granular gabbro in the Pewabic quartzyte, dating from the gabbro revolution). N. H. W.

No. 1367. Greenwacke.

Various samples (10) obtained in the ascent of the hill (or mountain) from the southwest shore of Gabemichigama lake, near the narrows, intended to show the features that might be considered of sedimentary origin.
Ref. Annual Report, xvi, pages 93–95, 97–99, 123.

Meg. Of the lot thin sections have been made of only four. They are separately distinguishable for purposes of description as (*a*), (*b*), (*c*) and (*d*), though these distinctions were not recorded in the field-book.

(*a*) *Macroscopically*, the sample has a variable character, a fine-grained, dark rock, being associated with a coarser one, both being dark gray or greenish.

Mic. The section was evidently made from the coarser sort. The section consists essentially of long, spindling *feldspars*, somewhat radiating in arrangement and of *amphibole*, with some small, scattering grains of *pyrite* and of *magnetite*. In polarized light some quartz grains are brought to light. The materials of the rock are probably all, except the quartz, of eruptive, basic origin, and the structure of the slide indicates a fragment of an altered diabase. The intimate relations of the feldspar lamellæ with the amphibole, give the impression that they are both of secondary origin. Sometimes a rod of amphibole separates two otherwise contiguous lamellæ of the feldspar, and on emerging from the feldspar the rod of amphibole spreads out into a fan-shaped or palmate series of fibres. In most cases, however, such rods terminate near the termination of the feldspar lamellæ. The amphibole does not show any characteristic cleavages, but rather a fibrous and fragmental structure. (Compare the *cornes vertes* of Michel Lévy. Comptes Rendus, Société Géologique de France; Sess Extrord. 1890, page 916.) One section.

(*b*) *Meg.* Is a light-gray, fine-grained, apparently siliceous or feldspathic rock, having a somewhat elongated or schistose structure.

Mic. In high powers the section shows principally a greenish yellow (pyroxenic or amphibolic) element constituting at least one-half of the rock. It polarizes like pyroxene, probably *diopside*. Mingled with these is what appears to be granular *leucoxene* or *sphene*, but as it is in groups and isolated it is more like the former. According to Prof. Lacroix, the piece is almost certainly an altered limestone, what the French petrographers call *corne verte*.

In the midst of the green element is a granular transparent mineral which has the aspect of a feldspar and which on making the following tests proves to be *anorthite*.

I made a powder of the rock, and boiled the powder in hydrochloric acid for fifteen or twenty minutes. After washing and coloring it with malachite green, and again washing, the powder remained permanently colored, *i. e.*, a large portion of it did, showing an attack by the acid and the formation of a gelatinous or skeleton silica, like that formed by anorthite under such treatment. Yet in this colored powder are still numerous, clear, nearly colorless grains, which have high refraction and high double refraction. While clear and glassy they still have a little tinting of a yellow or a greenish yellow. They constitute in some cases apparently one-third of the powder, and show the proportion of pyroxene in the rock. They give the faintly green tint to the rock *en ensemble*. The sphene is not so much as to make any impression on the powder nor on the rock as a whole. One section.

Remark. This is a remarkable result. No such a rock could have been expected in this greenstone. It is, of course, so far as it goes, testimony to the fragmental character of the whole rock, for this is but a fragment like many fragments included in it, though most of the foreign pieces are not of this character. The entirely altered character of this rock leads one to expect that all the other fragmental parts have suffered a similar profound alteration, or at least have suffered the same metamorphosing force.

I found a fragment of the anorthite which gave an oblique bisectrix n_g. Extinction on it with a cleavage, was 29°. While this is not determinative for anorthite, it is not discordant with that mineral if the obliquity of the section be considered.

I made an assay Boricky, and it gave chiefly lime, but also considerable soda, indicating not a pure anorthite.

(*c*) *Meg.* Is quite a different rock. It contains a large amount of quartz, so much as to make this the most evident and abundant ingredient, and the rock can be described best from that point of view.

Mic. The quartz surrounds and encloses all the other substances except the dark sub-opaque element, whose nature is problematical. The most frequent of these enclosures is a triclinic feldspar whose extinction on n_p in one of the larger grains is 65°, indicating *andesine* according to the late tables of M. Fouqué (Bulletin de la Société de Minéralogie de France, 1894). This feldspar is sometimes in grains of sizes sufficient for the determination of the orientation of the lamellæ by the microscope, when they are also well preserved, and such grains appear to have preceded by but a very short interval, if at all, the small grains, which are completely surrounded frequently by the quartz plages poikilitically, and which are much changed to a mica, probably *damourite* according to Lacroix. These little changed feldspars are frequently rounded, but were probably originally simple, stout crystals, whose corners have been destroyed. Their habit and greater decomposition indicate that they were originally of some other species, but it is impossible now to identify it. It was probably more alkaline than the other larger crystals.

The dark substance mentioned has the wandering outlines of a magma residue, and its opacity agrees with that supposition. But it is not of uniform character. Sometimes it surrounds the quartz and the undecayed feldspars. But throughout it are shapes which indicate the former existence also of some of the changed feldspar grains. They are now nearly opaque, but they pass by an insensible gradation into the grains which are certainly of the more changeable feldspar. There is a gradation from the grains of feldspar which now consist essentially of damourite into the nearly opaque substance. It seems as if the change to which the whole rock has been subjected was concentrated here, and that the damourite has lost by it its crystalline structure. There are also, in these semi-opaque spots, signs of the former existence of large mica plates which have now become opaque, except that they show yet a kind of striation of dark and light in the presumed direction of the original cleavage. These mica plates, if they were such, were of the original rock, are much larger than the microscopic damourite scales in the changed feldspars, and were evidently more changeable than they, since they are only found in this altered state, while the damourite, itself a result of a transformation of the same kind, is usually well preserved.

In short, according to the suggestion of Prof. Lacroix, this sample, No. 1367 (*c*), is a metamorphosed granite, the original mica having been fused by the heat of the surrounding molten rock, and the molten result having then enclosed some of the smaller and more decomposable feldspars. These feldspars themselves, previously changed to damourite by the same cause, suffered further change, even becoming like the original mica. The only parts of the original rock fragment which were not sufficiently heated for fusion are the quartz, the andesine(?) feldspars and the most of the damouritic feldspars. One section.

Remark. This being apparently a fragment in the midst of a tuffaceous rock, it must have been thrown out as a granitic mass from the deeper-seated portion of the crust, and the changes above described took place while it was floating loosely in the molten matter within the volcano from which it was finally ejected. It is thus in harmony with the change evinced by specimen (*b*). What later metamorphism, if any, this mass has suffered, is not shown here.

(*d*) ***Mic.*** Is similar to No. 1367 (*a*), with the addition of pyroxene, but the feldspars are not radiated and spindle-shaped. They occur more scantily as in a clastic rock. Much amphibole pervades the slide, usually in fine, granular form, but sometimes spreading and fan-shaped or curved and one-sided. The pyroxene is in large crystals, much shattered and separated along the cleavages. The grain and texture vary from place to place in the slide, with micro-granulitic areas. One section.

Age. These are all from the Archean (Keewatin). N. H. W.

NO. 1368. DIORYTE. (*Greenstone.*)

Same place as No. 1367, but intended to show the most evident eruptive characters. From near the summit of the hill.

Ref. Annual Report, xvi, pages 94, 99, 123.

Mac. A hard, green or gray, compact rock, fine grained.

Mic. This rock does not differ from No. 1367(*a*) essentially. The feldspar is in form of spindle-shaped, often radiating microliths, whose lamellæ are frequently separated by a narrow, rod-like amphibole. Yet in the main the feldspars run rigidly amongst the fibres of the amphibole, the latter frequently having the palmated form mentioned under No. 1367. The spindle-shaped microliths of feldspar look quite fresh compared to a few larger albite-twinned feldspars which are scattered throughout the slide. One section.

Age. Archean (Keewatin). N. H. W.

No. 1369. Marble.

Just east of Ogishke Muncie lake, near the centre of N. ½ sec. 24, T. 65–6 W.
Ref. Annual Report, xvi, pages 95, 123.

Meg. A fine-grained, siliceous, pinkish and greenish marble, similar to No. 1371. No section.

Age. Archean (Keewatin). U. S. G.

No. 1371. Marble.

Northeast end of Ogishke Muncie lake, sec. 24, T. 65–6. From the hill of greenstone where the marble becomes involved in the greenstone conglomerate. Compare Nos. 746, 760, 1378 and 1681.
Ref. Annual Report, xvi, pages 96, 123; Annual Report, xvii, pages 199, 205.

Meg. Light colored, dense, irregularly faintly striped with impurities, and considerably separated by short joint-planes and seams.

Mic. While the rock is composed of *calcite*, there are small spaces which are nearly isotropic, and in these there are also small isolated and attached crystals of calcite that are idiomorphic. In this isotropic substance are also a few needle-like, bright blades, which, having parallel extinction, appear to be *muscovite* or microliths of some feldspar, as well as a few other transparent crystalline grains which cannot be distinguished from feldspar, but whose nature cannot be determined. One section.

Age. Archean (Keewatin).

Remark. This marble is supposed to be a product of segregation from the alteration of the feldspars in the adjoining greenstone. N. H. W.

No. 1372. Conglomerate. *(Greenstone.)*

Sec. 24, T. 65–6, shore of Ogishke Muncie lake.
Ref. Annual Report, xvi, pages 96, 98, 123.

Meg. Greenstone, appearing conglomeratic.

Mic. The rock is plainly a fragmental one, but *calcite* is the most conspicuous and most abundant single mineral. It is disseminated widely, and almost everywhere, even in the pebbles, in minute particles. With the calcite is a considerable amount of fresh *feldspar* in form of microlitic crystals. These lie in the calcite in an ophitic manner. These seem to be simple crystals. Although two or three are sometimes adjacent and parallel, they do not extinguish as if twinned. There are more numerous isotropic areas similar to those mentioned in the marble (No. 1371), and these are sometimes specked with fine grains of calcite and with feldspar microliths. There is a considerable amount of dust of a dark *leucoxene* or of *magnetite* and red *hematite* scattered through the slide, and the differences in the manner of distribution of these materials have much to do with the pebbly aspect of the slide, for they are wanting in places and abundant in others, or very fine in some and coarse in others. The isotropic areas are occupied mainly by a faintly-green substance, apparently chloritic, and this extends also through the body of the rock as a bond of coloration. This substance is also unevenly disseminated, adding to the pebbly aspect of the section. These differences of aspect accompany other slight differences of composition, viz.: in some of the pebble-like spots the calcite is in fine round pellicles, and having high colors, appears like globular pyroxene. Such areas are markedly contrasted with the surrounding rock in which the calcite is in distinctly crystalline forms. Again, the feldspar spicules are more abundant or are nearly absent in some angular or sub-rounded areas. One section.

Age. Archean (probably Upper Keewatin).

Remark. The differences mentioned can be explained apparently only by assuming original differences in the composition of the rock, however uniform and simple the mineralogical composition at present. The isotropic areas, which in bright light also show very fine, globular, indistinct spots, which faintly transmit light, are therefore to be considered as bits of glassy volcanic debris now devitrified. This rock illustrates well the effusive or agglomeratic composition of the great bulk of the greenstones of the Keewatin in the region south and east from Ogishke Muncie lake. N. H. W.

No. 1373. Chert (?)

Fragment in No. 1372, near the marble.
Ref. Annual Report, xvi, pages 96, 123.

Meg. Chert of a light greenish-gray color, connected with rock No. 1372.

Mic. The most of the slide is exceedingly fine grained and its individual components cannot be made out, presenting an overlapping interference and an aggregate gray color in common light. Between crossed nicols the field is nearly dark, but sprinkled with small angular spots in which some colored light gets through. It is probable that the rock consists largely of chloritized *hornblende* and *calcite*, for there are quite a number of idiomorphic crystals of calcite, porphyritically scattered throughout the slide. One section.

Age. Keewatin.

Remark. Owing to its composition this rock is perhaps not properly called chert. N. H. W.

No. 1374. Greenwacke. *(Conglomerate.)*

Same place as the last.
Ref. Annual Report, xvi, pages 97, 123.

Meg. Rounded, concretionary, or pebble-like masses, from a quarter to a third of an inch in diameter, seen on the weathered surfaces of the same conglomerate.

Mic. The section is made parallel to the weathered surface. The slide appears, in general, much like that of No. 1372, but is nearly free from calcite. There are variations in the fineness of the grain, and some dark areas of hematite, but the differences are not worthy of special description. The slide seems not to cut any of the round masses that are visible on the weathered surface. It contains, however, several large feldspar fragments. The weathered surface of this rock is shown by figure 12, plate II. One slide.

Age. Archean (Keewatin). N. H. W.

No. 1375. Greenwacke.

In section 13, adjacent to the above; in the narrow place between Ogishke Muncie lake and the lake south of Townline lake.
Ref. Annual Report, xvi, pages 97, 123.

Meg. Schistosely disintegrating, light green and siliceous condition of the same conglomerate.

Mic. The slide shows much *calcite* and coarser grains of *feldspar*, as well as areas nearly isotropic which were probably of volcanic glass originally. They are now devitrified as in No. 1372. The rock, indeed, must be very near No. 1372 in all respects. One section.

Age. Archean (Keewatin). N. H. W.

No. 1378. Marble.

Same place as No. 1375.
Ref. Annual Report, xvi, pages 97, 123.

Meg. Rusty and calciferous; appears in patches.

Mic. The slide shows a rock made up like the marble at Ogishke Muncie lake (No. 1371), and like it, and like the sideryte of the Animikie near the west end of Gunflint lake, it contains patches, now coarsely devitrified, which were probably of the nature of volcanic glass when they were deposited in this rock. These indicate some close connection, geographic if not genetic, between the origin of these rocks and the action of volcanic forces. One section.

Age. Archean (Keewatin). N. H. W.

No. 1379. Greenwacke.

South end of the east bay of Saddle Bags lake on the town line between T. 65-5 and T. 65-6.
Ref. Annual Report, xvi, pages 98, 123.

Meg. Gritty greenstone.

Mic. In the slide are the outlines of numerous large pieces of feldspar crystals, now wholly filled with the usual elements of this rock, viz.: *chlorite*, *calcite*, etc., only differing from the rest of the rock in being more brightly transparent in common light, and more dark between crossed nicols. The rock is well charged with *calcite*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1380. Greenwacke.

The same from the east side of the east bay of Saddle Bags lake.
Ref. Annual Report, xvi, pages 98, 123.

Meg. Greenstone.

Mic. This rock varies, not so much for having had original fragments of feldspars, as from being more abundantly supplied with the substance that has given it isotropic areas. Some of these appear like old vesicular scoria. Otherwise it is like the last. One section.

Age. Archean (Keewatin). N. H. W.

No. 1381. Dioryte (?) (*Greenstone.*)

West side of Frog Rock lake.
Ref. Annual Report, xvi, pages 98, 123.

Meg. Green and rather massive.

Mic. Conspicuous forms of *uralite* and of *feldspar* are the first noticeable feature. This uralite came from a twinned pyroxene, which is still preserved in the twinning and in the idiomorphic outlines of some of the sections. These lie in a matrix which appears fragmental, made up of similar materials in finer grains with considerable *chlorite*. The rock is less altered than most of the foregoing greenwackes, but more altered than the similar tuffaceous rocks (as No. 1049, etc.) seen about Kekequabic lake and about the lakes westward from there. The rock shows much *leucoxene* and *chloritic* isotropic material, some *calcite* and apparently a little *epidote*. One section.

Age. Archean (Keewatin).

Remark. It remains uncertain whether this rock is an altered diabase, or a debris of basic rock. N. H. W.

No. 1382. Dioryte (?) (*Greenstone.*)

Near the centre of sec. 19, T. 65-5, south of Frog Rock lake.
Ref. Annual Report, xvi, pages 98, 123.

Meg. Same kind of rock as the last.

Mic. Much of the rock is isotropic, occupied by the well-known chloritic substance, but there are outlines of crystals and parts of crystals of *feldspar*, all much decayed. Of *calcite* and of *uralite* there is less than in No. 1381. One section.

Age. Archean (Keewatin). N. H. W.

No. 1383. Greenwacke.

From the centre of the same section, south of Frog Rock lake.
Ref. Annual Report, xvi, pages 98, 123.

Meg. Greenstone.

Mic. With the elements mentioned in Nos. 1381 and 1382, in this rock are also angular grains of *quartz*, and a large increase of *calcite*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1384. Greenwacke.

Associated with the last, interbanded with it, and finer grained.
Ref. Annual Report, xvi, pages 98, 123.

Meg. Finer grained than the last.

Mic. Similar to the last. Here, however, the areas of the larger crystals are occupied sometimes entirely by *calcite* in a finely granular state. One section.

Age. Archean (Keewatin). N. H. W.

No. 1385. Argillyte.

West end of Ogishke Muncie lake at the southern portage to Dike lake. Near the centre of the west side of the S. W. ¼ sec. 27, T. 65-6 W.
Ref. Annual Report, xvi, pages 78, 99, 124.

Meg. Almost black, fissile argillyte, showing markings on the surface like minute ripple marks, but which may be due to movements since the solidification of the rock. No section.

Age. Archean (Keewatin). U. S. G.

No. 1386. Dioryte. *(Greenstone.)*

Summit of East Twin mountain.
Ref. Annual Report, xvi, pages 99, 124.

Meg. A coarse greenstone.

Mic. The original ophitic structure is very evident, although the pyroxene is now wholly altered to *uralite*. The *feldspar* is well preserved, considering the age of the rock and the position of great exposure, showing its twinning lamellæ distinctly, both albite and pericline. There is one large crystal which shows a pegmatitic intergrowth of quartz and feldspar, and isolated angular areas of quartz appear elsewhere. The uralitic product takes the form, also, of numerous needles, which, by reason of their higher double refraction and their form, appear to be of *actinolite*. A little *calcite* is sheltered in some of the interstices of the larger crystals. One section.

Age. Archean (Keewatin).

Remark. This was plainly an original basic igneous rock of the diabase order, and owing to its known age it illustrates the preservation of the mineral composition in the oldest known rocks having a known igneous origin, and, by comparison, it indicates that most of the others, foregoing, in which the origin is doubtful, and the rock is much more changed, were probably not originally massive, but are rather of the nature of rock No. 1395, *i. e.*, clastic. N. H. W.

No. 1387. Dioryte. *(Greenstone.)*

From the north slope of the same hill as No. 1386.
Ref. Annual Report, xvi, pages 99, 124.

Meg. Finer grained.

Mic. The ophitic structure is less evident, but in all other respects this rock does not essentially differ from No. 1386. Between the twin lamellæ of the *feldspars* is frequently a thin layer of the *hornblendic* material. One section.

Age. Archean (Keewatin). N. H. W.

No. 1391. Flint. *(Gritty.)*

From one of the more northerly subordinate hills north of East Twin mountain.
Ref. Annual Report, xvi, pages 100, 124.

Meg. Appearing quartzose, the weathered surface showing whitened pebbly forms of old feldspars.

Mic. The most conspicuous feature is the angular *quartzes* and micro-granulitized old feldspars, which lie in a fine matrix made up of greenstone debris, *feldspathic*, *chloritic* and *leucoxenic*. In high power this darker debris can be resolved sufficiently to disclose also the characters of *actinolite*. The old feldspars are so completely lost that the mass appears flinty. They appear distinct on removing the upper nicol. One section.

Age. Evidently a part of the Ogishke conglomerate. N. H. W.

No. 1392. Conglomerate. *(Greenstone.)*

From the same subordinate hill range, between Ogishke Muncie lake and East Twin mountain.
Ref. Annual Report, xvi, pages 100, 124.

Meg. Imperfectly porphyritic, fine grained, siliceous.

Mic. Of the two sections with this number, one is similar to, but more apparently fragmental than, some of the Kekequabic porphyry, except that the ferromagnesian element is wholly altered to irregularly spreading and often branching masses of hornblendic material, and is also scattered as a chloritic powder throughout the slide. There is some *calcite* and much *quartz* in the fine groundmass, which otherwise, along with some *feldspar*, has a granulitic structure, causing the rock to resemble the porphyry referred to. The greater decay of the augitic element, and the rather scant or wholly absent secondary growths about the large feldspar crystals, ally it, however, to the conglomerates about the west end of Ogishke Muncie lake, which also contain debris from some porphyry.

The other section having the same number is a dark flint, composed of debris from the basic rocks, similar to No. 1391, but less acid. Two sections.

Age. Archean (Keewatin). N. H. W.

NO. 1394. FLINT.

In the same subordinate series of low hills as No. 1392.
Ref. Annual Report, xvi, pages 100, 124.

Meg. Flinty, often greenish or grayish, several samples, closely related and banded together in a gritty greenstone (No. 1393).

Mic. Two sections have this number. They both show a thinly banded rock. In one the bands consist of coarser and finer granulitic quartz, accompanied by belts of *actinolite* needles. In the other the banding is caused by greater and less amounts of *calcite* accompanied by fine *actinolite* needles. In this also the interlocking of the quartzes is less evident. Indeed, some of the quartz is angular and coarser and sharp like fragmental non-detrital debris. Two sections.

Age. Archean (Keewatin). N. H. W.

NO. 1395. CONGLOMERATE. *(Greenstone.)*

In the same series of subordinate hills as No. 1392.
Ref. Annual Report, xvi, pages 100, 124.

Meg. Conglomeratic, green, showing some sedimentary structure; a widely disseminated rock.

Mic. The rock contains some large *feldspars*, but more ragged than in No. 1392, and somewhat more permeated by products of alteration, still perfectly evident as feldspars with twinned lamellæ. A large part of the rock is of hornblende, which exists as patches and as scattered fibres and cleavage-plates. The differences in the appearance of the rock, whether in hand specimen or under the objective, are due in part to the differences in the manner of distribution of the larger elements, feldspar and hornblende. There are pebble-like areas in which these crystals are not present, but which consist of granulitic quartz and feldspar, and there are others of pure *quartz* with a single orientation. There are others still in which there is much fine hornblende in spicules, with fine feldspars and *magnetite.* In most cases these parts are distinctly separable from the general rock mass, but it is evident that in the rock mass all these parts are more finely commingled to make the general matrix. One section.

Age. Archean (Keewatin).

Remark. These differences of grain are explicable on the assumption that the rock is a conglomerate, a part of the Ogishke conglomerate, but were the differences somewhat less marked, the rock would be similar to several that have been called amphibolyte and dioryte, and others whose origin has been uncertain and which have been named greenstone. This seems to be the prevalent character of the greenstone area about Ogishke Muncie lake. These rocks have not been sheared; indeed, shearing is almost unknown in this district, and is rare in the state, and all original structures as well as original composition are well preserved, as shown by the characters of the rock forming the summit of East Twin mountain (No. 1386). Nos. 1391-1395 represent the broken and sedimentary beds intervening between the Twin peaks and Ogishke Muncie lake, sometimes running in lower ranges and also forming isolated small hills. N. H. W.

No. 1396. Greenwacke. *(Regenerated.)*

From the hill directly east of Alpha lake, sec. 29, T. 65-6 W.
Ref. Annual Report, xvi, pages 100, 124.

Meg. Uniform, green, rather fine-grained, appearing like a massive rock.

Mic. This rock does not show the differences of granular structure seen in No. 1395, but the grains are of uniform size. They are all small. The most abundant are of *hornblende*, and invariably show two periods of growth, but there are a few of epidote(?) indicated by a faintly yellow color and higher double refraction. These are yellowish and short, while the hornblendes are greenish and mostly elongated in section. The *feldspar* grains are smaller, and indistinct, hiding themselves in the obscurity of the fine groundmass, which last is largely isotropic between the nicols, though plainly containing numerous imperfectly polarizing crystalline elements.

Several of the hornblendes appear between crossed nicols like enlarged feldspars, but on making tests in convergent light these give the figure of an optic axis in the field, which fully accounts for their low illumination, and hence for their resemblance to feldspars. One section.

Age. Archean (Keewatin).

Remark. This rock, which is allied to the green schist of Kekequabic lake, is a difficult one to name. In the field it was taken for a part of the fragmental rocks of the region. Its secondary hornblendic growths are perhaps due to the action of later metamorphic force, intensified by the dike(?) (No. 1397) which cuts it near the lake shore. N. H. W.

No. 1397. Diabase.

Cutting No. 1396.
Ref. Annual Report, xvi, pages 100, 124.

Meg. A medium-grained diabase, with its augite evidently largely changed to hornblende. Also contains pyrite. No section.

Age. Archean, probably. U. S. G.

No. 1398. Esterellyte.

North side of Kekequabic lake on the point on which is the southwest corner of sec. 29, T. 65-6 W. Same as No. 1399.
Ref. Annual Report, xvi, pages 100, 124.

Meg. The hand sample consists of some of the esterellyte and some fine-grained, hard, greenish graywacke. The latter is probably a fragment included in the former, although from the hand specimen and the field description this point is not clear. No section.

Age. Archean (Keewatin). U. S. G.

No. 1399. Esterellyte.

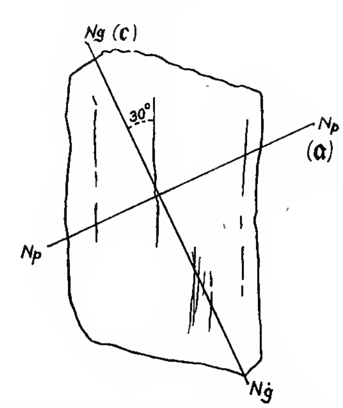
From the knob, southwest corner sec. 29, T. 65-6, Kekequabic lake. Taken from the weathered surface. Compare Nos. 1061, 1062, 1094, etc.

Ref. Annual Report, xvi, pages 100, 124.

Meg. Coarsely porphyritic with feldspar and more finely porphyritic with pyroxene. Shows pebbly forms.

The gray porphyry (No. 1094) at the southwest corner of sec. 29, T. 65-6, rises about 100 feet above the lake, and composes the whole peninsula, making a knob by itself. It is very siliceous (No. 1398). It is massive, or coarsely jointed. The feldspar crystals are not always perfect in form, but approximate a true crystalline shape. They seem to be of orthoclase. They weather red. The long exposed (or at least the burnt) surface of the whole rock becomes reddish, but the surface scales off by fire and keeps a fresh gray color exposed. There is in some places a prevailing direction—that of the general strike—seen in the longer axes of the crystals. They are also apt to stand vertical, edgewise, in the same direction. In the rock are boulder forms. These are most frequently of greenstone, and then they are not porphyritic, but sometimes they are of some rock which weathers a pinkish-red color. They are also of a siliceous gray rock, resembling the matrix of the porphyry, but finer grained, and also of other light-weathering kinds. But in the main this is a homogeneous rock. These boulder-forms are by no means a common occurrence, at least at this place. Yet, in other places, there is a various distribution apparent in the crystals. They are either more conspicuous and more numerous, or else less frequent, in rounded spots; or they stand out at different angles, as if they had been dependent on the varying nature, position, structure or grain of the enclosing rock. This distribution and confused arrangement are so combined as to bring out to view indistinct outlines of former included boulders. From this I conclude that the whole rock is a modified condition of the sedimentaries here prevalent, and that it indicates what would become of the whole formation (conglomerate, graywacke, slate, chert, etc.), if under similar conditions the rearrangement and recrystallization had been carried to completion—a syenyte or a granite, at least an acidic rock. Here there is no basic surplus to give the rock a doleritic aspect. Where this has been the case the singular "ambiguous greenstone" has apparently been the product, a kind of fragmental basalt.

Mic. The much-twinned *feldspars* are conspicuous and remarkable. In one instance one of these crystals embraces completely one of the *pyroxenes*. This is, however, a rare structure. Usually the crystals of the porphyritic elements are wholly independent. Sometimes *quartz* figures amongst the large elements in a granophyric manner, but in general it is confined to the finer groundmass in which it is granulitic with feldspar.



Section oblique to 010, showing the positions of Ng and Np in the principal part of the crystal.

FIG. 44. ÆGYRINE-AUGITE IN NO. 1399.

It is very difficult to decide from optic properties what is the species of the feldspar. Several observations make it certain that n_g is in the acute bisectrix, and hence the mineral is optically positive. The optic angle is also small, comparatively, being nearer to that of anorthoclase (45°) than of any of the feldspars. On such an index of elasticity, extinction (on indistinct cleavage) is 4° to 5°. The section shows, at the same time, no albite or other twinning. It is hence about parallel to 010. A section showing n_p nearly perpendicular has both albite and pericline(?) bands. The extinction angle here, between the optic plane and the albite bands, is 72° to 74°. The angle of the axes round n_p is evidently larger than round n_g. The angle between the albite and pericline(?) macles on a section cut perpendicular to n_p is 87° 30′. It is noticeable that the pericline(?) bands extinguish simultaneously with the albite bands, set by set, as in microcline twinning, although the albite lines are long and frequent, and the periclines (?) are short, far apart and infrequent. The twinning of all the crystals is coarse, very abundant and distinct. There are also twinnings on the Carlsbad and Boveno plans. Some of these characters indicate labradorite or *andesine*, and some indicate *anorthoclase*.

The pyroxene is also interesting. It is, in general, green, but frequently the color fades out in patches, or at the centre, which extinguishes at a different angle. Indeed, there is an irregular zonal structure in some of the crystals, this being made evident by the successive extinctions, there being four, and indistinctly sometimes six different extinctions in a crystal favorably cut. These are distributed in zones which are generally better developed at one end of the crystal than at the other.

As shown by the diagram above, the axis n_g is in the acute angle of the crystal, making a large angle with the vertical axis, which is an anomaly for augite, indicating the soda-bearing ægyrine. There seems to be no exception to this in the numerous sections (010) of the slide.

There is a little *biotite* and some scattered grains of *sphene* in the rock. One section.

Age. Archean (intrusive in the Upper Keewatin).

Remark. See under No. 1094. N. H. W.

No. 1400. Esterellyte.

From the south side of Kekequabic lake, near the great diabase dike which crosses the lake, making a couple of islands.

Ref. Annual Report, xvi, pages 101, 102, 124.

Meg. Similar in aspect to Nos. 1398 and 1399. Compare No. 1061.

Mic. It is unlike the last in having lost its augites, which have become altered to *actinolite*, some of which is blue in common light. The rock has also taken in a notable amount of *calcite*. *Sphene* is quite common. One section.

Age. Archean (Keewatin).

Remark. It is noteworthy that the effect of the dike with its hot water and gases has been to destroy the augites in the porphyry. N. H. W.

No. 1401. Diabase.

Small island in Kekequabic lake; E. ½ N. E. ¼ sec. 31, T. 65–6 W.
Ref. Annual Report, xvi, pages 101, 124; see, also, Annual Report, xv, pages 153, 368.

Meg. A rather fine-grained, fresh, dark-gray diabase. No section.

Age. Perhaps Keweenawan. U. S. G.

No. 1402. Granite.

On the west side of the dike in the southerly of the islands.
Ref. Annual Report, xvi, pages 101, 124; Bulletin ii, pages 41, 422.

Meg. Fine, gray, red-weathering.

Mic. The section appears like the granite seen on the south side of the lake further west, in larger amount, but rather finer. There is no augite, but in its place is a congeries of *biotite* scales mingled with some *actinolite.* The old feldspars are present, but smaller and apparently in fragmentary condition, and crowded with minute crystalliths resulting from alteration; while, with the appearance of considerable *calcite*, the micro-granulitic groundmass of quartz and feldspar has risen to the aspect and proportions of a granitic structure. One section.

Age. Archean (intrusive in Upper Keewatin). N. H. W.

No. 1403. Granite.

A little further west.
Ref. Annual Report, xvi, pages 102, 124.

Meg. Somewhat porphyritic. Compare Nos. 1044-1046.

Mic. The rock shows the old zoned feldspars, but in the sparse matrix which embraces them the grains are coarse, and, with their own fragments, constitute a granitic rock. There is no augite, but in its place is *actinolite*, or at least some amphibole, *epidote* and *biotite.* In this rock, in fine grains, are also *magnetite*, *hematite* and *sphene*, and apparently a little *garnet.* One section.

Age. Archean (intrusive in Upper Keewatin). N. H. W.

No. 1404. Greenwacke. *(Conglomeratic.)*

From a ridge near the centre of the south side of sec. 31, T. 65–6, south shore of Kekequabic lake.
Ref. Annual Report, xvi, pages 102, 124.

Meg. Hardened, graywacke-like greenstone. Compare Nos. 1051 and 1059.

Mic. The green element in the rock is *hornblende*, which appears in the form of ragged crystals and crystal fragments which sometimes appear to have slight secondary enlargements and as fine debris throughout the slide. The next most abundant ingredient is a micro-granulitic rock which is in rounded pebbles. Sometimes the micro-granulitic structure is sub-microscopic, and sometimes it is quite coarse. Debris of the same kind is evidently dispersed widely and generally throughout the rock, constituting the most of the finer matrix. Then comes *quartz*, clear and glassy, in isolated grains of considerable size, generally angular, and quartz in a granitic grouping of several grains interlocking. Then are to be noted ragged, much twinned, old *feldspars*, evidently of the same kind as seen in the granite and in the porphyry a little further south. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1405. Granite.

Point on the south side of Kekequabic lake, N. W. ¼ S. W. ¼ sec. 31, T. 65-6 W.
Ref. Annual Report, xvi, pages 102, 124.

Meg. A very fine-grained, light pinkish-gray rock which seems to be a phase of the granite of Kekequabic lake. Much like the light-colored dike near Ely. No section.

Age. Archean (Keewatin). U. S. G.

No. 1406. Greenwacke.

From the point, N. W. ¼ S. W. ¼ sec. 31, T. 65-6, south shore of Kekequabic lake.
Ref. Annual Report, xvi, pages 192, 124.

Meg. Greenish schist-conglomerate. Compare No. 1060.

Mic. This rock is almost identical with No. 1404, but with a less number of large quartz grains and many more of old feldspars, and of larger hornblendes. The margins of the large hornblendes are converted into a fringe of dirty yellow fibres, largely of hornblende still, but apparently also in part of *biotite.* These marginal parts have their fibres confused and bent, and appear to have been formed by friction against the hornblendes. This yellowish disintegration product sometimes enters along the fissures of the hornblende and appears sometimes in isolated areas in the hornblendes. It is also rather widely disseminated in the rock in general, becoming stained by *hematite(?)* so as to have an orange yellow color. The rock is plainly pebbly, but at the same time amongst the old feldspars, which are so much decayed as to be hardly discernible in some parts of the slide, there has been developed a fresh growth of secondary interlocking *quartz* of granitic structure. This is sometimes in isolated areas and is sometimes within the areas of the old feldspars. In the former case it might be interpreted as constituting pebbles or other debris of the clastic rock, but in the latter position it must have been developed within the rock. The pebbles in this rock are, so far as observed, of a fine micro-granulitic association of quartz or of quartz and feldspar. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1409. Greenwacke. *(Pebbly.)*

From the little island just west of the narrows near the north shore of Kekequabic lake.
Ref. Annual Report, xvi, pages 102, 105, 125; Annual Report, xvii, pages 200, 206. See, also, Annual Report, xxi, pages 23-26.

Meg. Hornblendic schist.

Mic. The rock consists of *hornblende* in crystals and in fragments, lying in a fine matrix of granular interlocking quartz and *feldspar*, through which sometimes the slenderest needles of hornblende run without deviation, and the larger hornblendes have been slightly enlarged by borders and by spicules from the extremities of the sections. They have been originally twinned. There are no large feldspars visible in the section. One section.

Age. Archean (Keewatin).

Remark. The hornblendes in this rock frequently show contrasting colors, *i. e.*, the central portions, with outlines of former augite crystals, are darker colored. This character, seen in many instances, is shown in another place to have been due to the manner of origin of the hornblendes, and indicates that this hornblendic element was derived wholly from alteration of augite. The original rock was probably a volcanic tuff. Compare No. 1060. N. H. W.

No. 1410. DIORYTÉ. *(Schist with quartz.)*

From the top of the same island.
Ref. Annual Report, xvi, pages 102, 105, 125.

Meg. The same rock mass.

Mic. This rock has a surprisingly different aspect. It is much coarser grained. The *hornblendes*, though ragged and fragmentary, are large and are accompanied by *biotite* and *epidote*, the former encasing the latter poikilitically (compare No. 1106). In addition, there are conspicuous triclinic *feldspars* twinned on the Carlsbad and albite types, as well as on the pericline. They appear to be the same "old" feldspars as characterize the granite and the porphyry of the region. They are sometimes interfered with by the hornblendes and enclose small hornblendes as if the hornblendes, or that from which the hornblendes are derived, were of earlier date. Along with this are areas which appear to be of pebbly shapes and sizes, consisting of micro-granulitic quartz and feldspar, and lastly there are coarsely granitic interlocking quartzes, which appear to be the most recent element of the rock. Add to this a very little *calcite* and *magnetite* and *hematite* and the description is complete.

Age. Archean (Upper Keewatin).

Remark. This rock does not differ essentially from the "granite" of the south side of Kekequabic lake (compare No. 1414). The hornblende has a distinct tendency toward a green-blue color when cut perpendicular to one of the horizontal axes. It has n_g nearly parallel with the elongation, and hence is not riebeckite. The hight of the island is about twenty feet. See the field description, Sixteenth Annual Report, page 103.

This rock again connects the granite petrographically with the rock No. 1409, the peculiar pebbly green schist of the region. Another section from No. 1410 shows characters of the hornblendic schist of the region without feldspars.

Remark 2. Owing to the important bearing of this rock section on the hypothesis of the generation of the granite of Kekequabic lake from metamorphism of the schist of the region, still another section was made of the rock No. 1410; and as this section is entirely of the character of the second slide above mentioned, being a hornblendic schist similar to rocks Nos. 1409 and 1411, from the same island, it is to be inferred that the rock above described as No. 1410 did not come from the top of this island, but from some part of the granitic rock of the region, an error being made in giving it this number; and hence that it does not prove such selective distribution of metamorphism on this island as above presumed.

It is deemed best to allow the foregoing description to stand with this correction, inasmuch as this idea of selective metamorphism along certain strata rather than others has since been published (American Geologist xxii, November, 1898, page 308), based on this thin section, and since, although here there is no warrant for the inference, it is a feature that is likely to be produced in the clastic rocks under the process of metamorphism which here is supposed to have taken place. Three sections.

N. H. W.

No. 1411. Greenwacke. *(Pebbly.)*

From the middle of the south cliff of the same island.
Ref. Annual Report, xvi, pages 103, 105, 125.

Meg. More siliceous, showing sedimentary banding.

Mic. This rock is like No. 1409. Besides the pebbly spaces occupied by microgranulitic structure, there are others which were once apparently feldspars which have lost their integrity and are now charged with the same kind of secondary grains, being revealed only by a faint extinction that supervenes four times over the grain in one revolution. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1412. Greenwacke.

The same as No. 1411, near the water, having boulders of rock like itself; Kekequabic lake.
Ref. Annual Report, xvi, pages 103, 105, 125.

Meg. Green, but having lumps of harder rock.

Mic. This rock is like No. 1409 in nearly all respects. The hornblendes show the forms of the original augite grains in the existence of the darker central areas. The surrounding fine interlocking matrix shows variations of size of grain, indicating transformations from a more coarse feldspathic (though clastic) condition. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1413. Greenwacke.

The same, near the water.
Ref. Annual Report, xvi, pages 103, 105, 125.

Meg. With hard, lenticular sheets.

Mic. The section is cut perpendicular to the structure. The rock consists of the same elements as the above, but is banded by variations in fineness and by the occurrence of some fragments of feldspar in the coarser bands, which are not visible in the finer. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1414. Esterellyte.

Near the south side of sec. 35, T. 65-7. In a low bluff at the shore of Kekequabic lake.
Ref. Annual Report, xvi, pages 103, 125.

Meg. Different forms of porphyry.

Mic. Only one section has been made. The slide shows a rock identical with the porphyry at the narrows of the lake (No. 1094, etc.). The old *feldspars* are encroached on at their corners, and all about their margins, by the micro-granulitic quartz and feldspar, and in some cases the same substance appears within the feldspars. Some grains, indeed, are almost destroyed by such encroachment. These feldspars are not zoned, but much twinned. One part of the slide shows a rock not porphyritic, but largely hornblendic (with some globular *pyroxene ?*) with *biotite* and remnants of the old feldspars, being rather a quartz dioryte, but finer grained than that at the summit of the small island (No. 1410). One section.

Age. Archean (Keewatin). N. H. W.

No. 1415. Dioryte (*or amphibolyte*).

Same place as No. 1414.
Ref. Annual Report, xvi, pages 103, 125.

Meg. Underlying No. 1414; greenish, massive.

Mic. With much *hornblende*, some *œgyrine-augite* and a little *actinolite* is much feldspar, these together making up the rock, so that there is very little of the fine, granular, interlocking matrix seen in the greenwackes in general. The ægyrine is included in the feldspars and appears to have maintained its composition more easily in such position, since generally only hornblende is seen in the rock. One section.

Age. Archean (Keewatin).

Remark. If a granular disintegration should permeate the feldspars of this rock it would be like some of the green schists of the region, and especially if at the same time the ægyrine were all converted to hornblende. N. H. W.

No. 1416. Gneiss.

Same locality as No. 1414.
Ref. Annual Report, xvi, pages 103, 104, 125.

Meg. Reddish, porphyritic; intended to show the intergrading of the gneissic, the porphyritic and the conglomeritic characters of this rock.

Mic. The rock is mostly composed of ragged *feldspars* which are zoned, twinned, replaced by micro-granular new growths and reconstructed by secondary feldspathic material. The rock, therefore, is quite compact and firm. *Hornblende*, more or less changed to chlorite, comes next in amount. This runs in irregular, spreading streaks and strings, somewhat as in a schist, but not in a schistose uniformity of direction. It is accompanied by *magnetite* and by *actinolite*. *Epidote* is in scattered fine particles and *calcite* is quite common. Throughout the whole, and generally between and around the feldspars is more or less of the common micro-granulitic mosaic of *quartz* and *feldspar*. This varies in fineness. In some areas this structure alone fills the slide, and spreads in a band which runs with more or less distinctness from one side of the slide nearly to the other. This fine mesh is evidently due to a secondary development of later date than the deposit of the feldspars in the places they occupy, and indicates that a fine debris, largely feldspathic, has been entirely worked over and given this new crystalline condition, a structure, however, which did not much change the forms of the larger old feldspars. One section.

Age. Archean (modified Upper Keewatin). N. H. W.

No. 1417. Gneiss.

Shingwak island, north of Animikie island, Kekequabic lake.
Ref. Annual Report, xvi, pages 105, 125.

Meg. Rock appearing like No. 1416.

Mic. The description No. 1416 will apply to this rock. One section.

Age. Archean. N. H. W.

No. 1418. Gneiss.

Same island.
Ref. Annual Report, xvi, pages 105, 125.

Meg. The red crystals are in bands that alternate with others of a greenish biotitic rock.

Mic. Similar to No. 1417, except that the larger feldspars are more obscured and replaced by secondary, often micro-granulitic structure. One section.

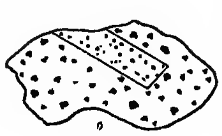
Age. Archean. N. H. W.

No. 1419. Greenwacke. *(Pebbly tuff.)*

From a very small island directly south of Shingwak island.
Ref. Annual Report, xvi, pages 105, 125.

Meg. Fine grained, greenish.

Mic. The most of the rock is constituted of a varying granulitic association, supposed to be in part of *quartz* and *feldspar*, but so fine that it is difficult in some cases to prove it. This variation consists in the coarseness and the fineness of this substance, and in the consequent degree of translucency which it presents. Sometimes this variation is caused principally by the presence in varying amount of a greenish coloring matter. This matter is composed of globular *epidote*, of *actinolite* fibres and of *chlorite*, and it is evenly distributed throughout any individual space, differing from space to space, but it is always accumulated about the borders of the spaces in distinctly greater amount, so as to outline the spaces and separate them one from the other. These spaces are evidently those formerly occupied by volcanic glass or by fragments of minerals such as feldspar and perhaps by some ferro-magnesian mineral. Their shapes can be seen best by using converging light and by lowering the condenser. Sometimes there is a remnant of the old feldspar still visible in the central part of a space, which indicates the nature of the original grain. If this be the nature of these variations, they may have been (in some cases foregoing) mistaken for pebbles of devitrified glass, but in general they do not appear to be derived from feldspars. Again, if this be their nature, or whatever their nature, it is to be explained how it happened that, scattered through the slide, there are still preserved crystal fragments both of hornblende and of feldspar that show no such change, some of the former of which have slight increments of later date. These are accompanied by quartz in rounded and angular form, evidently fragmental in its present place. Such an association as shown by figure 45 rather indicates that this was a pebbly rock. Here, in a roundish space, is an altered angular area, the two having different coarseness and different transparency. The crystal was ophitically embraced in the matter surrounding it, and both have suffered a micro-granulation or alteration of the same kind. Whether this took place in the present rock or in some rock from which both were derived is an important question. The existence of unchanged crystals in this rock points to some earlier state in which such change as the above was effected, and that by some agency the two were brought in a pebbly state, along with fresh crystal fragments, and were contributed to the formation of the present rock. This rock is illustrated by plate III, figure 1. One section.



1418.
FIG. 45.

Age. Archean (Upper Keewatin).

Remark. Material like the pebbly forms seen in this rock, but usually more broken and lost by friction and decay, is apparently quite commonly distributed amongst the clastic greenstones. N. H. W.

No. 1420. Gneiss.

West end of Animikie island, Kekequabic lake.
Ref. Annual Report, xvi, pages 105, 125.

Meg. Similar to Nos. 1417, 1418, 1419.

Mic. The largest feldspars are reconstructed by a microperthitic intergrowth of a fresh feldspar, which sometimes composes more than a half of the whole. The rock also contains more *calcite* and coarser *quartz* than the others. One section.

Age. Archean (modified Upper Keewatin). N. H. W.

No. 1421. Amphibolyte. (*Greenwacke.*)

Southwest end of Kekequabic lake; sec. 4, T. 64–7.
Ref. Annual Report, xvi, pages 105, 125.

Meg. Somewhat conglomeritic.

Mic. The most conspicuous feature is the abundance of *hornblende*, which is not only in distinct crystals, often showing its prismatic cleavages in basal sections, but in minute fibres scattered everywhere. The old feldspars are in remnants, in the main, from their original sizes, being eaten up by the prevalent alteration of the micro-granulitic substance mentioned in the description of No. 1419. In some cases a considerable portion of the feldspar substance remains and extinguishes uniformly. In other cases parts of it remain, contiguous, but extinguishing at slightly different angles, those parts being permeated at their borders by the same granulitic alteration, and in still other feldspars the entire crystal is sufficiently intact to show its form and its size, with complete and simultaneous extinction (though still varying in a shadowy manner). These most intact feldspars are still sprinkled throughout with *calcite*, *pyroxene* and *zoisite*, so that their albite twinning is scarcely visible.

The hornblendes are supplied with slight secondary growths. In some places they are bent, and certain branching ramifications, which enclose the large hornblendes, are composed of a yellowish and dirty granulated substance, which is apparently hornblendic and has resulted from a crushing of the hornblende crystals along their mutual contacts. These all lie, as in numerous other instances, in a very fine plexus of *feldspar*, *actinolite* and *quartz*, with a little *leucoxene* and *magnetite*, the amount of quartz being small and uncertain. One section.

Age. Archean (modified Upper Keewatin). N. H. W.

No. 1422. Gneiss.

From a small island south of the point, west part of sec. 3, T. 64–7, Kekequabic lake.
Ref. Annual Report, xvi, pages 105, 125.

Meg. Greenish, with sparsely disseminated red crystals.

Mic. There is much *calcite* in this rock. The old feldspars are very much permeated and replaced and zoned by secondary feldspars, and very much of the rest of the rock (aside from *calcite* and *actinolite*) is composed of a coarse reticulated mosaic of new feldspar (with little or no quartz). One section.

Age. Archean (modified Upper Keewatin). N. H. W.

No. 1423. Greenwacke. *(Knotty.)*

At the head of the bay, on the town line, west end of Kekequabic lake.
Ref. Annual Report, xvi, pages 106, 125.

Meg. Greenish, schistose conglomerate, apparently decayed.

Mic. This rock is similar to No. 1419, with the exception that all original parts are finer, and the distinctions all fade out to a more uniform rock, into which also is introduced much *calcite.* There is also a larger proportion of crystals, as compared with pebbles of glass. There appears to be also some *epidote*, and there is one remarkable group of crystals of iron ore which are black and apparently rhombohedric, like *ilmenite*, in accord with the presence of some *leucoxene.* One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1424. Greenwacke.

Same place as the last.
Ref. Annual Report, xvi, pages 106, 125.

Meg. Knotty projections in No. 1423.

Mic. In this section the structure and nearly the composition of No. 1423 are presented, but the old crystals are still larger and more abundant; the augite is converted to a *uralite*, preserving, however, the angular form of the augite. At the same time the feldspars are dim by the introduction of chlorite and *calcite* and by a general breaking down of the grains so that they do not show any enlargements nor any clear and unique extinction. Notwithstanding these deformities they are perfectly evident as feldspars. The surrounding fine matrix is almost entirely feldspathic; whether of fragmental debris or of secondary growth is not apparent. But amongst the coarser elements is occasionally an angular quartz. One section.

Age. Archean (Keewatin). N. H. W.

No. 1425. Diabase.

Dike on the north shore of the bay at the west end of Kekequabic lake; E. ½ S. W. ¼ sec. 34, T. 65–7 W.
Ref. Annual Report, xvi, pages 106, 125.

Meg. A rather fine-grained, fresh, black diabase. No section.

Age. Perhaps Cabotian. U. S. G.

No. 1426. Greenwacke.

S E. ¼ sec. 34, T. 64–7, near the head of the broad, shallow bay, Kekequabic lake.
Ref. Annual Report, xvi, pages 107, 125.

Meg. Geenish and fine grained, with evident hornblendes.

Mic. In the usual fine groundmass, largely of actinolitic and feldspathic materials, are *hornblendes* which, having the form of the augite in the porphyry, are evidently derived from that mineral by uralization. The rock contains no evident old feldspars. The hornblendes have secondary growths. One section.

Age. Archean (Keewatin). N. H. W.

No. 1427. Granite.

On the portage from Spoon lake northward.
Ref. Annual Report, xvi, page 125.

Meg. A drift piece showing the red rock cutting a biotitic gneiss. Must have come from some place further north or northeast.

Mic. The nature of the rock shows that it belongs with the Kekequabic lake series of granites. The supposed "vein" consists of a belt across the slide in which biotite is wanting, making it appear lighter colored and perhaps causing a redness on weathering. The whole rock is coarsely crystalline. Indeed the old feldspars are regenerated by new growths, and in many instances the clear new growths make up their principal portion. They embrace ophitically new *hornblendes, pyroxenes* and *biotite,* while the old ones are free (or almost free) from them, are much twinned, clouded and eaten into by the fresh quartz-feldspar granulitic (and granitic) groundmass. The old feldspars are abundant in the so-called vein, and the fresh growths are in the rock on either side. One section.

Age. Archean (Keewatin).

Remark. This is a rock, whatever its source, which must, however, be near its present place, which shows how the old feldspars and hornblendes, and the old micro-granulitic matrix are converted into a coarser, fresh, firm granite. What could have caused this but igneous contact? It indicates that further toward the northeast is probably an outcrop of such granite in the midst of the green schists, and if it has been correctly explained, there should be evidence of some sort of gabbro activity in the vicinity. N. H. W.

No. 1428. Graywacke. *(Slaty.)*

Southeast shore of Knife lake; the point which is near the centre of the east side of N. E. ¼ sec. 28, T. 65-7 W.
Ref. Annual Report, xvi, pages 109, 125; Annual Report, xvii, pages 200, 206.

Meg. Siliceous slate.

Mic. A fragmental rock, of *quartz* and old *feldspars* (the coarsest elements), *calcite* and a fine matrix of quartz, feldspar and *leucoxene.* One section.

Age. Archean (Keewatin). N. H. W.

No. 1436. Granite.

Sec. 10, T. 64-10, Bassimenan (Basswood) lake.
Ref. Annual Report, xvi, pages 110, 126; Annual Report, xvii, pages 200, 206.

Meg. Medium grained, granitic or gneissic.

Mic. This rock, in the same manner as No. 1427, is made up of old *feldspars* and new generations, with *biotite* and *hornblende*, all embraced in a coarse, granitic, interlocking, new generation of quartz and feldspar. The old feldspars are completely permeated by quartzes and by new-grown feldspar and are sometimes almost lost by the new invasion, but very frequently they remain as cloudy nuclei surrounded by fresh borders. There is also in the section a light-yellow *pyroxene* resembling epidote, but differs from epidote in not having the axial plane perpendicular to the main cleavage, but forming an angle of 30°± in the section exposed. This is probably *diopside*. This diopside is developed in a spreading, straggling manner, often in scattered small granules, in the midst of one of the old feldspars. One section.

Age. Archean granite.

Remark. Coming upon this rock after the details of the examination of the Kekequabic lake granite, the comparison is vivid and complete. It suggests the question whether all the Bassimenan lake granite is not of the same sort, a regeneration of clastics. As to the cause of that regeneration, it is not possible here to enquire. But that the process seen commenced in some of the graywackes or green schists and carried out to an imperfect degree in the granitic rocks about Kekequabic lake, is completed here in the Bassimenan lake granite (or gneiss), is as palpable as any petrogenetic process can be made. N. H. W.

No. 1437. Amphibolyte.

S. W. ¼ sec. 5, T. 64–10. Long peninsula in Bassimenan lake.
Ref. Annual Report, xvi, page 126.

Meg. Dark, micaceous and hornblendic.

Mic. *Hornblende*, much of it zoned by second growths is the chief coloring matter, but *biotite* is common, also *sphene*, which indeed is unusually common. The hornblendes are earlier than the *quartz* and than most of the *feldspar*, being idiomorphic toward all the rest and unbroken except by their own interference and by an occasional biotite. There are a few nuclei of the old feldspars still visible, but most of the feldspar and all of the quartz is of secondary granitic origin and structure. One section.

Age. Archean (Keewatin). N. H. W.

No. 1439. Amphibolyte. (*Greenstone.*)

Bluff on the right bank, just below the Pipestone rapids, southwest extremity of Bassimenan lake.
Ref. Annual Report, xvi, pages 111, 126.

Meg. Even-grained, schistose greenstone.

Mic. The *hornblendes* are rather small and prevailingly elongated in the same direction. It is green or bluish-green with variation to yellowish on rotation.

Sphene is rather common mainly in the form of irregular groups of small globules or grains, but occasionally in isolated crystals. These groups have an elongation parallel with the hornblendes. With an occasional large *quartz* the foregoing constitute the colored elements. These elements lie in an interlocking fine network which is in the main feldspathic, but somewhat quartzose, wholly of fresh and secondary date, the *quartz* sometimes becoming coarser and forming nests of interlocking grains from which feldspar is wholly excluded. There is occasionally a trace of an older feldspar, shown by its decayed state. This network of quartz and feldspar is also interlocked in the margins of the hornblendes and encloses innumerable small hornblende shreds. The hornblendic fragments here differ noticeably from those at Kekequabic lake. They are not sharp nor idiomorphically crystalline, but rounded at their extremities. They do not show crystal boundaries, but appear to be shreds or remnants (though fresh still) of hornblendes left after some destroying action had passed over them, without any secondary growths. They surround the sphenes and they sometimes embrace feldspar grains. They probably originated about cotemporary with the surrounding network. One section.

Age. Archean (Keewatin). N. H. W.

No. 1440. Chlorite Schist. *(Greenstone.)*

From the same bluff as No. 1439.
Ref. Annual Report, xvi, pages 111, 126.

Meg. Very fine grained.

Mic. The rock embraces the same elements in about the same structure as No. 1439, but all much finer, and in place of sphene is a dark colored *leucoxene.* There is also a much greater proportionate amount of decayed *feldspar*, which is accompanied by the generation of considerable *calcite* and by needles and scales of muscovite (?). Throughout the slide there is also much isotropic chloritic(?) substance. Indeed the green element which takes the place of hornblende is in the main in this condition. One section.

Age. Archean (Keewatin). N. H. W.

No. 1441. Granite.

Cuts Nos. 1439 and 1440.
Ref. Annual Report, xvi, pages 111, 126.

Meg. Chloritic granite.

Mic. The structure is granitic, with *quartz*, *orthoclase* and *microcline.* The small amount of *chlorite* and of *hornblende* is hardly worthy of notice in giving name to the rock. The feldspars (except the microcline) are not much altered, though interspersed with fine *calcite* and *muscovite.* In the rock is a large percentage of quartz. One section.

Age. Archean. N. H. W.

No. 1444. Greenwacke.

Head of the portage from Fall lake to Garden lake. Replaces abruptly the jaspilyte at the head of the portage.
Ref. Annual Report, xvi, pages 111, 126.

Meg. Greenstone.

Mic. *Hornblende* in sharp, angular shreds and spicules, with secondary enlargements, and decayed *feldspars*. These seem to make up this rock, which has not a distinct schistose structure. The appearance of the hornblende is in contrast with that of No. 1439. Its spicules are sharp and fine, and twinning is not uncommon. At the same time the crystals are ragged and defective, even the zonal enlargements, and the sharp spicules. *Chlorite* and some of the old feldspathic element are within them in irregular spaces. The feldspar grains are all small, roundish and much decayed, having *chlorite* and apparently minute scales of *muscovite* and of actinolite, generated as secondary products. Still they are bound together in an interlocking plexus of secondary fresh feldspar. That the hornblende was a product of alteration from *pyroxene* is indicated by the remnants of that mineral still visible within the larger hornblendes. A little *leucoxene* is disseminated in rather dark coarse groups. One section.

Age. Archean (Keewatin). N. H. W.

No. 1446. Quartz Schist. *(Magnetic.)*

At the rapids between Garden and White Iron lakes (once known as Silver City).
Ref. Annual Report, xvi, pages 112, 126; Bulletin vi, pages 8, 10, and plate V, figure 3. (Compare Nos. 950 and 951.)

Meg. Thin-bedded magnetic quartz schist.

Mic. Two sections have been made, and the description of Hensoldt was made from them. They were very thick. On reducing one of them to the standard thickness the parts all become more distinct. *Magnetite* is seen to be distributed not only in somewhat regular bands, intermixed with quartz, but in finer particles is everywhere throughout the slide. The *quartz* is wholly of the secondary, interlocking kind, and its grains are somewhat elongated prevailingly in the direction of the structure. These two, with *actinolite*, constitute the rock. If there be any glassy, fresh feldspar it is masked by its resemblance to the quartz, and none has been detected. The actinolite is in fine detached needles or fibres parallel with the structure. Two sections.

Age. Keewatin (recrystallized). N. H. W.

No. 1448. Greenwacke.

N. W. ¼ sec. 4, T. 62–14. At a fresh drilling for iron, north of Mud lake.
Ref. Annual Report, xvi, pages 112, 126.

Meg. Fine-grained, characterless greenstone.

Mic. The rock consists plainly of a fine debris of basic eruptive materials, in which, with much decay, has been a generation of much *calcite* and some fresh *feldspar*. It is much dimmed by *chlorite* and *leucoxene*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1449. Kaolin (?)

Stone mine at Soudan.
Ref. Annual Report, xvi, page 126; Annual Report, xix, pages 125, 127; Bulletin vi, pages 37, 422.

Meg. A soft, greasy-feeling substance, white or greenish and pinkish white in color. It is a much disintegrated schist.

An analysis of this material is as follows:

SiO_2	60.05
Al_2O_3	27.55
Fe_2O_3	1.30
CaO	.38
MgO	.77
Na_2O	.31
K_2O	4.26
P_2O_5	.11
H_2O	5.30
Total,	100.03

This would perhaps indicate kaolin mixed with some undecomposed orthoclase. No section.

Age. Archean (Keewatin). U. S. G.

No. 1450. Greenwacke. *(Graywacke.)*

Cut by the Tower spur track from the mines.
Ref. Annual Report, xvi, pages 113, 126.

Meg. Light colored, greenish, siliceous, mainly massive.

Mic. The rock has, microscopically, a decidedly schistose structure. It consists of the usual ingredients of graywacke, but finer than is usual in graywackes. It has a few spicules of *actinolite*, a little *calcite* and apparently a considerable zoisite, the last generally in fine grains, giving its characteristic very low polarization colors, but serving to give a light color to the rock, and by its high refractive index obscurity to the slide between the nicols. One section.

Age. Archean (Keewatin). N. H. W.

No. 1451. Jaspilyte.

Sec. 2, T. 61–15 W. Southeast from Tower, five miles.
Ref. Annual Report, xvi, pages 113, 126.

Meg. White and black-banded jaspilyte, the black bands being only in part of magnetite. A little pyrite is present. No section.

Age. Archean (Keewatin). U. S. G.

No. 1452. Graphite and Pyrite.

Same locality as No. 1451.
Ref. Annual Report, xvi, pages 113, 126.

Meg. A rough, apparently brecciated, rock composed largely of pyrite and a black substance which is in part graphite. No section.

Age. Archean (Keewatin). U. S. G.

No. 1453. Magnetite-Tremolite Schist.

Black River Falls, Wisconsin. Associated with magnetic ore of the York opening in the Tilden mound.
Ref. Annual Report, xvi, page 126.

Meg. Magnetite mingled with short, gray fibres.

Mic. The amphibole is colorless, has positive elongation and n_p in the acute angle of the axial plane. Its colorlessness and high double refraction with maximum extinction at 16° are the only known characters which necessitate the name tremolite instead of actinolite. With a little *calcite* and much magnetite the rock is rendered nearly black in hand sample. Three sections.

Age. Taconic(?) N. H. W.

No. 1454. Hornblende. *(Fibrous.)*

Same place as the last.
Ref. Annual Report, xvi, page 127.

Meg. The strongly, long-fibrous mass is faintly green, and presents a fold across the fibres.

Mic. The maximum extinction angle is 22°. The bisectrix (n_p) is in the acute angle of the axial plane, and lies oblique to the fibration, the optic plane being parallel with the fibration. These characters, with the faint pleochroism, make this to be common hornblende. One section.

Age. Taconic(?) N. H. W.

No. 1456 (?) Pyroxenyte.

Black River Falls, Wisconsin. Near the river, and near the granite. Just southwest from the so-called Tilden mound.
Ref. Annual Report, xvi, page 127.

Meg. The "bedding" is about vertical, and curiously twisted and curled.

Mic. The rock consists almost solely of *pyroxene*, having a few crystals of *sphene* and a few accessory small grains of *quartz*. One section.

Age. Archean (Keewatin?).

Remark. This rock differs so widely from the field description and from the preserved hand sample (Sixteenth Annual Report, page 127), that it appears there is some error in the notation. The preserved hand sample is a fine, siliceous, jaspilitic rock. N. H. W.

[NOTE. Nos. 1457 to 1500, inclusive, were collected north of Gunflint lake, outside of Minnesota territory, and there are no sections of them. They are not here described, but brief field notes concerning them can be found in the Sixteenth Annual Report, pages 75, 76, 127-129.]

NO. 1501. QUARTZ, PYRITE, ETC. *(Vein material.)*

West side of East Eagle Nest lake; N. E. ¼ N. E. ¼ sec. 34, T. 62-14 W.
Ref Annual Report, xviii, pages 13, 21, 59; Annual Report, xix, pages 125, 127; see, also, Annual Report, xv, pages 32 33.

Meg. Vein material composed largely of quartz, with considerable pyrite, some calcite and also apparently chalcopyrite. An assay was made of this specimen for gold and silver. A trace of gold was found, but no silver. No section.

Age. Archean (Keewatin). U. S. G.

NO. 1502. QUARTZ.

At the mines at Tower. Embraced in considerable masses in immediate proximity to the so-called chalcedonic silica in the green schist.
Ref. Annual Report, xviii, page 59.

Meg. Vitreous quartz.

Mic. The individual orientations extend parallel (roughly) with each other, showing a coarse fibrous structure. Each individual is united to its neighbors by a granular border, each extending into the other, as evinced by the orientations; at the same time a shadowy extinction goes over each grain. One section.

Age. Archean (Keewatin). N. H. W.

NO. 1503. QUARTZ.

Vein one-half inch wide, running transverse to the green schist at Tower.

Meg. Granular.

Mic. This has not the fineness of the jaspilitic silica, although it interlocks in the same way. The size, however, of the grains varies, some being not more than a hundredth part the size of others. One section.

Age. Archean (Keewatin). N. H. W.

NO. 1508. BLACK SCHIST *(with pyrite nodules).*

From pits north of Chester peak, near Soudan.
Ref. Annual Report, xviii, pages 11, 59.

Meg. Dark, heavy schist, which is apparently carbonaceous. In the schist is scattered some pyrite and there are also pyrite nodules, elongated and spherical. The largest spherical nodule of pyrite in the specimens collected is two and a quarter inches in diameter. It has a central mass half an inch in diameter, of granular pyrite, and the rest of the nodule is made of pyrite radiating out from this mass. In another nodule the centre is about an inch in diameter, and the radiating border only a quarter of an inch in thickness. No section.

Age. Archean (Keewatin). U. S. G.

No. 1509. QUARTZ. (*Chalcedonic veins.*)

In the jaspilyte on the top of Chester peak, near Soudan.
Ref. Annual Report, xviii, pages 11, 59.

Meg. Small, white veins, apparently of the same constitution as white jaspilyte, cross red jaspilyte. No section.

Age. Archean (Keewatin). U. S. G.

No. 1510. AGGLOMERATE. (*Basic.*)

Ely. From the agglomerate at the railroad cut.
Ref. Annual Report, xviii, pages 13, 59; American Geologist, vol. ix, pages 359–368. Compare Nos. 1624 and 1625.

Meg. Collected so as to show the forms of two boulders and the darker green rock separating them.

Mic. One section is from the interior of one of the boulder forms, and the other from the edge of the rounded mass. That from the interior shows a fine diabasic structure in the arrangement of the minute chloritic *feldspars*, which are radially arranged, for the most part, but are in other places grouped in a somewhat parallel arrangement. They are much altered, but reveal a fine albite twinning without distinct terminations. The surrounding material is dimmed by much alteration, but occasionally a grain of *pyroxene* is seen in the mass. It also contains *calcite*, *leucoxene*, and apparently a few *hornblendes* and some traces of a secondary feldspar.

The other section is completely altered. It shows no diabasic structure. The distribution of *leucoxene* is the most marked regular feature. At one side of the slide it is in annular groups and roundish nests of about uniform size. By degrees, departing from this part of the slide, these become larger, but thinner, and so dispersed at last that on breaking up they spread more and more diffusely, coalesce and cause a general dissemination of leucoxene throughout the slide. The most concentrated portion of this leucoxene is associated with a micro-granulitic generation of secondary (?) *feldspars*. These little grains do not interlock; indeed, they are entirely isolated and free from each other and may represent a feldspathic sand. In the midst of them are also a few *pyroxene(?)* grains. Suddenly appears, in the midst of this structure, a rectangular network of bright spicules whose individual cross-sections with the highest power have about the thickness (apparent) of the spider lines, and also have parallel extinction. They are too fine to be determined, but appear to be of *actinolite*. The rest of the slide appears to consist of a uniform granular mixture of all these parts with a preponderance of the feldspathic elements—all in a state of fine comminution, resolvable only in bright light by the high-power objective. Two sections.

Age. Archean (Keewatin).

Remark. This agglomerate extends widely southwestwardly from this locality. It has been discussed in the American Geologist (volume ix, pages 359–368), where it was supposed to be of early volcanic origin, the rounded masses having the nature of bombs, buried in the cotemporary pulpy product of trituration of basic ash and debris. This view as to the nature of the fine material separating the bombs is sustained by the general composition of the second slide above described. Examined with a low-power objective its aspect is that of a devitrified basic glass, which originally existed in the form of a sand, much resembling the rock No. 1419 (plate III, figure 1), and is illustrated by the photograph reproduced in plate III, figure 2. N. H. W.

No. 1511. Agglomerate. *(Basic.)*

From the greenstone agglomerate at the railroad cut, Ely. Taken from the "amygdaloidal" portions of some of the bombs.
Ref. Annual Report, xviii, pages 13, 59.

Meg. The tubes are filled with *calcite* and are at the circumferences of the bombs, penetrating from one-fourth of an inch to two inches from the interior surface radially toward the centre. Their diameter is about one-fourth of an inch and less.

Mic. The section does not show any of the tubes, but some large areas of *calcite.* The rock in general, seen in common light, is sprinkled rather uniformly with fine nests of *leucoxene*, but this element also appears in minute veinlets. In the groundmass, which is chloritic and rather dark, are minute microliths of *feldspar(?)* twinned on the albite plan, which, with a considerable decay, have apparently been extended right and left by secondary feldspathic growths so as to govern extinction on either side, and such microliths, as well as their enlargements, are frequently seen to present a stellar and radiated structure, extinguishing with an imperfect, constant black cross as they are rotated. It might perhaps be more reasonable to assume that this feldspathic element is altogether original, and that the crystals were concentrated from a magma, but have since decayed. This would be in keeping with their general appearance of alteration, and with the indefiniteness which characterizes the limits of their extension into the surrounding mass. Some *pyroxene* is seen, and in a single instance it is distinctly ophitic toward the feldspars. One section.

Age. Archean (Keewatin). N. H. W.

No. 1514. Granite.

Hinsdale stone quarry, *i. e.*, in the Giant's range at the crossing of the Duluth and Iron Range railway.
Ref. Annual Report, xviii, page 59.

Meg. The hand samples show two kinds of granite welded together in a distinct contact. One is quite coarse grained and the other is very much finer grained. The section was made from the coarser granite.

Mic. The rock is characterized by much *quartz* in large grains interlocking in the manner of the granitic and granulitic quartzes of Kekequabic lake. The feldspars are *orthoclase, oligoclase* and *microcline.* The former two are partly fresh and partly much altered, the altered portions being as a rule at the centres of the crystals. The interlocking border is nearly always composed of fresh feldspar. The microcline is wholly fresh and interlocking. *Sphene* and *apatite* are in distinct characteristic crystals. *Hornblende* and *biotite* compose an inferior portion of the rock. One section.

Age. Archean granite.

Remark. In the foregoing slide can be seen several instances of hornblende entirely included within the old feldspars, having the short, stout habit of the augites seen in the feldspars of the Kekequabic lake esterellyte, but in general the hornblende is elongated, and is distinctly associated with the later growths. N. H. W.

No. 1515. Granite.

North Redwood P. O., near Redwood Falls; Minnesota river.
Ref. Annual Report, xviii, page 59.

Meg. Massive, gray, uniform, without bands of color, but having a gneissic elongation of the crystals.

Mic. There is much of the old feldspathic element in this rock, and though filled with impurities it shows in some instances its albite twinning. The most of the rock still consists of fresh *quartz, microcline,* micropegmatyte and of *sphene,* with some *biotite* and *brown hornblende.* One section.

Age. Archean. N. H. W.

No. 1516. Gneiss.

Same place as No. 1515.
Ref. Annual Report, xviii, page 60.

Meg. Gray, with alternating and intershading of micaceous and feldspathic belts.

Mic. The section is made transverse to the banding, but the structure is not apparent in the slide. The rock is similar to the last, except that the contrast between decayed and undecayed feldspar is not so marked. There is a small amount of what may be considered an old feldspar, but the whole rock appears to have suffered a second incipient alteration. Even the fresh microclines are dimmed by it. *Biotite* and *sphene* as in the last, with a grain of *garnet.* One section.

Age. Archean. N. H. W.

No. 1518. Gneiss.

Morton quarries, Morton, Minnesota valley.
Ref. Annual Report, xviii, page 60.

Meg. Gneissic, with much red orthoclase.

Mic. *Orthoclase, oligoclase, microcline, quartz,* essentially compose this rock. The feldspar grains are all affected uniformly by a later process of decay which has given rise within them to scattered scales of *calcite* and *muscovite.* There are areas and grains included within the larger feldspars which show much more decay than the rest, but there is no marked general separation either in position or in stage of alteration between the fresh feldspar and the old. One section.

Age. Archean. N. H. W.

No. 1519. Hornblende Biotite Gneiss.

Morton quarries. From a dark, nearly black, inclusion in the body of the rock.
Ref. Annual Report, xviii, pages 24, 60.

Meg. Medium grained, micaceous.

Mic. *Hornblende* and *biotite* give the dark color to the rock. The rock is very fresh and clean. The feldspars are conspicuously twinned on the albite and pericline plans and occasionally zoned, but they contain frequently central cores so much altered that the twinning bands are destroyed. The twinning striations do not continue through the new zonal growths. In such cases it is possible that the fresh portion is a secondary growth about an old decayed crystal. But very little *quartz* is seen. One section.

Age. Archean. N. H. W.

No. 1521. Quartzyte.

Pokegama falls, Mississippi river, Itasca county.
Ref. Annual Report, xviii, page 60.

Meg. Gray, granular. (Compare Nos. 1525A, 1526 and 257H–259H.)

Mic. The grains have been enlarged by interstitial growths, forming a solid quartzyte. The grains almost without exception are loosely charged with minute acicular trichiths which are only visible when the quartz is extinct and in high power; they also extinguish parallel with the threads. If these be not due to an accidental impurity in the balsam, they are a feature of quartz not before noticed in the state. One section.

Age. Pokegama (bottom of the Animikie). N. H. W.

No. 1525(a). Quartzyte.

Pokegama falls.
Ref. Annual Report, xviii, page 60.

Meg. Spottedness shown in the quartzyte. One of the spots was in the centre of the chip from which the section was made.

Mic. There is nothing in the appearance of the slide which will explain the spottedness unless it be a greater amount of dirty impurities which seems to prevail irregularly in the *quartz* in certain places. This slide shows a small amount of *microcline(?)* and apparently a small amount of another feldspar, and also a grain of colorless *tourmaline*, which seems to be of secondary origin, since it surrounds several small quartz grains. This tourmaline has a yellow or orange color of double refraction, and a strong polychroism, darker when it agrees with the horizontal thread. It has n_p in agreement with its elongation, and an imperfect cleavage parallel with the cross section. One section.

Age. Pokegama (bottom of the Animikie.) N. H. W.

No. 1526. QUARTZYTE.

Pokegama falls; same place as the last.
Ref. Annual Report, xviii, pages 15, 60.

Meg. Shows another spottedness. Here the rusty spots weather out and produce a pitted surface on the quartzyte in which the round surfaces of the grains are exhibited.

Mic. Between the rounded *quartz* grains is much of a substance which is isotropic, but transparent, clear and colorless, having some hematitic staining in the form of dirty particles, as well as some indefinite microliths. Occasionally some of this inter-granular, isotropic substance is replaced by, or at least charged with, coarser crystalliths which appear to be actinolite, or both actinolite and mica. Still more rarely a cleaved grain resembling feldspar is seen in the midst of the same substance. Sometimes a dim translucency between crossed nicols appears in small spots, denoting imperfect crystallization. This substance is so abundant sometimes that the rounded quartzes that lie in it do not come into contact. It everywhere acts as a filling which surrounds them. While in general the rock consists of coarse clastic quartz, there are roundish spots or areas where this substance prevails, and this is no doubt the cause of the megascopic spottedness mentioned. The microscopic aspect is seen in figure 3, plate III. There seems to be no way to interpret this structure other than to refer it to fine volcanic ash accumulated cotemporary with the formation of the rock.

If this be volcanic ash it is comparable with the similar phenomena seen at the eastern end of the Mesabi range in the vicinity of Gunflint lake, and with the volcanic phenomena reported on the Penokee range by Van Hise.* The trichiths mentioned in No. 1521 do not appear in this rock nor in No. 1525A. One section.

Age. Pokegama (bottom of the Animikie). N. H. W.

No. 1527. HEMATITE.

Prairie River falls, S. E. ¼ sec. 34, T. 56–25 W.
Ref. Annual Report, xviii, pages 15, 60; Bulletin vi, pages 120, 422.

* *Bulletin of the Geological Society of America*, vol. iv, p. 435, 1893.

Meg. Compact hematite in polygonal forms, like small basaltic columns an inch and a half in diameter. In places the hematite has the granular texture so common in taconyte. No section. See plate IV. This basaltic structure is transverse to the bedded structure of the rock.

Age. Animikie (iron-bearing member). U. S. G.

No. 1528. TACONYTE.

Prairie River falls; at the horizon of the iron ore.
Ref. Annual Report, xviii, pages 15, 60.

Meg. Siliceous, somewhat granular and iron bearing.

Mic. The different individual round grains are in different degrees of internal fineness and have different amounts of hematite. In some the ore is magnetite, and in others hematite, and in others partly limonite. In some grains is no iron ore. The rock is completely silicified at the present time, making a very hard, compact mass. The ultimate granular structure varies from coarse jaspilitic quartz to "flint," and apparently to glass and devitrified glass. The constituent large grains of which the rock is composed do not differ from the usual rounded taconitic grains, but exhibit a remarkable difference of internal structure. One section.

Age. Pokegama (at the top of the quartzyte). N. H. W.

No. 1529. JASPILYTE.

Same place as Nos. 1527 and 1528, but somewhat above No. 1528.
Ref. Annual Report, xviii, pages 15, 60; Bulletin vi, pages 115, 422.

Meg. Peculiar "streamed" or interleaved and brecciated, white, red and black jaspilyte. In some places coarsely crystallized quartz is present. No section.

Age. Animikie (iron-bearing member). U. S. G.

No. 1530. TACONYTE.

Prairie River falls; at the horizon of the iron ore. (Compare No. 1294.)
Ref. Annual Report, xviii, pages 15, 60; Bulletin vi, pages 115, 120, 422.

Meg. Jaspilyte and hematite, closely intermixed, but not interlaminated, presenting an oölitic aspect.

Mic. There is a concentric fine layering that forms the periphery of most of the compound or taconitic grains, same as seen in No. 1294, but in some cases this layering is wanting on one side of a certain grain, and in others it appears to cross the central part and again to be enclosed in a later layering unconformable with that of the central part. From this it can be inferred that these pebbles had this structure prior to their being incorporated in this rock. They are made up of finer grains of interlocking or jaspilitic quartz than that which lies between them. The iron is not abundant, only serving to give a ferriferous tone to the rock. One section.

Age. Pokegama (top of the quartzyte).

Remark. Nos. 1530 and 1294, from opposite ends of the known Mesabi Iron range, are remarkable phases of the taconyte, and are alike in their remarkable characters. Several photographs are shown on plate III, viz.: figure 4 from No. 1294, shows the general oolitic structure in its best condition; figure 5, from the same rock, shows the same when permeated and almost lost by the accumulation of iron ore; figure 6, from No. 1294, shows the amorphous nucleus which, having been once surrounded by the oolitic concentric bands, was broken and again surrounded by similar concentric bands non-conformable with the former. Such irregularities are common and show that this structure did not grow up within this rock since consolidation, but pertained to these grains prior to their lodgment in this mass. Figure 7, from No. 1294, shows the non-conformity of the nuclei with the encircling bands, proving the earlier existence of the nuclei. This figure shows, also, an irregular streamed structure in the nuclei and a passage of this into the conspicuous peripheral banding. This, with other similar gradations from one to the other, indicates that the internal structure of the nuclei, although usually amorphous, might sometimes assume an imperfect banding, having perhaps the same origin. Figure 8, from No. 1530, shows the general aspect. At the centre of the photograph is a grain which is shown magnified in figure 9. In this grain the nucleus is different from any other seen in either No. 1294 or No. 1530. It is distinctly a fragmental compound nucleus. It embraces eleven main parts, and three of them are of angular apparently earlier quartz, the others being of flint (or devitrified glass) and of coarser interlocking taconitic quartz of varying size of grain. This shows that the "taconitic" structure of the rock taconyte, so far as it involves the fine interlocking quartz, sometimes was formed before the rock taconyte, as now ordinarily known, was deposited; and therefore, that within the individual, rounded, pebbly grains of the taconyte, the interlocking quartz may have developed earlier than in the mass of the taconyte, and may have been in each pebbly grain dependent on a primordial condition of the pebble itself. This different development of the interlocking quartzes, in the different rounded pebbles, even in the pebbles of the nucleus shown in figure 9, may not, however, have been due to difference of time, but the general silicification may have been all simultaneous throughout the rock, and the varying grain of the interlocking quartz may then have been due to this primordial difference of the original pebbly masses. Figure 10, from No. 1530, shows the encircling bands about an amorphous but ferruginated nucleus, broken and displaced. This also shows that these encircling bands were formed before the pebbles acquired their present positions. Some of the pebbles cracked irregularly, apparently by shrinkage, after the formation of the encircling bands, and in some cases they seem to have separated permanently into angular pieces which again were encircled by the same kind of bands. This shrinkage is also shown in figure 10. Some of the pebbles are but scantily furnished with the encircling bands. In those cases the nuclei are not distinctly amorphous, but are finely granular and ultra-microscopically crystalline like "flint" or devitrified glass. Yet some of these also appear to have had, and to have lost, such encircling bands. In such flinty pebbles the hematite of the rock is distributed as a crystalline powder, greatly in contrast with the hematitic blotches and opaque nuclei of the other pebbles. In some cases, however, these contrasts appear in the same pebble, showing that whatever was the nature and origin of one was also the nature and origin of the other.

It is impossible to say that there are any other minerals than quartz and hematite in these slides. The former, in an interlocking mosaic, fills all the spaces between these oölitic pebbles, penetrates within the bands, and into the nuclei. In the bands it embraces the hematitic powder and extinguishes in the "patchy" manner of apobsidian. In the nuclei it variously mingles with the hematite, but sometimes it forms microscopic spheruliths whose rays, having a mass of hematite at the centre, are of negative elongation, and hence appear to be of chalcedony. This negative character cannot be affirmed of the interlocking quartz in general, although it has frequently been designated chalcedonic quartz; with one nicol it shows a faint absorption or pleochroism.

It seems impossible to explain these taconitic pebbles except by assuming that they were originally volcanic ash or sand. Compare Part III for further considerations. Compare No. 1630A. N. H. W.

No. 1532. Conglomerate.

Same locality as No. 1527. Underlies the ore.
Ref. Annual Report, xviii, pages 15, 60.

Meg. The matrix of the conglomerate is a coarse, gray, granular quartzyte. The pebbles are small, rarely over half an inch in diameter. They are of quartz (largely), dark, fine-grained schist or argillyte, greenstone and red hematitic rock. No section.

Age. Animikie (Pokegama quartzyte member). U. S. G.

No. 1537. Hematite.

N. W. ¼ N. W. ¼ sec. 21, T. 56–24 W.
Ref. Annual Report, xviii, pages 18, 60.*

Meg. A red, slaty, impure hematite, more or less granular like taconyte. Gives forty-seven per cent of metallic iron. No section.

Age. Animikie (iron-bearing member). U. S. G.

*On page 60 the locality is, by a typographical mistake, given as T. 56–14 instead of T. 56–24.

No. 1541. Granite and Diabase. *(Contact specimen.)*

Duluth. On the Weller road, so-called, one and one-half miles from lake Superior, but about two miles from the business part of Duluth.
Ref. Annual Report, xviii, pages 26, 61.

Meg. A specimen showing the contact of Nos. 1540 and 1542. The two rocks are closely welded together; the contact plane is sharp and distinct and there is practically no blending of the two rocks, but the dark rock (No. 1540) has some reddish feldspar in it. Neither of the rocks is particularly finer grained at the contact. No section.

Age. Cabotian. U. S. G.

No. 1542. Granite. *(Red.)*

Duluth. On the Weller road (formerly so-called), now Piedmont avenue, at about two miles from the business part of the city.
Ref. Annual Report, xviii, pages 26, 61.

Meg. Crystalline, red, with some light-green spots.

Mic. The red, striated *feldspars* are surrounded by *quartz* which has also in some cases insinuated itself into the feldspars in a micropegmatitic manner. The latter are zoned by differing shades of hematitic redness. There is (or was) a little green *hornblende,* but it is largely chloritized. About these hornblendic spots can be seen remnants of *pyroxene* in isolated areas and grains. One section.

Age. Cabotian.

Remark. The rock appears to have been at first a part of the gabbro, but is now much altered by its contact on the clastics. N. H. W.

No. 1544. Calcite, Laumontite. *(Vein material.)*

From a vein in the gabbro at Rice's point, Duluth.
Ref. Annual Report, xviii, page 61.

Meg. A roughly banded vein, an inch to an inch and a half in thickness, composed of calcite and laumontite, with some serpentine-like material on the surfaces. No section.

Age. Vein in Cabotian rocks. U. S. G.

No. 1545. Serpentine.

In a vein in the gabbro at Rice's point, Duluth.
Ref. Annual Report, xviii, page 61.

Meg. Fine, yellowish.

Mic. The nearly isotropic substance shows a cloudiness distributed characteristically of serpentine, in which are the remnants of some highly polarizing ferromagnesian minerals *(pyroxene?)*, and occasionally of a twinned *feldspar*, with disseminated *calcite*. One section.

Age. Cabotian. N. H. W.

No. 1547. Jaspilyte.

Lee mine, Tower.
Ref. Annual Report, xviii, pages 28, 30, 39, 61; Bulletin vi, pages 59, 422.

Meg. Reddish, earthy-looking, with pyrite.

Mic. There is some variation in the fineness of grain, there being some roundish and irregular areas much finer than the rest, suggesting a confused mechanical manner of accumulation. The "earthy" appearance is due apparently to the presence of a considerable *chlorite.* This completely fills some small areas, and is finely disseminated generally. Iron is in the form of *hematite, magnetite* and *pyrite.* One section.

Age. Archean (Keewatin). N. H. W.

No. 1549. Breccia.

Lee mine, Tower.
Ref. Annual Report, xviii, pages 29, 61.

Meg. A brecciated mass, cemented by quartz. Composed of quartz and hematite, with some copper sulphide, probably both bornite and chalcopyrite; also a little azurite. No section.

Age. Archean (Keewatin). U. S. G.

No. 1550. Jaspilyte.

Lee mine, Tower.
Ref. Annual Report, xviii, pages 29, 61.

Meg. Pinkish, finely-banded jaspilyte, with some magnetite and red jaspilyte. No section.

Age. Archean (Keewatin). U. S. G.

No. 1557. Graywacke.

Tower; at the railroad, just south of the Tower mine (Nos. 8 and 9).
Ref. Annual Report, xviii, pages 42, 61; Bulletin vi, pages 37, 44, 46, 422.

Meg. Light-colored graywacke, greenish white, with distinct grains of quartz; dips N. 75° to 80°.

Mic. The large *quartzes* are in a matrix of finer quartz, *calcite, sericite* and interlocking micro-granulitic quartz, the last evidently occupying places once filled by fragments of some feldspar crystal. The quartzes show slight shadowy extinction. One section.

Age. Archean (Keewatin).

Remark. This rock was originally a coarsely-fragmental accumulation of quartz and feldspars, like some of the green schists about Kekequabic lake, but by the exigencies of geological time the feldspars have been lost. N. H. W.

No. 1559. Jaspilyte.

Stone mine, Tower, at the railroad cut.
Ref. Annual Report, xviii, page 61.

Meg. Interbedded in No. 1558, *i. e.*, in the green schist of the region.

Mic. Insinuated amongst the quartzes and the grains of ore, and sometimes extending sparsely throughout the rock, as seen in the slide, are shreds of green *hornblende*, the element of the green schists, having a uniform elongation, and plainly being a portion of the schists cotemporary with the jaspilyte. The *quartz* is finely granular and interlocking, varying in fineness from band to band.

The most interesting portion of the slide is the *siderite*, which not only is in fine grains, but in two instances is in crystals of considerable size in which are included both quartz and iron ore grains. One section.

Age. Archean (Keewatin).

Remark. The fact that the siderite, which has been taken to be the source of the iron ore of the Vermilion range, surrounds both the ore and the quartz, shows that it is the latest of the elements to take its place, instead of being the first, and the source of the ore. It is related to the oxides of iron and of silicium as augite is related to labradorite in the well-known ophitic structure of diabase. N. H. W.

No. 1560. Jaspilyte. *(Disintegrated.)*

Dump of the Stone mine.
Ref. Annual Report, xviii, page 61.

Meg. Loose white quartz, a naturally disintegrated jaspilyte.

Mic. The fineness varies; the grains are all angular. One preparation.

Age. Archean (Keewatin). N. H. W.

No. 1561. Breccia.

Dump of the Stone mine, Soudan.
Ref. Annual Report, xviii, page 61.

Meg. A beautiful breccia of jaspilyte and hematite cemented by quartz. The quartz is commonly coarse grained like ordinary vein quartz, but in places approaches the fineness of the jaspilyte quartz. In spots the quartz has not entirely filled the spaces between the rock fragments, thus leaving cavities into which quartz crystals project. No section.

Age. Archean (Keewatin). U. S. G.

No. 1563. Breccia.

Dump at the scram southwest of the Breitung mine, Soudan.
Ref. Annual Report, xviii, page 61; Bulletin vi, pages 51, 422.

Meg. Rough green schist, apparently brecciated, and more or less iron stained. There is considerable of a mineral with a mica-like cleavage, quite soft, but the cleavage lamellæ are not elastic. No section.

Age. Archean (Keewatin). U. S. G.

No. 1564. Hematite and Limonite.

Same place as No. 1563.
Ref. Annual Report, xviii, pages 34, 36.

Meg. "There is in this ore belt, besides, a considerable amount of limonite, some of it in botryoidal surfaces on quartz crystals, and on hematite (No. 1564). The limonite sometimes is further covered with a thin blue coat, and in some cases, especially in the vicinity of pyrite, there is a surface of coxcomb crystals, like hematite, covered with black, which last possibly is manganese." No section.

Age. Archean (Keewatin). U. S. G.

No. 1565. Jaspilyte. *(Gray.)*

Dump of the scram, southwest of the Breitung mine.
Ref. Annual Report, xviii, pages 34, 62; Bulletin vi, pages 77, 78, 422, plate VIII, figure 2.

Meg. Flinty, gray to dark-gray jaspilyte.

Mic. This is a "cherty iron carbonate," so called, supposed by some to be the primal nature and source of the iron ore of the district. It consists essentially of interlocking secondary *quartz*, but irregular multiple grains of *siderite*, sometimes of rhomboidal shape, are mingled with it. There is also a finer dust of hematite, but this plays a very unimportant part. This dust is embraced in the quartz and in the siderite, and occasionally a quartz is surrounded by the siderite. One section.

Age. Archean (Keewatin). N. H. W.

No. 1567. Jaspilyte *(with coarse quartz)*.

Breitung mine, Tower, in a ridge separating this mine from the old Tower mine.
Ref. Annual Report, xviii, pages 35, 62.

Meg. Pebbly, with vitreous but angular quartz, appearing detrital.

Mic. The *quartz* is quite different from that which forms the jaspilyte at large, being in large grains of single orientation, though having a shadowy extinction, and evidently enlarged by new quartz. It all seems to be crowded by lines of inclusions, whether old or new, and also is penetrated about the margins by minute crystals of hematite, making it appear to be of later date than the hematite. These quartzes lie in hematite. One section.

Age. Archean. N. H. W.

No. 1568. Jaspilyte.

From the cut made for the high tunnel running south from the Tower mine where it crosses the light "ore streak."
Ref. Annual Report, xviii, pages 40, 62; Bulletin vi, pages 59, 60, 76, 422.

Meg. The egg-shaped mass was entirely enclosed and isolated in the schists. It showed somewhat peripherally concentric color bands, rather indistinct and broad, hardly comparable with the banding of the jaspilyte and iron.

Mic. There is nothing noteworthy different from the normal jaspilyte of the region. It is a uniform mass of fine, interlocking *quartz* grains, with scattering grains of *hematite*. One section.

Age. Archean (Keewatin). N. H. W.

No. 1571. Jaspilyte. (*Greenish.*)

Banded in the jaspilyte north of the Tower mine.
Ref. Annual Report, xviii, page 62; Bulletin vi, pages 54, 78, 80, 422, plates II, IX.

Meg. The rock appears in the main green, but has a large percentage of silica and of iron.

Mic. There is a banded variation in the relative amounts of the three elements, *iron*, *quartz* and *hornblende* (or *chlorite*), producing the same structure as seen in the ordinary jaspilyte. Indeed, this varies from the ordinary jaspilyte only in having present a varying amount of the green element, which is identical with that of the adjoining schists. It is sometimes distinctly green hornblende and sometimes largely of chlorite. Two sections.

Age. Archean (Keewatin).

Remark. This specimen shows the alliance of the jaspilyte in its manner of origin, with the enclosing green schists. N. H. W.

No. 1572. Jaspilyte. (*with siderite*).

East end of the Stuntz mine; east end of the North ridge, Tower.
Ref. Annual Report, xviii, page 62.

Meg. Siliceous, white and red jaspilyte, with white granular veinings, one vein being a quarter of an inch wide, effervescing feebly in cold HCl.

Mic. The veinings are of *siderite* and cross the rock in all directions. The same substance also permeates the red jaspilyte and is seen to surround the hematite grains. One section.

Age. Archean (Keewatin).

Remark. There could be no better demonstration of the later date of the siderite.

N. H. W.

[Note.—Nos. 1573 to 1606, inclusive, were collected in Ontario, outside of Minnesota territory, and only those are here described of which we have sections. Brief field notes concerning the others can be found in the Eighteenth Annual Report, pages 50–59, 62, 63.]

No. 1573. Gneiss.

North bay, on lake Nipissing, Ontario.
Ref. Annual Report, xviii, pages 50, 51, 62.

Meg. Gray gneiss, fresh, quite siliceous, banded.

Mic. The section shows *quartz* and glassy *feldspars* much resembling quartz, with a little *biotite*, *apatite* and *sphene*. The centres of the feldspars are sometimes, but not usually, occupied by a mass of alteration products in a manner precisely like those noted in the "old feldspars" of the region of Kekequabic lake. One section.

Age. "Laurentian."

Remark. This rock is a recrystallized sedimentary one, shown by its universal coarsely banded structure, and the constant and parallel direction and width of the bands. The existence of the central decayed cores in the feldspars can be referred to the survival of remnants of older feldspars existing in the original clastics.

N. H. W.

No. 1579. Amphibolyte.

Stobie mine, Ontario. From the dump of the deep shaft which was abandoned.
Ref. Annual Report, xviii, pages 52, 62.

Meg. Coarsely crystalline with hornblende.

Mic. Two-thirds of the slide is composed of a large *hornblende* crystal. In the rest of the slide is a mingling of small hornblendes, *feldspar*, *sphene*, *magnetite*, *biotite*. Sphene frequently surrounds the magnetite grains. One section.

Age. (?) N. H. W.

No. 1590. Graywacke.

Railroad crossing of Vermilion river, Ontario.
Ref. Annual Report, xviii, pages 54, 63.

Meg. There are four specimens of this number. Three of them show a dark, laminated, little slaty, fine-grained, graywacke-like rock. The other is much coarser grained, non-laminated and rough weathering; it has distinct grains of quartz.

Mic. The section was made from the last mentioned specimen. *Quartz* and *feldspar* grains make up the mass of the rock. These are sub-angular, angular and sub-rounded. The quartz is more abundant than the feldspar, which appears to be sometimes *orthoclase*, sometimes *plagioclase*, and rarely microcline. The feldspar is frequently considerably altered and filled with dust-like black inclusions. This black material, which is perhaps carbonaceous, is common throughout the slide, especially between the grains of quartz and feldspar. There are some small flakes of *chlorite* and also of a colorless to yellowish, brightly polarizing, micaceous mineral, though not certainly muscovite. One section.

Age. "Huronian," probably Lower Cambrian. U. S. G.

No. 1592. Tuff. *(Volcanic.)*

Northwest from the railroad crossing of Vermilion river, Ontario. From a ridge that rises from seventy-five to a hundred feet above the railroad.
Ref. Annual Report, xviii, pages 54, 63.

Meg. Appears like a "curious conglomerate."

Mic. In general the slide is nearly dark between crossed nicols, but angular areas, more light than the rest, are more or less sprinkled with small polarizing crystals of various kinds. These angular areas are mainly filled with chloritic substance, which frequently is arranged perpendicularly to the peripheries in fibres, and is also sometimes actinolitic, with high polarization colors. It is also variously irregular, streamed, and in rosettes. Some of the finer angular areas are of quartz, and some are striated feldspar crystals. The matrix which contains these angular areas is at present nearly dark, even in common light, apparently because of spicules and grains of magnetite. One section.

Age. "Huronian," probably Lower Cambrian.

Remark. Volcanic products from this region have already been signalized by G. H. Williams (Bulletin of the Geological Society of America, vol. II, pages 138–140). This locality is easily accessible, and the deposit forms a conspicuous hill, or ridge, at the railroad. On the authority of Dr. Robert Bell, who stated that the black slates graduate conformably into this rock, the slates at the Vermilion river (No. 1590) are here made the same age as this volcanic tuff. N. H. W.

No. 1595. Conglomerate.

At one and a half miles east of Algoma, Ontario. In the typical Huronian region, by the railroad. Logan's "third slate conglomerate," underlying a gray to black roofing slate.
Ref. Annual Report, xviii, pages 55, 63.

Meg. Conspicuously conglomeratic, but not distinctly bedded.

Mic. The fine gray matrix consists of clastic materials in which are some fine *quartz* and some *pyroxene*, but which is mostly composed of indeterminable and inseparable debris of basic elements (chloritic, leucoxenic and basaltic). In this matrix are angular grains of quartz, of triclinic *feldspar*, of *microcline*, *sphene* and apparently of a devitrified *glass* or aporhyolyte. These elements were evidently not long exposed to friction of oceanic agitation, if at all, and indeed the whole rock may be of the nature of volcanic tuff, having an origin very similar to that of many pebbly greenstones of the Archean. One section.

Age. "Huronian." N. H. W.

No. 1598. Quartzyte. *(Feldspathic.)*

Four miles east of Algoma, Ontario, by the railroad.
Ref. Annual Report, xviii, pages 55, 63.

Meg. Fine, reddish.

Mic. Amongst the fine compacted and feebly-interlocking *quartz* is also interlocking striated *feldspar*, the latter being perhaps one-tenth of the whole. There are also a few grains of *siderite(?)* with rusty surroundings. Shreds of *hornblende* are scattered throughout the slide, also some *sphene* and *leucoxene*. One section.

Age. "Huronian." N. H. W.

NO. 1605. DIABASE. *(Coarsely porphyritic.)*

As boulders at Algoma. (Compare No. 601.)
Ref. Annual Report, xviii, pages 58, 63.

Meg. Diabasic, with coarse feldspars.

Mic. The large feldspars are permeated by bands and isolated scales of *sericite* and by clusters of *zoisite* grains. In a section somewhat oblique on n_g extinction on a cleavage is 46°, indicating *bytownite*. The *pyroxene* is frequently twinned on 100, and has a strong cleavage parallel to 100, showing the species to be *diallage*, and less conspicuous cleavages, seen in basal sections parallel to 110 and $\bar{1}\bar{1}0$. The section also has conspicuous large angular masses of dark *leucoxene*. With a little *biotite* and also a little *hornblende*, the rock is quite a complex and interesting one. One section.

Age. (?)

Remark. This is apparently the rock which exists in form of dike near Silver Islet (No. 601), the coarse feldspar of which has been named *huronite*. N. H. W.

NO. 1607. CALCITE. *(Spherulitic.)*

Dietz and Dugan's slate quarries, three miles north of Carlton. (Compare No. 1616.)
Ref. Annual Report, xx, pages 27, 33.

Meg. Soft, rusty calcareous masses in the slates. These are sometimes a foot or two in longer dimension.

Mic. The *calcite* is arranged spherulitically, and in spreading, radial fans, the central part being more highly doubly refracting than the fans. The coarse characteristic cleavages form approximate concentric rings round the central part, crossing the fans in curving lines. In some of the interstitial angular areas is a very fine, dusty substance, composed apparently of debris of the same kind as in the slates. One section.

Age. Animikie. N. H. W.

NO. 1609. CALCITE. *(Massive.)*

A mile and a half south of Cloquet, at the old trial quarry in the slates opened by the St. Paul and Duluth railroad.
Ref. Annual Report, xx, page 33.

Meg. An unweathered portion of the calcareous concretions abounding in the slates.

Mic. The *calcite* here is more granular, massive, and mingled evenly with a certain amount of fine debris, apparently of *feldspar* and *quartz*. One section.

Age. Animikie. N. H. W.

NO. 1611. CALCITE. (*Gritty.*)

Calcareous nodule from the slates at Carlton, east of the depot, north of the railroad, ten to twenty feet above the railroad grade.

Ref. Annual Report, xx, page 33.

Meg. Even grained, dark, apparently gritty.

Mic. The slide shows large interlocking *calcites*, in which are scattered angular *quartz* grains and *feldspar* fragments. Two sections.

Age. Animikie.

Remark. The presence of this rock debris in these nodules rather precludes the assignment of them to any organic agency. N. H. W.

NO. 1616. CALCITE AND GRAYWACKE.

Two miles north of Thomson, near the St. Louis river.

Ref. Annual Report, xx, pages 29, 32.

Meg. One of the calcareous, rusty-weathering nodules, from the slate formation at this place. Compare Nos. 1607, 1609 and 1611. This specimen seems to be composed of graywacke cemented by calcite. No section.

Age. Animikie. U. S. G.

NO. 1618. IRON ORE. (*Magnetic.*)

"Ore from the narrow magnetic belt on Camp's land, S. W. ¼ sec. 33 [T. 63-12 W.], about a mile southwest of Ely."

Ref. Annual Report, xx, page 34; Bulletin vi, page 202.*

Meg. Soft, black, slaty, magnetic and graphitic iron ore with lenses of jaspilyte. No section.

Age. Archean (Keewatin). U. S. G.

NO. 1619. IRON ORE.

Same place as No. 1618.

Ref. Annual Report, xx, page 34; Bulletin vi, page 202.

Meg. Rather pure, but somewhat porous, iron ore consisting largely of hematite. The mass is magnetic, but when powdered only a few grains are attracted by a hand magnet. No section.

Age. Archean (Keewatin). U. S. G.

NO. 1621. GREENSTONE.

S. W. ¼ sec. 33, about a mile southwest from Ely. In the midst of an indefinite greenstone is a harder and apparently a more siliceous area which still is visibly a portion of the same rock; from this harder mass this sample is taken.

Ref. Annual Report, xx, page 34.

*By a typographical error this rock is referred to in Bulletin vi as No. 1613 instead of No. 1618.

Meg. Fine grained, light green.

Mic. There is a very fine, almost structureless mingling of all the products of change of basic rock materials, viz., *calcite, leucoxene, chlorite,* glassy *feldspar, sericite.* There are, besides, areas over which the general extinction is simultaneous, though enclosing numerous of the above minerals, due apparently to the remnant of old feldspar crystals whose characters are otherwise undiscoverable.

There is a general elongation of all the substances in one direction, making a close schistosity. One section.

Age. Archean (Keewatin). N. H. W.

No. 1624. Agglomerate. *(Basic.)*

From the greenstone agglomerate cut by the railroad at Ely. Same rock as No. 1511.
Ref. Annual Report, xx, page 34; American Geologist, vol. ix, page 359.

Meg. Fine grained, with amygdaloidal tubes of calcite. Part of the scale that surrounds the bombs.

Mic. The section shows only the rock, which is in all respects the same as No. 1511, and especially in showing in part a somewhat radiated or sheaf-like arrangement of the little feldspars. One section.

Age. Archean (Keewatin). N. H. W.

No. 1625. Agglomerate. *(Basic.)*

Same place as No. 1624.
Ref. Annual Report, xx, page 34.

Meg. Some of the dark green schistose rock that fills the interspaces between the bombs.

Mic. *Chlorite, calcite, leucoxene,* and scattered small grains of a highly polarizing mineral which is certainly secondary, resembling *epidote;* these compose the rock, but the latter two are in the form of isolated small grains in the large masses of the former two. There is also a little *pyrite.* One section.

Age. Archean (Keewatin).

Remark. The internal structure of No. 1624 is plainly igneous; that of No. 1625 has no suggestion of igneous origin. N. H. W.

No. 1626. Agglomerate. *(Basic.)*

Same place as No. 1624.
Ref. Annual Report, xx, page 34; Annual Report, xxiii, pages 204, 213.

Meg. A part of the bomb from toward the centre. Compare No. 1511.

Mic. The feldspars are fine, and are arranged in radiated or sheaf-like clusters. They are long and slender. Much leucoxene clouds the rock. There are a few isotropic areas of *chlorite* and many scattered grains of *calcite.* One section.

Age. Archean (Keewatin).

Remark. It appears from all the microscopic examinations made on these bombs that their interiors and the surrounding amygdaloidal scales are of igneous structure, the feldspars being arranged as if consolidated at the second stage of cooling, while the rock filling interstices between the bombs is destitute of igneous structure, but similar to some of the greenstone itself where no agglomeratic structure is seen, and may have been originally a volcanic ash or a basic detrital debris. N. H. W.

No. 1628. Actinolite, Magnetite Schist.

No. 2 of the drill at Wicks', sec. 27, T. 60-13, one mile south of the granite.
Ref. Annual Report, xxi, pages 82, 153; Annual Report, xxii, page 161; vol. iv, page 391.

Meg. Black and gray, fine, banded rock, with magnetite.

Mic. There is much *actinolite* in fine needles which pierce the section in all directions. Besides *magnetite* there is apparently only a feldspar which proves to be *oligoclase-albite*, by extinction of 84° on n_p taken on a twinning line, the acute optic angle being apparently that which contains n_g. The actinolite fibres are frequently placed at an angle of about 90° with each other over considerable areas, suggesting that they are arranged in an obliterated feldspar crystal in the directions of the principal cleavages, since in all cases the actinolite penetrates the feldspars with great freedom. Two sections.

Age. Animikie. N. H. W.

No. 1629. Slate. *(Ferruginous.)*

No. 3 of the drill at Wicks', sec. 27, T. 60-13.
Ref. Annual Report, xxi, pages 82, 153; Annual Report, xxii, page 161; vol. iv, page 391.

Meg. Collected under the name "black slate."

Mic. The rock consists chiefly of *magnetite*, but this is evidently mingled with *feldspar* and *actinolite* as in No. 1628. The section is too thick to separate them optically. One section.

Age. Animikie. N. H. W.

No. 1630. Quartzyte. *(Gray, jaspilitic, magnetic.)*

No. 4 of the drill at Wicks'.
Ref. Annual Report, xxi, pages 82, 153; Annual Report, xxii, page 161; vol. iv, page 391.

Meg. Gray quartzyte, sometimes porous, sometimes non-homogeneous, with angular and rounded masses.

Mic. The *quartz* is all secondary and interlocking, varying much in coarseness. It is very fine within the rounded pebbles. It is clouded by gray and dirty powder which in high power seems to be resolvable into fine *magnetite*. One section has strictly the taconyte structure and is illustrated by figure 11, plate III. Two sections.

Age. Animikie. N. H. W.

No. 1630A. Taconyte.

Ref. Annual Report, xxi, pages 82, 84, 153; vol. iv, page 391.

Meg. Balls about one-third of an inch in diameter from No. 4, siliceous, and lighter colored than No. 4.

Mic. The rock is the same as that section of No. 1630, which shows the taconitic structure, except that it is less ferruginous. The taconitic globules are surrounded by a rim of iron ore. Compare No. 1530. One section.

Age. Animikie. N. H. W.

No. 1631. Iron Ore.

No. 5 of the drill core at Wicks'.
Ref. Annual Report, xxi, pages 82, 84, 153; Annual Report, xxii, page 161.

Meg. Magnetite.

Mic. Reflected light shows that the ore embraces both *hematite* and *magnetite.* One (thick) section.

Age. Animikie. N. H. W.

No. 1632. Quartzyte. *(Pinkish.)*

No. 6 of the drill at Wicks'.
Ref. Annual Report, xxi, pages 82, 153; Annual Report, xxii, page 161; vol. iv, page 391.

Meg. Pinkish quartzyte, fine grained.

Mic. The rock is a little stained by *hematite.* Mingled with the interlocking *quartzes* are a few grains of some triclinic *feldspar*, very fine needles of *actinolite* lying scattered in the quartzyte mass, and occasionally a green hornblende shred of larger dimensions and rarely a small epidote. One section.

Age. Animikie (Pokegama).

Remark. This rock was originally essentially a clean quartz sand, and it has been changed by interstitial quartz, which has rendered the grains angular. At the same time there is no evidence of any of the "taconitic" quartz in the slide, although there are some grains that are nearly isotropic and contain hematite dust, which may have been originally of the same nature as the globular masses that characterize the taconyte. N. H. W.

No. 1633. Quartzyte. *(Clastic.)*

No. 7 of the drill at Wicks'.
Ref. Annual Report, xxi, pages 82, 153; Annual Report, xxii, page 161; vol. iv, page 392.

Meg. Quartzyte, partly fragmental.

Mic. The three sections illustrate different conditions of this rock: 1. Fragmental grains of *quartz*, perfectly rounded and mostly of uniform size, but with secondary borders interlocked in a surrounding matrix of secondary fine, taconitic quartz. Within one of these larger rounded grains of quartz is a small *zircon(?)* crystal, its length about four times its width. 2. The rock consists wholly of secondary interlocking quartz, of varying fineness, but which, in common light, reveals a taconitic structure with *magnetite*, some *limonite*, the latter being yellowish red, often staining *actinolite(?)* so that it is opaque. 3. With a more or less broken taconitic structure and fine interlocking quartz, is a considerable amount of glauconite, so-called, and of rusty and green pleochroic *chlorite* as well as (apparently) *actinolite*, some powder of magnetite, and numerous rhombs and irregular grains of *siderite*, the last being stained sometimes to a light yellow by oxidation. The siderite lies in the glauconite, and also within the rusty chlorite. The glauconite is mingled intimately with the iron-stained elements, but usually maintains its distinctness and its color. The chlorite is apt to be stained by iron. When it appears in slender spicules it can be seen to be partly green and partly rusty, the green color being apparent when, on rotation over the polarizer, it is brought into coincidence with the principal section of the polarizer. When perpendicular to it the rusty color only is visible. The glauconite itself appears to be a mass of finer scales of chlorite. Three sections.

Age. Animikie. N. H. W.

No. 1634. Conglomerate.

No. 8 of the drill at Wicks'.
Ref. Annual Report, xxi, pages 83–85, 153; Annual Report, xxii, page 160.

Meg. "Greenstone" materials, embracing many pebbles and grains of quartz.

Mic. The quartz grains are the most conspicuous and important element. They are not altogether rounded, and are sometimes occupied by several interlocking orientations, with also many minute inclusions. They are embraced primarily in a fine groundmass of interlocking quartz. This groundmass of interlocking quartz varies in fineness and appears pebbly, *i. e.*, it is in pebble-like areas, as if it depended on old feldspars which it had permeated and replaced. Mixed irregularly throughout the whole is much green dichroic chlorite in fine grains and shreds. This is frequently compact, scaly, and then resembles the *glauconite*, which has been noted at this stratigraphic horizon many times. It is disposed in somewhat angular and subrounded areas, but not so as to show the taconitic structure. Its arrangement seems to be dependent on that of the coarser grains of quartz, etc., occupying the spaces between them. In one of the slides the pebbly appearance of the areas of interlocking quartz is quite marked, and resembles that seen in the Ogishke conglomerate, and in some of the fragmental rocks about Kekequabic lake, where the pebbly aspect was found to be due to replacement of old feldspars which formed constituent parts of the original conglomerate. Three sections.

Age. Animikie (Pokegama).

Remark. The green element in this rock is evidently derived from a debris from the Archean greenstones. It never shows the taconitic globular structure. That appears at a higher horizon and at this place contains only quartz and iron ore.

N. H. W.

No. 1635. Conglomerate.

The lower portion of No. 8 of the drill at Wicks'.
Ref. Annual Report, xxi, pages 83, 153; Annual Report, xxii, page 160.

Meg. No. 8 consists of "greenstone" materials embracing many pebbles and grains of quartz.

Mic. The slide is made from the lower portion of No. 8 and consists of a granitic debris with considerable infiltration and alteration. This debris is old *feldspars* now containing much *muscovite*, some being apparently *oligoclase* and some *orthoclase*, *quartz*, *hornblende* (largely chloritized), *leucoxene* (alteration from *sphene*) and *chlorite*. One section.

Age. Animikie (Pokegama). N. H. W.

No. 1636. Granite.

No. 10 of the drill at Wicks'.
Ref. Annual Report, xxi, pages 83, 153; Annual Report, xxii, page 160.

Meg. Granite.

Mic. The rock is not fresh, but consists of coarse *oligoclase*, *microcline*, *orthoclase* and *quartz*, of which quartz is the latest, with small amounts of *pennine*, *apatite*, *calcite* and *sphene*, and with much kaolinic alteration throughout the feldspars. One section.

Age. Archean (granite). N. H. W.

No. 1637. Grit. (*Green.*)

N. E. ¼ S. W. ¼ sec. 22, T. 60-13, near Wicks', on the Mesabi range.
Ref. Annual Report, xxi, pages 83, 84, 153.

Meg. Like No. 1634, mainly fragmental material (green), in which are conspicuous grains of lavender quartz.

Mic. The green color of the rock is due to débris of green *hornblende* largely chloritized, but in which are distributed coarse *quartzes*, with irregular borders and large irregular crystals of *microcline*. One section.

Age. Animikie (Pokegama). N. H. W.

No. 1638. Quartzyte.

S. E. ¼ N. W. ¼ sec. 28, T. 60-13, near Wicks', on the Mesabi range.
Ref. Annual Report, xxi, pages 84, 153.

Meg. Nearly all quartz, in form of clastic grains.

Mic. This rock consists of grains of quartz, rounded, somewhat increased in size by secondary growth, its margins interlocking in a fine groundmass of interlocking quartz. It is like one of the sections described of No. 1633. One section.

Age. Animikie (Pokegama). N. H. W.

No. 1639. SANDSTONE. *(Green.)*

Same locality as No. 1638.
Ref. Annual Report, xxi, page 153.

Meg. Green, with included sand grains.

Mic. Angular and sub-rounded grains of *quartz* are thickly set in a matrix of amorphous green debris similar to much of that already noted at Wicks', but which in this section is chloritic, rarely revealing any hornblendic remnants. One section.

Age. Animikie (Pokegama). N. H. W.

No. 1640. QUARTZYTE. *(Pinkish.)*

N. W. ¼ N. E. ¼ sec. 32, T. 60–13, near Wicks'.
Ref. Annual Report, xxi, pages 85, 153.

Meg. Similar in aspect to No. 1632.

Mic. This rock is coarser than No. 1632. It appears like a fragmental quartzyte with borders (narrow) of secondary growth. Cotemporary, probably, with the secondary *quartz* has been an occasional development of a small grain of triclinic *feldspar*, in all respects like that in the quartzyte of Pokegama falls (No. 1525A), and of *microcline*. These feldspars, however, may have been original clastic grains in the rock. One section.

Age. Animikie (Pokegama). N. H. W.

No. 1641. MAGNETITE.

"Magnetite from N. W. ¼ N. E. ¼ sec. 32, T. 60–13; natural loadstone, only found in small quantity; blends off into the rock of the iron belt (No. 1631 of the drill record)."
Ref. Annual Report, xxi, page 153.

Meg. Rather coarsely crystalline magnetite. No section.

Age. Animikie. U. S. G.

No. 1642. GNEISS. *(Very fine grained.)*

At the so-called "silver pit," opened by Chester (compare No. 442), sec. 11, T. 59–14.
Ref. Annual Report, xxi, page 153; Bulletin vi, page 203, and foot-note.

Meg. Average character of the rock of the dump at the old "Silver pit." Finely siliceous.

Mic. The rock consists largely of *quartz*, but also contains some *feldspar*. These are very fine grained and interlocking, and hence wholly of secondary origin, the original rock having been a jaspilyte. There are also clusters of fine globular grains of pyroxene, probably *diopside*, and some *hornblende*, *muscovite*, *sphene*, and *apatite*. One section.

Age. Archean (Keewatin).

Remark. The name gneiss is applicable only in the sense that it is a recrystallized fragmental, and contains all the elements usual in that rock, but it would be correctly denominated a feldspathic quartzyte, the darker elements being merely accessory. The rock is on the south side of the Giant's range of granite, and is not far distant from a deposit of jaspilitic hematite. It was no doubt once covered by the Animikie, as well as by the gabbro, and it may owe its recrystallization either to the gabbro or to granite. N. H. W.

[NOTE. Nos. 1643 to 1669, inclusive, were collected outside of Minnesota. We have sections of only two (Nos. 1644 and 1649) of these specimens described below. Notes concerning Nos. 1643 to 1669 can be found in the Twenty-first Annual Report, pages 153 and 154; also, on pages 86 to 112.]

NO. 1644. GREENSTONE.

From the north side of the Republic hill, Republic, Michigan.
Ref. Annual Report, xxi, page 153.

Meg. Approaching hornblende schist.

Mic. *Feldspar, hornblende, quartz, leucoxene,* evidently sheared basic eruptive, originally of coarse grain. One (thick) section.

Age. (?) N. H. W.

NO. 1649. GNEISS.

At the dam in the Racket river, at Potsdam, New York.
Ref. Annual Report, xxi, page 154.

Meg. Very quartzose, medium grained, sometimes reddish and sometimes gray.

Mic. Fresh, glassy *microcline, quartz*—these are plainly of the latest generation. There are older (at least centrally altered) grains of a triclinic feldspar, having extinctions near *oligoclase*, a little *hornblende, magnetite, sphene, biotite, leucoxene. Calcite* appears as a product of decomposition, lodged in the cores of the altered feldspars. The small, isolated sphenes are in the fresh quartz and microcline. Two sections.

Age. (?) N. H. W.

NO. 1670. DIORYTE (?) *(with quartz).*

Segregation from the slates at Little Falls, Morrison county.
Ref. Annual Report, xxi, page 154; Streng and Kloos, Annual Report, xi, pages 74–76.

Meg. One of the smaller segregations.

Mic. *Hornblende* and *garnet,* both presenting idiomorphic contours, thus appearing to be of *earlier* date, lie in a groundmass of fine interlocking *quartz,* the grains of which they enclose poikilitically, and hence are of *later* date than the quartz. The groundmass also embraces a few grains of *sphene* and irregular dust-like spangles of dark *leucoxene(?)* approaching magnetite in opacity. One section.

Age. Archean (Keewatin). N. H. W.

NO. 1671. DIORYTE (?) *(with quartz).*

Same place as No. 1670.
Ref. Annual Report, xxi, page 154. Compare Annual Report, xxiv, pages 3–10.

Meg. Fragment of the hornblendic layer which encloses the segregation shown in No. 1670.

Mic. Like No. 1670 except that the *garnets* are nearly absent, being very small and scarce. One section.

Age. Archean (Keewatin).

Remark. Rocks Nos. 1670 and 1671, having been called "quartz dioryte" by Streng and Kloos, we prefer not to change from their designation, although there are some peculiarities of structure which might warrant another name. This rock is not an eruptive, but forms isolated knots in the garnetiferous schists of the place, these knots varying in size from a few inches to a foot or two. They are indigenous in the slates in the same manner as granitic knots are sometimes seen in schists. N. H. W.

NO. 1672. DIORYTE *(with quartz).*

Same place as No. 1670.
Ref. Annual Report, xxi, page 154.

Meg. Similar to No. 1670. A dense, fine-grained black rock with porphyritic hornblendes and garnets. No section.

Age. Archean (Keewatin). U. S. G.

NO. 1673. SLATE. *(Garnetiferous.)*

Little Falls, on the Mississippi river, in Morrison county.
Ref. Annual Report, xxi, page 154.

Meg. A rather fine-grained, black, slaty rock, containing porphyritic garnets and also apparently some hornblendes. No section.

Age. Archean (Keewatin). U. S. G.

NO. 1677. "GREENSTONE."

Randall, Morrison county.
Ref. Annual Report, xxi, page 154.

Meg. A roughly schistose, siliceous and also calcareous, rusty-weathering, indefinite greenstone. No section.

Age. Archean (Keewatin). U. S. G.

NO. 1678. GABBRO *(with biotite).*

Quarried at Little Falls, Morrison county, on the west side of the river.
Ref. Annual Report, xxi, page 154.

Meg. Having much the aspect of the gabbro at Duluth.

Mic. The rock is slightly ophitic, but some of the augite was earlier than the feldspar, and takes the form of *diallage.* It encloses the *olivines,* which are wholly altered and have given place to *magnetite* and to *bowlingite*, the latter of a yellowish green color, and entirely separated from the irony ingredient, which seems to have been concentrated almost entirely into the fine crystals of magnetite which lie alongside. The diallage has sometimes a faint pink or rose tint, and shows the twinning 100. *Biotite* encloses all the other minerals, and is strongly dichroic. The feldspar, having an extinction on n_g of 23°, is *labradorite*. One section.

Age. Cabotian (?)

Remark. This rock is petrographically, in all essentials, like the Duluth gabbro, and it may be reasonably inferred that it is of the same age. It is also in the general line of extension of the strike of the mass of that rock. N. H. W.

No. 1681. Marble.

West bank of the Mississippi, just below the mouth of Swan river, Morrison county.
Ref. Annual Report, xxi, page 154.

Meg. Fine grained, slightly pinkish. Compare Nos. 746, 760, 1371.

Mic. The rock shows a fine, even grain, without impurities, and without cavities. One section.

Age. Archean (Keewatin). N. H. W.

No. 1682. Gneiss. *(Biotite quartz schist.)*

Near the centre of the S. E. ¼ N. W. ¼ sec. 30, T. 128-19, Morrison county.
Ref. Annual Report, xxi, page 154.

Meg. Fine grained, hardly gneissic, not banded.

Mic. The most of the rock is *quartz*, interlocked, but *biotite* is conspicuous in small scales. *Garnet* and a little *sphene* are scattered sparsely in the quartz groundmass. Mixed with the interlocking quartz are numerous glassy feldspars. One section.

Age. Archean.

Remark. In its garnetiferous character this rock is allied to the schists at Swan river and at Little Falls. It also contains similar segregations of "quartz dioryte."

N. H. W.

No. 1683. Quartz Dioryte (?)

"Hardened segregations from No. 1682, similar to those seen at Little Falls." See Nos. 1670 and 1672.
Ref. Annual Report, xxi, page 154.

Meg. Fine-grained, nearly white, siliceous rock, holding crystals of hornblende. No section.

Age. Archean. U. S. G.

No. 1684. Gabbro. *(Hornblendic.)*

Philbrook, near the mouth of Fish Trap creek, northwestern corner of Morrison county.
Ref. Annual Report, xxi, page 155.

Meg. Rather coarse grained, gray.

Mic. Except that the augite has been converted to *hornblende,* this is like the Duluth gabbro, the large crystals of *labradorite* also being somewhat altered by the introduction of *zoisite* and *sericite.* There seems never to have been any olivine in the rock, but there are several crystals of *apatite* of the first consolidation. The hornblende lies about the feldspars in an ophitic manner. One section.

Age. Probably Archean.

Remark. This rock has the characters of the Cabotian gabbro when affected by contact with clastic acid rock. N. H. W.

No. 1685. Gabbro. *(Hornblendic.)*

"A darker, more magnetited condition of No. 1684."
Ref. Annual Report, xxi, page 155.

Meg. A very dark, greenish-gray, almost black, coarse-grained rock, composed of feldspar, much hornblende, and perhaps some augite. Apparently a uralitized gabbro. No section.

Age. Probably Archean. U. S. G.

No. 1685A. Gabbro.

The same place as No. 1684.
Ref. Annual Report, xxi, page 155.

Meg. Similar to No. 1684.

Mic. The *augite* is not entirely changed to *hornblende* in this slide, and there is a remarkably frequent supply of idiomorphic *apatites.* These lie in the hornblende, in the *magnetite* and in the unchanged augite. One section.

Age. Probably Archean.

Remark. This rock is allied petrographically to No. 1678, the gabbro quarried at Little Falls. N. H. W.

No. 1686. Gabbro. *(Saussuritized.)*

Same place as No. 1684. Somewhat quarried.
Ref. Annual Report, xxi, page 155.

Meg. Nearly white.

Mic. The rock consists, in places, entirely of *zoisite,* but in general the *feldspars* also contain numerous scales of *sericite.* Through the whole sometimes the remnants of feldspar crystals can be seen to be present by the continuance of the interrupted straight belts of albite twinning. This indicates that this alteration is not due to shearing, since if sheared the twinning lines would be likely to be distorted. One section.

Age. Probably Archean. N. H. W.

No. 1687. Gabbro. *(Sheared.)*

Same place as No. 1684, Philbrook, Morrison county.
Ref. Annual Report, xxi, page 155.

Meg. Schistose.

Mic. The original crystalline structure is entirely broken up and fragmentary. The augite has given place to *hornblende*, polychroic (blue, green, yellow) and fibrous; olivine is wanting, and *magnetite* is abundant. The feldspars, while broken and dislodged, are not saussuritized markedly, although some small grains of *zoisite* and of *sericite* are developed. The most frequent element which permeates the broken feldspars is hornblende in form of more minute fibres. *Calcite* is generally distributed. One section.

Age. Probably Archean.

Remark. The marked contrast between this rock, which is known to have been sheared, and No. 1686, which consists largely of zoisite, without other signs of shearing, taken from the same rock mass, rather indicates that the shearing process is not that which first tends to the destruction of the feldspathic element in this gabbro. The areas occupied by these variations from the normal condition of this gabbro are quite small. N. H. W.

No. 1688. Taconyte.

"Three samples of taconyte showing various conditions of change toward hematite, Hale mine, near Merritt, on the Mesabi range."
Ref. Annual Report, xxi, page 155.

Meg. One of the samples shows a very hard, fine-grained, grayish taconyte, iron-stained and altered to limonite and hematite along fissures. Another sample is a yellowish chert with considerable limonite, and another is a similar cherty rock with crystallized limonite. No section.

Age. Animikie (iron-bearing member.). U. S. G.

No. 1689. Breccia (?)

From the Cincinnati property (sec. 2, T. 58-16 W.), Mesabi Iron range.
Ref. Annual Report, xxi, pages 118, 155.

Meg. A heavy, iron-bearing, black taconitic rock, containing fragments of dark chert and magnetite. The fragments are in part rounded and in part angular and often not sharply separated from the matrix. The rock may be a conglomerate or a breccia, but from its position, apparently near the base of the black slate member of the Animikie, it seems more likely to be a breccia. No section.

Age. Animikie (near the base of the black slate member). U. S. G.

Remark. This remarkable rock has not as yet been examined microscopically. It may be of the nature, in part, of a volcanic tuff. N. H. W.

No. 1690. Sandstone.

Bottom of shaft No. 2, at the Cincinnati mine, sec. 2, T. 58-16 W.
Ref. Annual Report, xxi, pages 119, 155.

Meg. A disintegrated sandstone, composed of rounded, iron-stained quartz grains. No section.

Age. Animikie (Pokegama quartzyte). U. S. G.

No. 1691. Sandstone. *(Ferruginous.)*

"Form showing the penetration of iron into this quartzyte, hardened and reddened, Cincinnati mine." Sec. 2, T. 58-16 W.
Ref. Annual Report, xxi, page 155.

Meg. Same as No. 1690, but cemented by iron ore, both limonite and hematite. No section.

Age. Animikie (Pokegama quartzyte). U. S. G.

No. 1692. Taconyte.

"Taconyte from a shaft on the Cincinnati mine." Sec. 2, T. 58-16 W.
Ref. Annual Report, xxi, page 155.

Meg. Yellowish, grayish and brownish, fine-grained, cherty taconyte, with some limonite. No section.

Age. Animikie (iron-bearing member). U. S. G.

No. 1693. Taconyte.

"Ditto, from the Duluth Ore company (Berringer)."
Ref. Annual Report, xxi, page 155.

Meg. Rather soft, gray, granular taconyte cemented in bands by silica and iron ore, much of which is magnetite. No section.

Age. Animikie (iron-bearing member). U. S. G.

No. 1694. Wad.

Shaft No. 23, Biwabik mine, ninety-four feet down.
Ref. Annual Report, xxi, page 155.

Meg. Soft, black, crumbling bog manganese. Gives off water in closed tube. No section.

Age. Animikie (iron-bearing member.) U. S. G.

No. 1695. Iron Ore.

Shaft No. 25, Biwabik mine.
Ref. Annual Report, xxi, page 155.

Meg. Hard, massive hematite, also softer hematite, somewhat brecciated, and limonite. No section.

Age. Animikie (iron-bearing member). U. S. G.

No. 1696. QUARTZYTE.

Pit in S. E. ¼ N. E. ¼ sec. 4, T. 58-16 W., Chicago property.
Ref. Annual Report, xxi, pages 124, 155.

Meg. A very fine-grained, compact, pinkish quartzyte. Similar to No. 1632. No section.

Age. Animikie (Pokegama quartzyte). U. S. G.

No. 1697. QUARTZYTE. *(Ferruginous.)*

McKinley, Mesabi range. From the well sunk for water at the mining camp.
Ref. Annual Report, xxi, page 155.

Meg. Collected as "black slate."

Mic. The rock is essentially composed of fine interlocking *quartz*, but with so much iron that it has a dark color. The iron is in at least three forms: (1) *Magnetite*, which is black, and in very fine grains, grouped loosely in certain areas; (2) *Goethite*, which is rusty yellow and arranged frequently in radiating spangles; and (3) a reddish-brown, feebly translucent form which is in coarser isolated grains coated with a thin opaque crust of what appears to be magnetite. This reddish-brown ore is like chromite. On uncovering the slide and after washing off the Canada balsam in benzine, this dark-brown portion was dissolved in boiling hydrochloric acid, and is therefore *hematite*. One section.

Age. Animikie. N. H. W.

No. 1698. HEMATITE.

"A clayey ball changed to hematitic rock, from the southern pits at McKinley's; probably from the black slate horizon."
Ref. Annual Report, xxi, page 155.

Meg. A mass, somewhat slaty, of soft red hematite. No section.

Age. Animikie. U. S. G.

No. 1699. HEMATITE.

Lone Jack mine, Virginia.
Ref. Annual Report, xxi, page 155; vol. iv, pages 371, 372.

Meg. Iron gravel, reddish, angular and sub-rounded.

Mic. The sections consist of slices of two of the balls composing the gravel. They are chiefly opaque, but slightly translucent with dark brownish red color in a few scattered small areas. Two sections.

Age. Cretaceous (?) N. H. W.

No. 1700. SILICA-KAOLIN.

"Mixed kaolin and spongy ochre and hematite, Mesabi Mountain mine, near Virginia."
Ref. Annual Report, xxi, page 155.

Meg. Soft, greasy, white, reddish and brownish material, the result of alteration of the taconyte. See under No. 1701. No section.

Age. Animikie (iron-bearing member). U. S. G.

No. 1701. Silica-Kaolin.

Same place as No. 1700.
Ref. Annual Report, xxi, page 155.

Meg. Similar to No. 1700, but harder and finely banded, white and brownish. This specimen is closely similar to No. 70(S), the description of which is as follows:*

"Specimen No. 70 is a consolidated fine white powder, with a greasy feel. It can be easily cut with a knife into any desired shape. It is mainly white, with frequent bands of brown or light red. That these bands are later in origin than the reduction of the rock to its present condition, and result from the precipitation of iron oxide from infiltrating waters, along the weakest zones, is quite certainly shown by a study of this and other specimens from the same place. For while the bands are in general beautifully distinct and parallel, yet they take advantage of any weaker line which offers, whatever the direction, and offshoots from the main band may be found, striking off at an angle, and generally terminating blindly. This material was at first supposed to be a kaolin, and later, from its evident origin and by analogy with other powders of like nature, but developed on a smaller scale, it was suspected to be a silica powder. An analysis was made of the white portion of the rock with the following result:

Analysis of No. 70 (Chemical Series No. 238) by C. F. Sidener.

Silica	SiO_2	77.89	per cent
Alumina	Al_2O_3	13.55	"
Sesquioxide of iron	Fe_2O_3	1.83	"
Lime	CaO	trace	
Magnesia	MgO	.36	per cent
Potash	K_2O	.84	"
Soda	Na_2O	.58	"
Water	H_2O	4.45	"
Total		99.50	

"This analysis shows the rock to be mainly a pure silica powder, with a large amount of the hydrous silicate of alumina, or kaolin; a very small residual portion of the decomposed and leached iron oxides, here evidently in the form of the hydrous sesquioxide; and small amounts of the calcium, magnesium, potassium, and sodium which entered into the composition of the rock from which this was derived." No section.

Age. Animikie (iron-bearing member) or Cretaceous kaolin. U. S. G.

No. 1702. Silica-Kaolin.

Same place as No. 1700.
Ref. Annual Report, xxi, page 155.

Meg. A banded rock similar to Nos. 1700 and 1701, except that it is hard and flinty. No section.

Age. Animikie (iron-bearing member), or Cretaceous kaolin. U. S. G.

*J. E. Spurr. *Bulletin x*, pp. 81, 82.

No. 1703. Taconyte.

Security mine, near Virginia.
Ref. Annual Report, xxi, page 155.

Meg. Gray, granular taconyte containing blotches of limonite, which is in part weathered out, leaving roughly-rounded cavities. No section.

Age. Animikie (iron-bearing member). U. S. G.

No. 1704. Silica-Kaolin.

Mesabi mountain.
Ref. Annual Report, xxi, page 155.

Meg. Soft, white, greasy rock, similar to Nos. 1700, 1701 and 1702, but not banded. See under No. 1701. No section.

Age. Animikie (iron-bearing member), or Cretaceous kaolin.

No. 1704A. Flint.

From No. 1704.
Ref. Annual Report, xxi, page 155.

Meg. Rounded flint pieces from No. 1704, apparently jaspilitic quartz. No section.

Age. Animikie (iron-bearing member), or Cretaceous kaolin. U. S. G.

No. 1705. Taconyte.

Virginia mine.
Ref. Annual Report, xxi, page 155.

Meg. Hard, gray, granular taconyte with streaks and blotches of limonite and red taconyte. The specimen is porous, due to the weathering out of part of the limonite. No section.

Age. Animikie (iron-bearing member). U. S. G.

No. 1706. Hematite.

Probably from the Virginia mine.
Ref. Annual Report, xxi, page 155. (Compare No. 1939.)

Meg. Soft, granular hematite. Scattered through the specimen are minute specks of white, kaolin-like material. One side of the specimen shows a conglomeratic or brecciated structure. No section.

Age. Animikie (iron-bearing member). U. S. G.

Remark. This rock has some resemblance to the volcanic ash No. 1939, from the Gogebic iron range, but is much more highly charged with iron ore. N. H. W.

No. 1707. Hematite.

Virginia, Mesabi range.
Ref. Annual Report, xxi, pages 132, 155.

Meg. A crucial specimen from the Virginia, taken so as to show the transition between the ore and the rock, there being a gradual change from the rock to the hematite of the range.

Mic. The fine *hematite* particles are formlessly grouped, with intervening spaces which were probably occupied by some other substance, but which in the slide are entirely empty except for a dust which is doubtless derived from the process of grinding followed by careless washing. It is hence impossible to detect from this slide the steps of last transition. One section.

Age. Animikie. N. H. W.

No. 1708. Mica Schist. *(Hornfels with cordierite.)*

Near Partridge river, a little west of Allen junction.
Ref. Annual Report, xxi, page 155. (Compare Nos. 370H, 387H.)

Meg. Black or gray, collected as a part of the "black slate" of the Animikie. Fine grained and dense.

Mic. The slide is thickly sprinkled with small isolated scales of *biotite* and a little *magnetite*. Mingled with the biotite scales are a few of *tourmaline*, which resemble the biotite, but are distinguished readily by noting the direction of greatest absorption, which is parallel with the horizontal spider line, that in biotite being parallel with the vertical line. The vertical axis of tourmaline is n_p while with biotite the elongated sections have n_p perpendicular to their greater dimension. These little crystals of tourmaline also show the characteristic basal cleavage. The section in general is noteworthy for containing much *cordierite* in good preservation. This mineral forms the largest crystalline element. It encloses poikilitically all the other grains. Its pleochroism is very low (indeed, it is inperceptible), as in cordierite from the schists of contacts. Small interlocking grains of a feldspar whose index of refraction is lower than that of the cordierite, are probably of *albite*. Quartz shares in the fine interlocking matrix. There are also many small globular grains of high refractive index, which are probably *diopside*, their small size preventing the usual high colors of double refraction. Three sections.

Age. Animikie.

Remark. By the kindness of Prof. A. Lacroix it has been possible to compare this rock with the almost identical metamorphic Devonian schists of Canterets of the upper Pyrenees, and with numerous other cordierite schists. The metamorphism produced on the Devonian schists is due to granite contact, but in Minnesota this metamorphism is to be attributed to the gabbro which lies near adjacent to the outcrop. N. H. W.

No. 1709. Magnetite. *(Ore.)*

S. W. ¼ N. W. ¼ sec. 4, T. 62–11, near the north end of White Iron lake.
Ref. Annual Report, xxi, page 155.

Meg. Associated with vitreous quartz and with hornblende.

Mic. The associated minerals constitute the most of the slide. Besides *quartz* and green *hornblende* there is much *microcline* and rusty chlorite(?) or fibrous *actinolite.* One section.

Age. Archean. N. H. W.

No. 1710. Gabbro (*with hypersthene and bastite*).

Sec. 23, T. 61–12, Spellman's, north side of Birch lake. Associated with the iron ore about 200 feet from the granite.
Ref. Annual Report, xxi, page 156.

Meg. Rather coarse grained, pyroxenic.

Mic. The slide is principally occupied by *bastite*, an alteration product probably of bronzite or enstatite. It has parallel extinction, but its axial plane is perpendicular to the evident cleavage. It might easily be mistaken for an orthorhombic pyroxene. It has low refraction and low double refraction. Mingled with bastite is a pyroxene having higher refractive index, and two systems of rectangular cleavage, with one of which its extinction is parallel, which is apparently *hypersthene.* The slide also contains *biotite, labradorite, magnetite*, and a multiple-twinned colorless amphibole having high double refraction and n_g nearer parallel with its elongation, apparently grünerite. The magnetite is in small grains distributed through the pyroxenes.

Age. Cabotian.

Remark. In another section this rock appears largely hornblendic, twinned on the face 100, apparently grünerite. N. H. W.

No. 1711. Magnetite. (*Ore.*)

From the same place as No. 1710.
Ref. Annual Report, xxi, page 156.

Meg. Black ore, but with impurities.

Mic. The appearance is that of a gabbro gradually eaten into and replaced by *magnetite* in all directions, leaving only remnants of the original minerals, which remnants are bounded by curvilinear sides, with sharply angular corners. The minerals are *labradorite, diallage(?) brown hornblende.* One section.

Age. Probably Keewatin jaspilyte modified by the gabbro.

Remark. The ore encountered at this pit shows another phase of the ore known about a mile further east forming a ridge a short distance inland from the shore (Nos. 960 and 1138). This rock is illustrated by figure 12 of plate III. N. H. W.

No. 1712. Hypersthene.

Same place as the last.
Ref. Annual Report, xxi, page 156. (Compare No. 960.)

Meg. Appearing hornblendic.

Mic. The slide consists entirely of *hypersthene*, but with numerous globular inclusions of *quartz* and apparently of labradorite. One section.

Age. Cabotian. An accident of the gabbro. N. H. W.

NO. 1713. GABBRO *(with olivine)*.

Same place as No. 1710.
Ref. Annual Report, xxi, page 156.

Meg. A medium-grained gabbro, composed of feldspar, augite, hornblende and apparently olivine. Biotite and pyrite are also present. No section.

Age. Cabotian. U. S. G.

NO. 1714. SLATE.

Same place as No. 1710.
Ref. Annual Report, xxi, page 156.

Meg. Hard, fine-grained, black, minutely banded, siliceous and magnetic slate, crossed by many quartz veinings. No section.

Age. Probably a dark jaspilyte of the Keewatin. U. S. G.

NO. 1717. GABBRO. *(Muscovadyte.)*

N. W. ¼ S. E. ¼ sec. 19, T. 63-9, Kawishiwi river, south side.
Ref. Annual Report, xxi, page 156.

Meg. Fine grained. The structure stands vertical.

Mic. The slide consists apparently wholly of olivine and plagioclase. One (thick) section.

Age. Cabotian. N. H. W.

NO. 1721. GREENSTONE. *(Granular and gritty.)*

Sec. 34, T. 64-9 W., Snowbank lake. From near the granite.
Ref. Annual Report, xxi, pages 97, 156.

Meg. Greenstone, appearing coarse and feldspathic.

Mic. The large *feldspars* are striated, but also considerably altered. They have ragged edges, due to decay, that interlock in a ragged, dentate manner with the surrounding matrix, but they do not interfere nor interlock with one another. They are not perceptibly zoned. They contain numerous minute inclusions uniformly distributed, resulting from alteration, chiefly *sericite*, but occasionally fresh glassy grains, evidently of some feldspar, which extinguish differently. Similar fresh feldspars are scattered generally throughout the fine matrix. *Quartz* appears as rather large grains in a manner similar to that of the feldspars, but has evident secondary enlargements, while *green hornblende* is so abundant as to have given name to the rock. It is in fine shreds and ragged masses, and shows no common structure or direction. Hexagonal *apatite* crystals rarely appear. One section.

Age. Keewatin.

Remark. There is but little sign of metamorphism in this rock. It appears in the main to be a debris of basic rock produced by erosion. Although it shows this coarser grain in a direction toward the granite, that change is not attributable to the advent of the granite, for the feldspars are all "old" feldspars. The hornblendes show no secondary growths. This rock suggests some of the coarse green schists of Kekequabic lake. N. H. W.

NO. 1722. GRANITE.

Boot island, in the central part of Snowbank lake.
Ref. Annual Report, xxi, page 156; Annual Report, xxii, page 157.

Meg. Rather fine grained, but with large crystals of a feldspar.

Mic. The coarse feldspar crystals seem to be largely of *microcline.* They enclose numerous smaller feldspars. One section.

Age. Archean (granite). N. H. W.

NO. 1723. DIÓRYTE. *(Camptonyte?)*

Near the same place as No. 1721.
Ref. Annual Report, xxi, page 156.

Meg. A dike, from six inches to thirty-six inches wide, cutting through the eastern continuation of No. 1721, which here becomes a coarse conglomerate, somewhat metamorphosed.

Mic. In a fine groundmass consisting solely of *feldspar* and *hornblende* microliths, the former tending indistinctly to a streamed structure (*i. e.*, a diabasic structure), are idiomorphic crystals of feldspar and hornblende. These later crystallizations are slightly zoned. One section.

Age. Archean (dyke).

Remark. The structure of this rock is much like that of esterellyte, with the exception that the flowage structure has not been noted in esterellyte in Minnesota. In like manner it cuts a rock (No. 1721), which resembles the green schists of Kekequabic lake, which are cut by the esterellyte of that locality. These coincidences are so striking that it is a reasonable inference to assume their equivalence of age, and an alliance in origin. N. H. W.

NO. 1724. QUARTZYTE. *(Gray grit.)*

Shore of Snowbank lake, N. W. ¼. sec. 35, T. 64-9.
Ref. Annual Report, xxi, page 156.

Meg. Gray, fine-grained crystalline rock. It appears some like the Ogishke conglomerate, and at the same time it is granitic, or granitized. There are areas which show a true granitic structure with abundant orthoclase(?) crystals. This rock and Nos. 1721 and 1723 are a part of the greenstone of this area. They sometimes rise in bold exposures 125 feet above the lake, becoming a characteristic coarse conglomerate, undistinguishable from the Ogishke conglomerate, hard, semi-granitized, generally green but weathering with a red tint. At points a little further east granitic dikes cut it and replace it, changing it to a micaceous condition (No. 1728).

Mic. The rock has a coarse schistosity, expressed in the uniform direction of the longer axes of the minerals. *Quartz* is the most conspicuous and the most coarse of the elements of the rock. It is of secondary origin, interlocking with the finer grains of the matrix in which it lies. These quartzes are isolated, having an oval or sub-oval general outline (with but few exceptions) and but seldom coming into contact with each other. There are also finer quartzes, pertaining to the matrix, equally of secondary date, and on careful examination it can be seen that a few grains occur intermediate between the coarse and the fine, thus causing a gradation from one to the other, but the contrast between the large quartzes and the groundmass is not destroyed by this gradation. The most conspicuous part of the groundmass consists of *hornblende* in small irregular and ragged bits. The larger pieces are about one-half or one-third the size of the larger quartzes, but there are many much smaller and quite irregular, not actinolitic. The groundmass, so called, also embraces isolated grains that are of *diopside(?)* of *sphene*, and considerable *epidote*. Still, the finer substance which embraces the coarser parts is apparently composed of altered old feldspar crystals and crystal fragments whose integrity is almost destroyed by inclusions, but which still can be discerned by an occasional feeble trace of albite twinning, and also by a general simultaneous extinction over certain areas. The minute inclusions in these feldspars are chiefly of *sericite*, globular minute feldspars whose orientations are various and thus obscure the general extinction, and other indeterminable grains, some of which are apparently of *zoisite*. There is also an occasional grain of iron ore which may be large enough to rank with the larger quartzes. One section.

Age. Archean (Keewatin).

Remark. Structurally and petrographically this rock is referable to the conglomerate, but it has been largely reconstructed in the generation of secondary minerals. Even the old, "much altered" feldspars appear in high powers to consist, so far as they are of feldspar, of a fresh feldspar material, generated in the same spaces as originally were filled by an older species. N. H. W.

No. 1725. Gneiss.

The country rock, a short distance east of No. 1724, S. W. ¼ sec. 26, T. 64–9, shore of Snowbank lake.
Ref. Annual Report, xxi, page 156.

Meg. Fine, granitic, a portion of the same mass as No. 1724.

Mic. The coloring element is green *hornblende* in irregular small shreds (with one or two grains of *zircon*) and a small amount of *hematite.* There are two or three feldspars and some *quartz,* all united in a fine, uniform, granular structure. One feldspar is filled with inclusions, largely of *mica,* but sometimes of *epidote,* hornblende and apparently of another feldspar. The feldspathic substance that now occupies these grains has a higher refractive index than quartz and is probably *andesine.* It is sometimes coarsely twinned. The fresh feldspars are *microcline* and apparently *albite* and *oligoclase.* One section.

Age. Archean. N. H. W.

NO. 1726. GRANITE. *(Augitic.)*

Appearing in irregular patches, somewhat dike-like, in No. 1725, though these two rocks apparently grade into each other.

Ref. Annual Report, xxi, page 156.

Meg. Intrusive granite.

Mic. This rock is much like No. 1725, but is coarser grained. It also contains *sphene,* while the *hornblendes* are replaced by augite, which is green, and appears like hornblende. The microcline exhibits microperthitic and other intimate relations to small grains of other feldspar, often surrounding them in a poikilitic manner. One section.

Age. Archean. N. H. W.

NO. 1727. GRANITE. *(Augitic.)*

S. W. ¼ sec. 26, T. 64-9, Snowbank lake, near No. 1726.

Ref. Annual Report, xxi, page 156.

Meg. As a dike, cuts the crystalline condition of the conglomerate, contact running about east and west.

Mic. Like No. 1726, but contains also a little hornblende. One section.

Age. Archean. N. H. W.

NO. 1728. MICA SCHIST.

S. W. ¼ sec. 26, T. 64-9, north shore of Snowbank lake.

Ref. Annual Report, xxi, page 156.

Meg. A micaceous, fine-grained condition of the conglomerate (No. 1724), cut by granitic dikes. There is a distinct dip visible on the tops of the knobs (E. S. E.), and the strike is 15° E. of N., the dip throwing the rock under the granite. Not schistose.

Mic. This rock differs from rock No. 1724 only in the following respects: Less *hornblende,* considerable mica *(biotite),* greater invisibility of many of the old *feldspars,* absence of quartz, and the greater number of the "globular feldspars," which last character gives the finer parts of the slide a granulitic, interlocking structure.

There are, at the same time, fewer of the "old feldspars" now apparent, and hence the granulitic structure has the appearance of a second generation from a molten rock, there being no visible schistosity. One section.

Age. Archean (metamorphosed Keewatin).

No. 1729. Quartz-Feldspar Schist.

North side of the same point, in a narrow westward-running bay. (Not shown on the township plats.) Underlies No. 1728.

Ref. Annual Report, xxi, page 157.

Meg. Appearing porphyritic with feldspar.

Mic. This differs from No. 1724 in the following respects: *Quartz* less common, almost wanting, but present in the finer portion of the slide, and in one case developed in the central part of the feldspar; the feldspars are frequently large, giving a porphyritic facies, but they are decayed about their margins and over large irregular areas, the little sericitic scales being uniformly prevalent. These large feldspars are much twinned on the Carlsbad, albite and pericline plans, and having an extinction on n_p of 86° seem to be near *anorthoclase* or *microcline-anorthoclase.* Numerous smaller fragments of the same feldspar are in various stages of decay—even to total obliteration. In case of the complete disappearance of a smaller feldspar grain its former presence is only evinced by the existence of a finely granular spot in the slide, the replacing minerals being interlocking fine feldspars, *sericite* and *hornblende,* like the same minerals in the slide at large, but usually with less of the hornblendic element. It is of course probable that all the finest original feldspathic debris has thus been replaced, and that the feldspars remaining visible are only visible because of their greater size, and hence greater endurance. There is no schistose structure. The rock suggests esterellyte.

Age. Archean (Keewatin). N. H. W.

No. 1730. Quartz-Feldspar Schist. *(Epidotic.)*

At the same place as No. 1729.

Ref. Annual Report, xxi, page 157.

Meg. Somewhat porphyritic with feldspars, irregularly associated with and blending into No. 1731.

Mic. The porphyritic aspect is due, as in No. 1729, to the occurrence of numerous clastic fragments of *feldspar* of large size. These are, however, very much altered, crowded with *epidote, sericite* and *zoisite* and almost lost in the general granulation; indeed, it appears that many of the smaller feldspar fragments have become entirely unidentifiable as such by reason of this tendency to fine granular disintegration and the generation of secondary interlocking quartz and feldspar. This gives the rock in general a fine micro-granitic structure. The large amount of *epidote,* with considerable *hornblende*, gives a greenish coloration to this rock. *Calcite* is also common. Some of the *quartz* seems to be in its original clastic state, but most of it is of secondary origin. One section.

Age. Archean. N. H. W.

No. 1731. Quartz-Feldspar Schist.

Same place as No. 1729.
Ref. Annual Report, xxi, page 157.

Meg. Part of the conglomerate, a phase of No. 1730. These are both intimately associated with characters pertaining to the Keewatin greenstone, of which they seem to be conditions more feldspathic and coarser.

Mic. The *feldspars* are all smaller, roundish, altered in the same way but usually also containing *chlorite* as one of their products of decay. The same chlorite is distributed sparsely, moreover, throughout the slide, result of alteration of hornblende. *Quartz* in clastic, angular grains of considerable size, considerable *epidote* and a little *pyrite* should also be noted. One section.

Age. Archean. N. H. W.

No. 1732. Hornblende Schist.

S. W. ¼ sec. 24, T. 64-9, shore of Snowbank lake.
Ref. Annual Report, xxi, page 157.

Meg. The conglomerate grades into this. It is cut by many dikes of red granite.

Mic. This rock differs from No. 1724 in the following points: The old feldspars were all small and have nearly disappeared; hornblende is abundant and is arranged in sheets of greater and of less abundance; a powder of *hematite* is sprinkled everywhere in the slide; quartz is almost wanting. One section.

Age. Archean (Keewatin). N. H. W.

No. 1733. Mica Schist.

Sec. 24, T. 64-9, shore of Snowbank lake.
Ref. Annual Report, xxi, page 157.

Meg. The conglomerate grades into this; fine grained.

Mic. With a strong schistose structure this rock consists of *biotite*, *quartz*, feldspar, in which last are included *microcline* and *oligoclase*. Microcline encloses the biotite and the quartz and interlocks with itself, while the biotite was earlier or cotemporary with the quartz. There are but slight traces of the original clastic grains, still in many places some of the old grains are visible in the presence of dirty and minutely finely crystalline spots, in which frequently many globular feldspars appear along with *sericite*.

Judged by its contents and its crystalline grain this might be called a granite, but it is distinctly schistose. One section.

Age. Archean (Keewatin). N. H. W.

No. 1734. Dioryte. *(Camptonyte?)*

Secs. 29, 30, T. 64–8, north shore of Snowbank lake.
Ref. Annual Report, xxi, page 157.

Meg. Seems to be a portion of No. 1733; dark gray, fine grained, sparingly interspersed with some crystalline red grains.

Mic. The *hornblende* (which is abundant) is partly porphyritic. The *feldspars* have central areas decayed, but marginal zones of fresh growth. A second development of feldspar is also dispersed throughout the rock, with *quartz*. *Epidote* is not abundant. Differs much from No. 1733. One section.

Age. Archean.

Remark. This rock has the appearance of being a massive crystalline one, and as such it cannot be a part of No. 1733 except by reason of more intense metamorphism. N. H. W.

No. 1735. Dioryte *(with quartz)*.

Forms the coast eastward from No. 1734, and also dikes in No. 1733.
Ref. Annual Report, xxi, page 157.

Meg. Rather dark, with hornblende.

Mic. Much of the feldspar is zoned and so altered at the centre, and over most of the grain, that it cannot be determined. The later feldspars are *oligoclase (?)* and *microcline*. *Quartz* is interlocked with the later feldspars. The hornblende is varied, sometimes but little polychroic, apparently *actinolite*, and sometimes simply green *hornblende*, but more absorptive and more polychroic. *Epidote*, *magnetite*, *chlorite* are more or less associated with this varying hornblende. One section.

Age. Archean. N. H. W.

No. 1736. Greenstone.

S. W. ¼ sec. 20, T. 64–8, Snowbank lake.
Ref. Annual Report, xxi, page 157.

Meg. Dark greenstone, cut by the next.

Mic. *Hornblende*, *chlorite* and *biotite*, with a little *magnetite* give the rock its dark color. The rest is feldspar in two stages, viz., much altered and fresh, with a little *epidote*. The grains are all small and roundish. The aspect is that of a clastic rock regenerated. One section.

Age. Archean. N. H. W.

No. 1737. Syenyte. *(Red.)*

Cuts rock No. 1736 as dike.
Ref. Annual Report, xxi, page 157.

Meg. Weathers red.

Mic. The rock consists almost solely of *microcline* and microperthitic feldspar. Some of the feldspar is near *andesine-oligoclase*. There is very little hornblende. One section.

Age. Archean. N. H. W.

NO. 1738. CONGLOMERATE. *(Greenstone.)*

At the outlet of Snowbank lake.
Ref. Annual Report, xxi, page 157.

Meg. Apparently like a graywacke.

Mic. The rock is composed of *feldspar* fragments, often conspicuously twinned, never interlocking, usually much decayed, and similar fragments of *hornblende.* Both the feldspar and the hornblende are slightly zoned and enlarged by growths at different epochs, though this feature is not conspicuous. Some *quartz,* apparently in original clastic condition, occurs in the midst of these coarser grains. The groundmass that surrounds these larger elements consists in part of fine feldspars, but mostly of fine interlocking quartz and feldspar of secondary origin, the arrangement and variation in fineness of which often show that this replacement occupies the areas of some older mineral which has disappeared entirely. The rock is exactly like many described about Kekequabic and Ogishke Muncie lakes, belonging to the Ogishke conglomerate. One section.

Age. Archean (Keewatin). N. H. W.

NO. 1739. AUGITE-SYENYTE.

East side of sec. 31, T. 64-8, Snowbank lake.
Ref. Annual Report, xxi, page 157.

Meg. Coarse, presenting the so-called bedded structure of much of that about Bassimenan lake.

Mic. The augite has a negative elongation and is hence *œgyrine.* It is twinned on 100. The feldspar is much ingrown as a microperthite, twinned, zoned and interlocked, several different orientations frequently appearing in the same crystal, each one occupying but a small area interlocking with the general crystal and with the other small areas. These feldspars are *oligoclase, orthoclase, anorthoclase* and a little *microcline. Biotite, apatite* and *sphene* are also in the slide. One section.

Age. Archean. N. H. W.

NO. 1742. GABBRO. *(Much altered.)*

At the great Knife Lake headland, southwest corner of the headland, at the water level.
Ref. Annual Report, xxi, page 157.

Meg. Rather coarse grained and gray, with evident quartz.

Mic. Quartz, hornblende, augite, leucoxene, biotite and an altered *feldspar* compose this rock, so far as represented by the slide at hand. One (thick) section.

Age. Cabotian(?)

Remark. In connection with Nos. 1742 to 1751, compare Nos. 798G and 799G, which are somewhat similar coarse-grained diabases from the vicinity of Knife lake.

N. H. W.

No. 1743. Gabbro. *(Much altered.)*

Same place as No. 1742, having a flint film or inclusion.
Ref. Annual Report, xxi, page 157.

Meg. The same rock as No. 1742.

Mic. The *quartz* has entered the *feldspar* in a micropegmatitic manner. The feldspar, which had an ophitic structure with reference to the original augite, is indeterminable in the section at hand. One (thick) section.

Age. Cabotian(?)

Remark. Although originally ophitic this great mass has the color, action and outward aspect of gabbro. N. H. W.

No. 1744. Gabbro. *(Much altered.)*

Same place as No. 1742.
Ref. Annual Report, xxi, page 157.

Meg. Same rock, but having a different grain.

Mic. So far as can be seen from the section at hand this is exactly the same as No. 1743. One (thick) section.

Age. Cabotian(?) N. H. W.

No. 1745. Quartz, Calcite, etc. *(Vein matter, altered.)*

Same place as No. 1742.
Ref. Annual Report, xxi, page 157.

Meg. One foot thick, running straight in the rock of the headland for at least twenty-five feet, when it becomes hidden under the water at one end and under soil at the other.

Mic. The section is so poor that it is only possible to say that the vein consists of *calcite*, *quartz* and apparently of some *feldspar*, stained and colored nearly black by *magnetite* and *leucoxene*, involving pieces of diabase. One (thick) section.

Age. Cabotian(?) N. H. W.

No. 1746. Gabbro. *(Much altered.)*

North side of Knife lake headland.
Ref. Annual Report, xxi, page 157.

Meg. Apparently a conglomeratic or brecciated portion of the rock of the hill, with many pyrite cubes. The rounded masses that are dislodged are from three inches to eight inches in diameter, charged with pyrite, same as the rock itself. The pyritiferous character gradually fades out upward and is entirely wanting at forty-five feet above the lake.

Mic. The section is from the pyritiferous rock, and with cubes of *pyrite* shows much calcite and a little *quartz* with fine needles of *sericite*, clusters of grains of *zoisite* and remnants of an indeterminable feldspar. One (thick) section.

Age. Cabotian.

Remark. This is evidently the rock of the hill in an altered condition. N. H. W.

No. 1747. Gabbro. *(Much altered.)*

North side of the headland, twenty-five feet above the water.
Ref. Annual Report, xxi, page 157.

Meg. A much-decayed, coarse diabase or gabbro.

Mic. *Quartz, diallage, leucoxene* and a much-changed feldspar, are the only identifiable minerals. One (thick) section.

Age. Cabotian(?) N. H. W.

No. 1748. Gabbro. *(Much altered.)*

North side of the headland, at fifty feet above the lake.
Ref. Annual Report, xxi, page 157.

Meg. Similar to the last.

Mic. *Diallage, uralite, leucoxene, quartz* and an indeterminable, much-altered feldspar, with *zoisite*, etc. One (thick) section.

Age. Cabotian(?) N. H. W.

No. 1749. Gabbro. *(Much altered.)*

North side of the headland, at the northern crest of the hill.
Ref. Annual Report, xxi, page 157.

Meg. Resembling gabbro.

Mic. As in the foregoing from this rock, the feldspar is entirely destroyed, as well as the olivine. There remain *leucoxene*, and a form of *pyroxene* (apparently in some cases *diallage*), as the only relics of the original minerals. Quartz has entered, most of the pyroxene is converted to *uralite*, and the spaces of the original feldspars are filled with a variety of decomposition products, which unfortunately, on account of the great thickness of the slides made from this rock, cannot be differentiated, but in which zoisite plays a leading part. One section. N. H. W.

Age. Cabotian(?)

No. 1750. Gabbro. *(Much altered.)*

Top of the headland, perhaps 250 feet above the lake, near the centre of the promontory.
Ref. Annual Report, xxi, page 157.

Meg. Gabbro-like.

Mic. In this slide the structure is sufficiently preserved to show that it was ophitic. The *leucoxene* shows a coarse *sagenite* structure of rutile, but is still only sub-translucent. One (thick) section.

Age. Cabotian(?) N. H. W.

No. 1751. Gabbro. *(Much altered.)*

Near the southern crest of the headland.
Ref. Annual Report, xxi, page 157.

Meg. Similar to the last.

Mic. This does not differ essentially from the foregoing, but shows *pennine* as well as the other alteration products. One (thick) section.

Age. Cabotian(?) N. H. W.

No. 1757. Conglomerate.

West Twin peak, southeast from Ogishke Muncie lake, northern slope; about section 33.
Ref. Annual Report, xxi, page 158.

Meg. Greenstone, pebbly.

Mic. The rock shows the characters of much of the Ogishke conglomerate. With a green tint, due to the fine dissemination of *hornblendic* shreds, modified by *leucoxene* and *hematite*, there are numerous large *quartzes*, angular and sub-rounded, and remnants of fragmental grains of *feldspar*. The most interesting feature is the different degree of alteration that these old feldspars have suffered. Some are wholly lost and some still show the albite twinning, while many are preserved sufficiently to serve barely for proof that they once were perfect. This alteration consists chiefly in the development within the areas of the feldspars of a micro-granulitic mass which encroaches from the borders toward the centre. This micro-granulitic substance consists largely of new feldspars and of quartz. It is nearly free from hornblende or other coloring matter, but the areas are set in a surrounding, greenish mesh which contains much debris of hornblende. Hence there is an aspect as of pebbles. In some cases this micro-granulitic structure is very fine, but in others it can be separated into its constituents by the higher power of the microscope, when it appears to consist very largely of granular interlocking feldspars. One section.

Age. Keewatin (Ogishke). N. H. W.

No. 1758. Diabase. *(Uralitic.)*

Northern slope of West Twin peak.
Ref. Annual Report, xxi, page 158.

Meg. Shows evident igneous characters.

Mic. This rock was originally semi-ophitic, but now consists almost wholly of *uralite* and plagioclase, with a small amount of *magnetite* and less of *hematite*. One section.

Age. Archean (Keewatin).

Remark. It is only rarely that a true igneous rock is encountered among the clastic strata of the northern slope of this mountain. N. H. W.

No. 1759. Diabase. *(Uralitic.)*

North slope of West Twin peak.
Ref. Annual Report, xxi, page 158.

Meg. A coarse uralitized diabase, similar to, but coarser grained than, No. 1758. No section.

Age. Archean (Keewatin). U. S. G.

No. 1760. Diabase. *(Uralitic.)*

From the top of West Twin peak. The country rock.
Ref. Annual Report, xxi, page 158.

Meg. Fine grained, without boulder forms.

Mic. This rock consists, like No. 1758, of *uralite* and *plagioclase*, but was originally not ophitic. On the other hand the augites were earlier than the feldspars and were small. One section.

Age. Archean (Keewatin). N. H. W.

No. 1761. Diabase. *(Uralitic.)*

Same locality as No. 1760.
Ref. Annual Report, xxi, page 158.

Meg. A medium-grained, uralitized diabase. No section.

Age. Archean (Keewatin). U. S. G.

No. 1762. Diabase *(with olivine)*.

West Twin peak, central part of a dike ten feet wide, cutting No. 1760, running northwest.
Ref. Annual Report, xxi, page 158.

Meg. Evidently diabasic.

Mic. With the ophitic structure are preserved also remnants of the *augite* and of the *olivine*. Some of the augite was as early as the feldspar and some of it is largely uralitized. The olivine shows the alteration to *bowlingite*. One section.

Age. Dike in the Keewatin. N. H. W.

No. 1763. Diabase *(with olivine)*.

West Twin peak, near the edge of the same dike as No. 1762.
Ref. Annual Report, xxi, page 158.

Meg. Dense and dark colored.

Mic. Like the last, but finer grained. The rock can hardly be called ophitic, since the *augites* are small and as early as the *feldspars*. This rock has more *magnetite*, less *olivine*, and is preserved better, showing, however, a little *biotite*. One section.

Age. Dike in the Keewatin (possibly Cabotian).

Remark. Being a part of the same dike as No. 1762, this slide shows an interesting contrast, in having its *augites* earlier than the feldspars, or cotemporary with them, never revealing an ophitic structure. It is apparent hence that the ophitic structure is not necessarily an intrusive character, nor the absence of it a character of massive rock. From the slides examined, not including Nos. 1762 and 1763, it is apparent that the central mass and summit of the West Twin peak consists of igneous rock. It is believed to represent the oldest rock known in the state, and to have been a part of the original crust of the earth, the Kawishiwin of the Keewatin.

N. H. W.

NO. 1767. ESTERELLYTE *(inclusions in).*

Corner of sec. 29, T. 65-6, Kekequabic lake, on the porphyritic knob. (Compare Nos. 1094, 1398, 1400.)
Ref. Annual Report, xxi, page 159.

Meg. Pebbles from the porphyry.

Mic. Three slides were made from these pebbles, viz.:

1. Granitic esterellyte. In this slide the rock differs from the normal condition of the porphyry (Nos. 1062 and 1095) in having very little of the fine groundmass surrounding the larger crystals. One portion is, however, distinctly micro-granulitic, and in that fact the pebble is allied to the normal porphyry. The augite, so-called, has a negative elongation, n_p being nearer the vertical axis, with which it makes an angle of 27°, as in the accompanying diagram. Dr. Grant shows that it may be 22° (Twenty-first Annual Report, page 46). This character shows that the augite approaches ægyrine.*

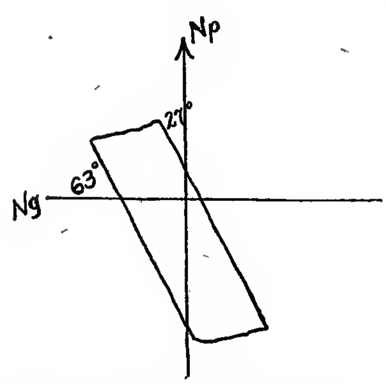


FIG. 46. ÆGYRINE-AUGITE IN NO. 1767.

2. Is composed entirely of amphibole, often showing a zoned enlargement, and also often in fine fibres placed at random in the slide. As inclusions the larger crystals contain much *magnetite* in fine powder and as small crystals.

3. Is so fine that it cannot be described exactly, but with a little *feldspar* it consists largely of some *amphibole*, and hence is allied to No. 2. Three sections.

Age. Archean (Keewatin).

Remark. These inclusions might all be styled *dioryte*, or No. 3 perhaps more correctly *amphibolyte.* They were collected with others, of which no sections were made, as pebbles in a supposed conglomerate. If, however, the rock in which they lie be considered an igneous rock they should rather be called inclusions. Such pebbly forms are distributed throughout this knob of porphyry, but are most numerous on the northeastern slope. They all appear to have been caused to approach the characters of the rock in which they lie. N. H. W.

NO. 1768. PORPHYRY. *(Pebbly.)*

From the same porphyry knob at the northeast extension.
Ref. Annual Report, xxi, page 159.

Meg. Not porphyritic, fine grained, not evidently fragmental, graduates into the porphyritic portion.

Mic. One section made is "porphyritic," like the rock of the knob, having fragments of crystals of the usual much twinned *feldspar* and of *ægyrine*, in a finer ground-

* *Minéralogie de France*, vol. 1, p. 568.

mass; the other is destitute of such crystals, very fine grained, and is a part of the schist or greenish conglomerate of the region. The feldspars in the latter have been eaten up by replacement by a micro-granulitic encroachment, leaving only remnants of the original crystals. *Hornblende* is in small crystals (after augite) and as irregular shreds, running down to very fine particles. As a secondary product it appears that *actinolite* needles have been developed. These are not connected with the hornblendes as borders or secondary growths, but are scattered through the fine-grained matrix. Several grains of *sphene* are evident in this slide. Two sections.

Age. Archean (Keewatin).

Remark. The relation of this rock to the porphyry of the knob is problematical, *i. e.*, whether it is anterior or posterior to the porphyry. The feldspars have the same much twinned appearance, so far as they are preserved. If the field observation is correct that there is a gradual passage from this to the porphyry, there is a genetic relationship which, while in accord with the field observations at the time they were made, seems also to be in accord with the microscopic features. The only difference between this rock and the porphyry prevalent on the knob is the different conditions of the feldspar crystals. Compare No. 1770. N. H. W.

No. 1769. Porphyrel. *(Conglomeratic.)*

From the north side of the narrows of Zeta lake.
Ref. Annual Report, xxi, page 159.

Meg. Conglomeratic.

Mic. The slide does not vary in a manner characteristic of a conglomerate, but it is more like a volcanic tuff. It consists of the peculiar *feldspars* and of *uralite* from *ægyrine* like the porphyry of Kekequabic lake, including some *sphene* and *magnetite.* These are generally entirely distinct, but occasionally a grain of ægyrine is wholly enveloped in a feldspar. There are also round small feldspars within the ægyrine. The surrounding matrix is composed of the same materials, but in a finer state of comminution. There is here visible none of the secondary micro-granulitic encroachment on the feldspars. The hornblende is frequently conspicuously zoned, but does not show the fibrous additions seen in some of the schists at Kekequabic lake. One section.

Age. Archean (Upper Keewatin).

Remark. The name porphyrel was applied to this rock in the prosecution of the field examination by Dr. A. Winchell. It is a rock like the Kekequabic Lake porphyry, but here plainly and abundantly conglomeratic. N. H. W.

No. 1770. Porphyrel. *(Conglomeratic.)*

South side of the narrows of Zeta lake.
Ref. Annual Report, xxi, page 159.

Meg. Conglomeratic.

Mic. This rock is like the last, but somewhat more decayed, showing areas of *calcite*, and some of the feldspar grains are affected by a micro-granulitic alteration. Such alteration of feldspar grains is not uncommon in the Ogishke conglomerate, as already noted. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1772. Graywacke. *(Tuff?)*

N. W. ¼ S. W. ¼ sec. 31, T. 65-5, north shore of Gabemichigama lake.
Ref. Annual Report, xxi, page 159.

Meg. Pebbly, no strike or dip visible, though there is a dim appearance of strike northeast.

Mic. Angular *quartzes* are sparsely distributed with fragmental *feldspars* and *hornblendes* through this rock. At the same time there are many areas of micro-granulitic structure which were formerly occupied by feldspars, a feature which is recognizable in much of the Ogishke conglomerate. This slide has more the structure of a fine agglomerate or tuff than of conglomerate. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1773. Graywacke. *(Tuff?)*

One hundred yards north of the last, on a low, sloping surface.
Ref. Annual Report, xxi, page 159.

Meg. Has no evident dip or structure.

Mic. Similar to the last, but with more abundant micro-granulitic structure. The larger (and fresher) feldspars and the *quartzes* lie in a general matrix of micro-granulitic structure in which it is not possible to distinguish the forms of older grains, but which still must be supposed to have originated in the same way, but from finer original material. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 1775. Gneiss. *(Biotitic.)*

From the older formation, near the gabbro, on the east side of the northeastward bay, Gabemichigama lake; S. W. ¼ sec. 29, T. 65-5 W.
Ref. Annual Report, xxi, page 159.

Meg. Fine grained.

Mic. Feldspar and biotite make up the most of this rock, but small globular *diopsides(?)* are also common, with a little *magnetite* and *pyrite*. It has no schistose structure, but was produced by a regeneration of a fine fragmental rock, probably some part of the Ogishke conglomerate. One section.

Age. Archean (Upper Kewatin). N. H. W.

No. 1776. Conglomerate. *(Finer portion.)*

N. E. ¼ S. E. ¼ sec. 30, T. 65-5, Gabemichigama lake. From a hill rising 150 feet.
Ref. Annual Report, xxi, page 159.

Meg. Collected as a doubtful muscovadyte.

Mic. This rock shows all the characters of the finer portions of the Ogishke conglomerate, angular *quartzes* and *feldspars*, with shreds of *hornblende* and occasionally of *biotite*, in a micro-granulitic matrix like that which has been frequently mentioned. This matrix occasionally takes on forms that suggest the former existence of old feldspars, or pebbles of *glass*. Owing to the comparatively good preservation of the evident feldspar grains, and the completely micro-granulitic structure of these pebble-like areas, there seems to be good reason to consider them as originally of glass. *Actinolite* fibres are scattered throughout the slide. One section.

Age. Archean (Keewatin). N. H. W.

No. 1777. Gneiss *(with biotite.)*

From the long point in the northeast part of Gabemichigama lake, near the centre of W. ½ sec. 32, T. 65-5 W.

Ref. Annual Report, xxi, page 159.

Meg. Gneissose. (Compare No. 1350.)

Mic. This is a more coarsely micro-granulitic condition of the same formation as No. 1776, with a more profound recrystallization. *Quartz, biotite, feldspar* form a mutually interlocking crystalline rock, penetrated by fine needles of *actinolite.* There are evident remnants of the old feldspars. These areas are less coarsely micro-granulitic, and they are also distinguished by fine brightly-polarizing scales that resemble *sericite.* The secondary feldspar gives an extinction angle on n_p of 64°, and n_g is in the acute optic angle, indicating *andesine.* In this rock the biotite was, in general, earlier than the quartz, but there are noticeable exceptions. One section.

Age. Archean (Upper Keewatin).

Remark. It appears from this and other slides that, petrographically, the Ogishke conglomerate grades into the gneiss of the northeastern part of Gabemichigama lake, into the "greenstone" of the region, and into the green schists of Kekequabic lake, as well as into the muscovadyte at Disappointment lake and the porphyrel of Zeta lake. N. H. W.

No. 1778. Muscovadyte.

N. E. ¼ N. E. ¼ sec. 34, T. 65-5 W., near the junction of two branches of the creek. From the top of the cliff facing north.

Ref. Annual Report, xxi, page 159.

Meg. Fine grained, gabbro-like.

Mic. The elements are all fine, and consist of some plagioclase, which was about cotemporary with the *pyroxene*, of *magnetite* and of *biotite.* One (thick) section.

Age. Cabotian (recrystallized Keewatin). N. H. W.

No. 1779. QUARTZYTE.

Same place as the last, on the north slope of the same hill.
Ref. Annual Report, xxi, page 159.

Meg. Some of this appears micaceous. Underlies the muscovadyte-gabbro (No. 1778).

Mic. The *quartz* is in coarse interlocking grains. It is accompanied by *actinolite* and *magnetite*, and has numerous inclusions. One section.

Age. Keewatin (recrystallized jaspilyte), or perhaps Animikie. N. H. W.

No. 1780. GREENSTONE. *(Regenerated.)*

Just across the creek, north from the foregoing, in the eastward extension of the greenstone and gneissic greenstone seen at the northeast corner of Gabemichigama lake.
Ref. Annual Report, xxi, pages 148, 149, 159.

Meg. Greenish gray, massive.

Mic. A pyroxene, probably *augite*, is abundant in this rock, forming ragged crystals that embrace not only *magnetite*, but also many globular pyroxenes and secondary *feldspars*, but *biotite* was later than some of the small globular pyroxenes, and *hornblende* sometimes replaces them. The rock shows numerous remains of the original old feldspars, now granulitized. It also contains a little hypersthene. One (thick) section.

Age. Archean (Keewatin).

Remark. The muscovadyte-gabbro No. 1778, which here immediately overlies the Pewabic quartzyte, is essentially the same as the regenerated greenstone which underlies it. They are both of the muscovadyte type. The nearness of one to the other topographically, and this close petrographic alliance, compel to the assumption that they are the same rock, and that the quartzyte is embraced in that rock. There seems to be here almost a demonstration that the Pewabic quartzyte and its ferruginous qualities result from an alteration of masses of jaspilyte in the greenstones of the Keewatin. N. H. W.

No. 1781. MUSCOVADYTE. *(Granulitic gabbro.)*

Lies below the same quartzyte. N. E. ¼ sec. 35, T. 65-5, a little east of No. 1780.
Ref. Annual Report, xxi, pages 148, 149, 159.

Meg. When collected this was supposed to be a part of the greenstone of the Archean.

Mic. But it is a form of the gabbro, constituting the well-known "muscovado rock," which pertains to the "basal" parts of the gabbro. It has essentially the structure of No. 1780, but the pyroxenes have more the color and habit of augite, earlier than the feldspars. There is considerable *magnetite* in fine grains scattered throughout the slide, some *quartz* and some *biotite* and a little *uralite* and brown hornblende. There are visible none of the remains of any old feldspars, and in that respect, as well as in the manner of the pyroxenes, this muscovadyte is different from the less regenerated greenstones. One section.

Age. Cabotian (regenerated Keewatin).

Remark. In the annual reports there was some confusion in the use of the term muscovadyte, and an effort was made in the Twenty-first Annual Report, (pages 143–152) to define it more exactly and to assign it to a phase of the gabbro, supposed to be due to shattering of the grains about the periphery of the gabbro mass. The name is based wholly on the mineralogic structure and the prevalent color.

It has since appeared, however, both in field examination and in the microscopical study, that the muscovadyte is altered both to the gabbro and to the greenstone of the Keewatin, being an intermediate stage in the transformation of the great Keewatin greenstone mass into the great irruptive gabbro mass. Compare the description of rock No. 2197; also the discussion in Part I. N. H. W.

No. 1782. Quartzyte.

Top of the ridge at the same locality as No. 1781.
Ref. Annual Report, xxi, page 159.

Meg. Vitreous quartzyte, varying from coarse to fine grained. Similar to No. 1779. No section.

Age. Pewabic. U. S. G.

No. 1783. Magnetite.

From a cliff at the southeast end of Paulson lake, S. E. ¼ S. E. ¼ sec. 25, T. 65–5 W.
Ref. Annual Report, xxi, page 159.

Meg. Rather fine-grained, crystalline magnetite. No section.

Age. Pewabic. U. S. G.

No. 1784. Muscovadyte.

North side of Muscovado lake.
Ref. Annual Report, xxi, pages 150, 160; Annual Report, xxiii, pages 212, 214.

Meg. Heavily jointed, nearly horizontal, slides in sheets into the lake toward the southeast, the sheets being from one-half inch to six inches thick. Prevails about the shores of Muscovado lake, and on the shores of the north half of the Bashitanequeb lake, forming hills north of the latter.

Mic. It has the elements of a gabbro, the *augite* being earlier or cotemporary with the feldspar, with considerable *magnetite* and *hypersthene*; no quartz, the grains being of even size, all rather fine and affecting a roundish habit. Very frequently the augites and hypersthene are embraced wholly within the feldspars. Two sections.

Age. Cabotian (altered Keewatin).

Remark. This rock is now believed to be a metamorphic condition of the Keewatin greenstone. A chemical examination by Meeds gave a strong test for titanium. N. H. W.

No. 1785. Muscovadyte.

North shore of Bashitanequeb lake.
Ref. Annual Report, xxi, pages 150, 160.

Meg. Fine grained.

Mic. Identical with No. 1784, but with less magnetite. One section.

Age. Cabotian (metamorphosed Keewatin). N. H. W.

No. 1786. Camptonyte.

Branching conspicuous dike, or bleb, which crosses, in part at least, the townsite of Ely, in the highest portion of the town, cutting the bouldery graywacke near the Catholic church.
Ref. Annual Report, xxii, page 5.

Meg. Coarsely granular or sub-porphyritic.

Mic. Idiomorphic crystals of dark *hornblende* are the most conspicuous part of this rock. They were older than the feldspars, as they sometimes cut across the feldspars. They are also generally slightly zoned, giving different colors of double refraction in a manner similar to the hornblendes in the dike of Stuntz island (No. 872), but this feature is much less noticeable. Occasionally can also be seen a green hornblende, which is doubtless a secondary development, since the brown(?) hornblendes have occasionally green borders and fibrous appendages. Throughout the slide are also numerous irregular grains of *epidote*, which are enclosed uniformly, and often numerously, in the feldspars. They are also enclosed within the large phenocrysts of pyroxene. They are usually, but not invariably, absent from the idiomorphic hornblendes. They have the peculiarity of presenting different colors and different angles of extinction within the same grain.

Pyroxene, probably augite, exists as skeletons of phenocrysts, which have been replaced in a micro-pegmatitic manner by *feldspar(?)* and by a growth of hornblende. These are larger than any of the feldspars, and evidently date from the first consolidation. The feldspar has extinction on n_g (acute bisectrix) at 19° to 20°, indicating *albite* or *andesine*. *Zoisite* is common, and *sphene* is rare. *Pennine* also fills some irregular spaces which were probably once occupied by an older feldspar. One section.

Age. Archean (dike).

Remark. The appearances suggest that this rock in its present state is not only altered by weathering, but that the magma from which it was formed suffered some change before it finally consolidated. There were at first some augites and some feldspars. These are now largely replaced and in their stead are epidote, calcite and hornblende, with another feldspar species. There may have been an accession of acid matter or such elements that the whole tone and tendency of the magma in consolidation was altered, resulting in a rock quite different from that which would have been produced had no such change supervened. Rock like this is found at Vermilion lake, in form of dikes. (Compare Nos. 872 and 877. Also compare No. 2102.)

However, the appearance of this rock is that of one crystallized from a debris rather than from a magma. N. H. W.

No. 1787. Greenstone.

"Amygdules, or pipe-like tubes, in the boulders or bombs of the agglomerate at Ely, filled with silica, which appears to be 'chalcedonic' or minutely granular. This new feature is found sparsely in the rock toward the southwest from the cut at the railroad already described."
Ref. Annual Report, xxii, page 5. Compare Nos. 1510 and 1511.

Meg. Specimen lost. No section.

Age. Archean (Keewatin). U. S. G.

No. 1788. Greenstone.

Southwest from the railroad cut at Ely, toward the Lockhart property, this rock abuts against a bouldery mass of the graywacke, or agglomerate, and its grain and substance seems to enter the bouldery mass, and to surround the bombs, at the same time becoming finer, forming the dark-green scale which envelops them.
Ref. Annual Report, xxii, page 5.

Meg. When collected this was considered a representative of the rock No. 1786.

Mic. It may be a representative of that rock, but it is much more decayed, showing a considerable *calcite*. There are no porphyritic hornblendes, but a fine and often fibrous *actinolite* or other amphibole is abundant, especially in the areas of the old pyroxenes. There is also a wide distribution of small, irregular grains of epidote like those mentioned in the description of No. 1786. There are multitudes of little feldspars, much smaller than in No. 1786, and there are remnants of old feldspars now mostly occupied by a micro-granulitic mass of fresh feldspar grains, the original orientation being sufficiently preserved, in some cases, to show the change that has taken place. A small amount of *quartz* can be seen to surround, occasionally, the small epidotes. Two sections.

Age. Archean (Keewatin).

Remark. If this is a representative of rock of No. 1786, and if that be camptonyte, then camptonyte is not entirely a dike rock. Again, this rock is quite similar to much of green rock which has been included under the name greenstone, and is allied to the tuffaceous greenstones. N. H. W.

No. 1789. Esterellyte (?)

About three-fourths of a mile west of Ely.
Ref. Annual Report, xxii, page 5.

Meg. A knob rising irregularly in the midst of the greenstone, presenting a nearly white color, contrasting with the dark tint of the greenstone. It extends eastwardly somewhat in the manner of a dike for a quarter of a mile, and can be seen along the northern slope of the hill. (Compare No. 2095.)

Mic. In a fine interlocking groundmass of feldspar and (apparently) of quartz are phenocrysts of altered *hornblende* and of *feldspar*, the former evidently derived from some augite (as they have frequently the forms of augite) and remnants of a more highly refractive mineral. Throughout the whole are many *sericite* scales. One section.

Age. Archean (dike?).

Remark. Except that the feldspars are not much twinned, this rock resembles the esterellyte of Kekequabic lake, and it apparently occurs in much the same manner. It is, unfortunately, as seen in the slide examined, much altered by weathering. N. H. W.

No. 1790. Greenstone.

North from the Chandler mine, Ely.
Ref. Annual Report, xxii, page 5.

Meg. Appearing rather massive, but pitted with depressions, like amygdules, filled with a dark-green mineral.

Mic. The supposed amygdule cavities are altered *pyroxenes.* They are not wholly changed, but retain enough of their original substance to show their orientation, which is negative, according to Lacroix's distinction (Minéralogie de France, vol. I, page 568), *i. e.*, the axis n_p is nearer the vertical axis than is n_g, in that respect being like the augite of the porphyry at Kekequabic lake, approaching *œgyrine.* These conspicuous phenocrysts are largely altered to *hornblende* and to *chlorite*, and hornblende spicules and shreds are disseminated through the whole rock, giving it the green color. The feldspathic element is fine, mostly microlitic albite twins, but also interlocking-granular. There is no certainty of any old feldspars absorbed by micro-granulitic encroachment, as the groundmass is evenly constructed of the feldspars already mentioned and the fine hornblendes. There is, however, much *calcite* showing a disengagement of lime. One section.

Age. Archean (Keewatin).

Remark. There is a narrow toothed border of hornblende, as seen in many other instances, projecting beyond the partially altered pyroxenes, while the general form of the pyroxene remains. It suggests that the so-called zoned hornblendes as of the porphyry at Kekequabic lake, are not truly zoned because of secondary growths, but that the difference of polarization colors, and all the contrasting characters are due probably to the difference of surroundings during the single development of a hornblende crystal, viz., that the darker, usually central portion is the space of the original augite, but that beyond the bounds of the original augite the continued growth of the hornblende was free from the effect of the augite, and took a more perfect hornblende color. All the irregularities of coloration are explicable on this hypothesis, there being allowance made for irregularities and imperfections in the original augites. If this be a correct interpretation, it would follow that such contrasts of color, called "frayed" ends, by G. H. Williams, due to supposed dynamic action, and "secondary enlargements," by Van Hise, are only evidence that the hornblende is derived from an original augite crystal or fragment of a crystal, and that there was but a single period of growth. N. H. W.

NO. 1792. MARBLE.

Near the same place as the last.
Ref. Annual Report, xxii, page 5.

Meg. In the conglomeratic portions of the greenstone, particularly in the matrix surrounding the boulders, is seen coarse quartz with *calcite*, mingled in which are also isolated pieces of some green shale or scale.

Mic. The slide only contains granular *calcite*, a kind of marble. One section.

Age. Archean (Keewatin). N. H. W.

NO. 1793. CONGLOMERATE. *(Irony pebbles.)*

Virginia.
Ref. Annual Report, xxii, page 6. See, also, chapter on the Virginia plate in volume iv.

Meg. "Basal conglomerate, from the bottom of the supposed preglacial gorge, at Virginia. This is of ferruginous pebbles, mingled with dust and dirt of the iron-bearing rocks. It may be of Cretaceous origin. It has a later infiltration of white silica which now forms its principal cementing bond." No section.

Age. Probably the basal beds of the Cretaceous. N. H. W.

NO. 1797. GABBRO *(with orthoclase)*.

Duluth.
Ref. Annual Report, xxii, page 6. Compare Nos. 1B, 5, etc., 854G and 854(A)G.

Meg. The rock in general contains numerous small masses of augite syenyte, and is therefore accompanied by numerous crystals of orthoclase.

Mic. The section shows both rocks. Along with reddish *orthoclase*, in one portion, are *quartz* and *hornblende*, with idiomorphic apatites of large (microscopic) dimensions, which show distinctly two cleavages, viz.: that transverse to the crystals and that parallel. The other part consists almost wholly of a single feldspar crystal. This also contains similar apatite. It is approximately parallel to 010, having n_g obliquely visible in the interference figure, and showing scant traces of albite maclation, as well as pericline. Its extinction is at 10° on the albite lines (*i. e.*, the cleavage 010) and 55° on the pericline. Neither cleavage is observable, as such, and it is impossible to decide the species. It is assumed that the red feldspar in the other portion is mainly orthoclase, but some of the smaller grains are twinned like the albite or Carlsbad type, and may be triclinic. One section.

Age. Cabotian. N. H. W.

No. 1798. Claystones (?)

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

Ref. Annual Report, xxii, page 6.

Meg. Oval, dark, slate-like masses, which in weathering stand out above the the surrounding schists and are of darker color than these schists on fresh fracture. They may be pebbles or they may be concretions. No section.

Age. Archean (Keewatin). U. S. G.

No. 1799. Gabbro.

Duluth, at No. 1013 Michigan street.

Ref. Annual Report, xxii, page 6.

Meg. "Pebbles of disintegration."

Mic. The *feldspar* grains are fractured as by dynamic action, and the most of the *augite* is changed to *uralite*; otherwise this seems to be a normal gabbro of the region. One section.

Age. Cabotian.

Remark. There is a thickness of twenty-five feet, visible in the bluff by the street, in which the gabbro is in a state of pebbly disintegration. It may have been caused, as indicated by the condition of this slide, by crushing under dynamic strain, rather than by normal disintegration. N. H. W.

No. 1801. Gabbro.

Duluth; taken at a point back of Rice's point, where the grand boulevard (running approximately on the upper beach) crosses a small creek, on the west side of the creek.

Ref. Annual Report, xxii, page 6.

Meg. The rock has a gneissic structure.

Mic. There is preserved an ophitic structure, and the feldspar, probably labradorite, is well preserved. The *augite* contains many small grains of *magnetite*, which also forms larger grains elsewhere. *Sphene* in small grains is distributed generally, and *zoisite* in aggregated fine grains is general in the feldspar. A small amount of *hornblende* has taken the place of some of the augite. One section.

Age. Cabotian. N. H. W.

No. 1802. Gabbro.

Duluth; same place as the last.

Ref. Annual Report, xxii, page 6.

Meg. Spotted with dark green, and with red-weathering.

Mic. The dark-green spots are caused by changed *augite*, which has given place to *hornblende* in fine interlacing fibres, which sometimes ramify in a *calcite* matrix. This hornblende is earlier in date than a second highly refractive mineral, which occurs often in the greenstones and in the gneisses, already noted, which much resembles *epidote*. It is light yellow in color, or almost colorless. It not only enters within the hornblende mesh, filling it in a measure similar to that of calcite, but it occurs as small grains within the altered feldspars, accompanying *zoisite*, *calcite* and *sericite*.* A little *apatite* is seen in the feldspars. One section.

Age. Cabotian. N. H. W.

No. 1805. Gneiss *(with cordierite?)*

Duluth; at a point midway between the dam of the above-mentioned creek and the station of the elevated railway. A large surface exposure of some old metamorphic rock. It is below the crest of the gabbro range, and on the southern slope, but within the general gabbro area. Some of the rock is red and some is blue, or gray, sometimes appearing like a conglomerate holding boulders of quartz and of granite. In some cases the red color shades into the blue, even on the surface.

Ref. Annual Report, xxii, page 7.

Meg. Represents the fine-grained, gray rock.

Mic. The slide is colored by *magnetite*, *hornblende* and by *diopside*, in very fine, roundish grains. The remainder consists of interlocking *feldspars* and probably with *cordierite*. These are all secondary minerals, due to the action of the gabbro on some clastic. There is a capricious distribution of these minerals, especially the magnetite, bunching up in certain areas, or being very fine or nearly absent in others, indicating an irregular, perhaps a pebbly, structure in the original rock. This rock resembles the gneiss of Gabemichigama lake, Nos. 1089, 1090, 1350, 1351. One section.

Age. Animikie(?) N. H. W.

No. 1806. Gneiss *(with cordierite.)*

Same place as the last.

Ref. Annual Report, xxii, page 7.

Meg. Spotted with small, green areas, appearing amygdaloidal, coarser grained than No. 1805.

Mic. The green areas are *hornblendic* nests. With a little *biotite* and more evident cordierite, this rock is not essentially different from No. 1805. One section.

Age. Animikie(?) N. H. W.

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*In order to distinguish between epidote and diopside, as in this slide, it is necessary to find a section which lies perpendicular to the optic plane, *i. e.*, one in the zone of symmetry. The coloration of such a section is very different from the highly colored conspicuous grains. Indeed, when the section is perpendicular, at the same time, to an optic axis, the color disappears entirely, and a dull gray takes its place as viewed between the nicols. It is only by noting the high refractive index that such a grain would be supposed to belong to the same substance. Either a bisectrix or an optic axis is always visible in sections perpendicular to the optic plane, either in pyroxene or in epidote. When found, such an interference figure will show the direction of the optic plane with respect to the longitudinal cleavage, which is then also visible. In case the optic plane is perpendicular to such cleavage the mineral is epidote, as in this instance. If it is parallel with the longitudinal cleavage the mineral is a pyroxene. In this case a peculiar distribution of the high colors of double refraction also shows these grains to be *epidote*. The same surface is at the same instant red, green or yellow, this peculiarity being connected with the powerful dispersion of epidote.

No. 1811. Diabase.

From the vertical cliff forming the west shore of Sickle (Chicago) bay, north shore of lake Superior; S. W. ¼ sec. 20, T. 62-4 E.
Ref. Annual Report, xxii, page 7.

Meg. A black, rather coarse-grained diabase (or gabbro), resembling the Beaver Bay diabase. No section.

Age. Cabotian (Beaver Bay diabase?) U. S. G.

No. 1813. Gabbro.

West side of Double bay, at the point; N. W. ¼ sec. 15, T. 62-4 E.
Ref. Annual Report, xxii, page 7.

Meg. A coarse-grained, dark-gray gabbro, possibly containing olivine, with large crystals of augite. No section.

Age. Cabotian (Beaver Bay diabase?) U. S. G.

No. 1814. Gabbro. *(Ophitic.)*

From the hill range at Double bay, at the west end of the near hills.
Ref. Annual Report, xxii, page 7.

Meg. Rather coarse grained and gabbro-like.

Mic. Owing to considerable alteration, due, apparently, to long weathering, this rock presents some interesting features. While a part of the *augite*, in large plates, showing an ophitic relation to the feldspar, is perfectly preserved, other grains have been changed entirely, and, along with an accompanying alteration in the olivine, there have resulted considerable *prehnite*, *epidote* and *antigorite*. The *feldspars* have also lost their integrity and some interstitial parallel growths have formed, some being apparently new feldspars, and others an undetermined zeolite(?). At the same time the titanic iron present has taken the *sagenite* structure of *rutile*, and within the mesh, as well as elsewhere throughout the slide, appears *leucoxene*. The prehnite encloses the epidote ophitically, the latter being in form of small idiomorphic crystals. One section.

Age. Cabotian. N. H. W.

No. 1814A. Gabbro.

"White-weathering lumps and patches in No. 1814."
Ref. Annual Report, xxii, page 7.

Meg. Rock in general similar to No. 1814. The feldspars are white, perhaps saussuritized. No section.

Age. Cabotian. U. S. G.

Remark. Nos. 1814 and 1814A illustrate the manner of segregation of the feldspars from the rest of the rock into irregular masses and groups, causing a remarkable petrologic variation, indicating the possible origin of all the "anorthosyte" masses. N. H. W.

No. 1824. Basalt. *(Zirkelyte.)*

Within the bay next east of Red Rock point, on the coast of lake Superior.
Ref. Annual Report, xxii, page 8.

Meg. Shaly looking, thin bedded.

Mic. The fine feldspars, which are somewhat altered, containing *sericite* scales, lie in a matrix consisting largely of devitrified glass, which is darkened by fine *magnetite* and by *leucoxene*, and contain, also, *augite(?)* and *calcite*, with a little quartz. One section.

Age. Cabotian lava. N. H. W.

No. 1825. Basalt. *(Zirkelyte with olivine.)*

Same place as the last.
Ref. Annual Report, xxii, page 8.

Meg. The same rock as No. 1824, but having a spotted aspect.

Mic. This differs from No. 1824 only in having fine *olivine* phenocrysts which, however, are entirely altered to a fine, greenish substance, which is probably some variety of *antigorite*. One section.

Age. Cabotian. N. H. W.

No. 1826. Basalt. *(Amygdaloidal.)*

Phase of No. 1824; same place.
Ref. Annual Report, xxii, page 8.

Meg. Rock like No. 1824, but containing numerous amygdules. These have a bluish-green coating, and inside of this coating are at times several minerals and at times only one. The common minerals are quartz, calcite, laumontite and thomsonite. No section.

Age. Cabotian. U. S. G.

No. 1826A. Amygdules.

From No. 1826.
Ref. Annual Report, xxii, page 8.

Meg. A collection of amygdules from No. 1826, most of them being of quartz. No section.

Age. Cabotian. U. S. G.

No. 1827. Quartzyte. *(Contact of gabbro.)*

Southern face of mount Josephine, 500 feet above lake Superior.
Ref. Annual Report, xxii, page 8.

Meg. Reddish, quartzitic.

Mic. The most of the rock is *quartz* in large grains that interlock with each other, though having in general a roundish outline. There is no trace of clastic characters, but nearly every grain is thickly sprinkled with minute spicules, like double-pointed needles, which are visible in high power as tiny scales by reason of their brightness when not parallel with either nicol. They cannot be determined specifically, but if they be not impurities in the balsam, they may be some form of *mica*. The *feldspar* is reddened by hematite, but is in part a triclinic form. *Sphene*, *hornblende*, *biotite* and *pennine* are accessory. One section.

Age. Wauswaugoning quartzyte, of the Animikie. N. H. W.

No. 1828. Diabase.

Concerned in the metamorphism of No. 1827; same place.
Ref. Annual Report, xxii, page 8.

Meg. Dark, basic, intrusive.

Mic. *Augite* is ophitic in its relation to the feldspars. The same is true of the olivine, which is abundant. This rare feature has been noted several times before (compare Nos. 258, 512, 560, 1275, 1829, and others). The olivine, however, is somewhat altered to *antigorite*, while *magnetite*, *quartz*, *biotite* are more or less accessory. One section.

Age. Cabotian. N. H. W.

No. 1829. Gabbro.

"Average rock of the top of mount Josephine, north shore of lake Superior, near the west side of sec. 2, T. 63-6 E."
Ref. Annual Report, xxii, page 8.

Meg. A rather fine-grained, gray gabbro, composed of feldspar, augite and magnetite, with perhaps olivine.

Mic. This rock resembles No. 1828 in having both *augite* and *olivine*, ophitic in relation to the feldspars, but the slide contains no quartz. The *augite* occasionally shows indications of being later than the olivine, which, having n_p in the acute optic angle has the diagnostic character which distinguishes *fayalite* from ordinary olivine. Round the borders of the magnetite is occasionally a brown *biotite*, and some of the feldspar is penetrated along its planes of albite twinning by a microperthitic alteration of another mineral having rather high double refraction and a refractive index higher than the original feldspar, whose nature is undetermined. The relation of the olivine and feldspar is shown by figure 1, plate V. One section.

Age. Cabotian. N. H. W.

No. 1830. Quartz-Porphyry.

"'Redrock,' kind of quartz-porphyry, from a hill northwestward from mount Josephine, where it forms an irregular patch elongated about east and west; visible on the southern slope of the gabbro range."
Ref. Annual Report, xxii, page 8.

Meg. A gray rock, with a fine-grained, granitic groundmass and porphyritic crystals of quartz and pink feldspar. Intimately associated with the quartz-porphyry is a fine grained, dark, greenish-black rock looking like a diabase. From the hand specimen it would seem as if this dark rock was included as fragments in the quartz-porphyry, but it may possibly cut the porphyry as an irregular dike. No section.

Age. Cabotian. U. S. G.

No. 1831. Conglomerate.

Northeast side of Grand Portage island, north shore of lake Superior; S. E. ¼ sec. 10, T. 63-6 E.
Ref. Annual Report, xxii, page 8. See, also, American Geologist, vol. xiii, pages 437-439; vol. xvi, pages 150-162.

Meg. A coarse sandstone, containing many pebbles, the most important of which are quartz, red granitic rock, quartzyte and gray and greenish slaty rock. No section.

Age. Puckwunge or Potsdam (bottom conglomerate). U. S. G.

No. 1832. Tuff.

East side of Grand Portage island; the upper portion of the same sandstone which is intercalated between trap beds.
Ref. Annual Report, xxii, page 8.

Meg. Darker and finer-grained portion of the sandstone.

Mic. The *quartz* grains are entirely angular; and are mingled with a few grains of *feldspar* and of devitrified *glass.* These all lie in a brown, rusty background which itself is apparently a devitrified glass of varying grain.

Age. Manitou. N. H. W.

No. 1833. Zirkelyte.

From the very top of No. 1832, where it is in contact with the overlying trap sheet.
Ref. Annual Report, xxii, page 8.

Meg. Nearly black, fine grained.

Mic. The specimen seems to have been taken actually from the bottom part of the trap sheet, as it contains no fragmental stuff. It is wholly of the igneous material. It is either glassy and very dark with magnetite, or finely sub-crystalline with the elements of a diabase, amongst which feldspars are distinct, but the augite and olivine have been almost entirely replaced by *uralite, calcite* and *limonite.* One section.

Age. Manitou. N. H. W.

No. 1834. Basalt. *(Globular.)*

From the top of Grand Portage island, north shore of lake Superior; S. E. ¼ sec. 10, T. 63-6 E.
Ref. Annual Report, xxii, page 8.

Meg. Same as No. 544. No section.

Age. Manitou. U. S. G.

No. 1834A. Basalt.

Same place as No. 1834.
Ref. Annual Report, xxii, page 8.

Meg. A collection of the spherical masses from No. 1834. See under No. 544. No section.

Age. Manitou. U. S. G.

No. 1834C. Quartz-Porphyry.

From a hill rising about 600 feet above lake Superior, about a mile and a half from Grand Portage village and on the west of the Grand Portage trail. Perhaps in sec. 31, T. 64–6 E.
Ref. Annual Report, xxii, page 9.

Meg. Red, fine-grained, granitic rock, with phenocrysts of quartz and red feldspar. The specimen resembles closely the porphyritic phase of the "red rocks" found on Pigeon point. No section.

Age. Cabotian. U. S. G.

No. 1838. Quartzyte. *(Metamorphic.)*

Foot of mount Josephine, head of Wauswaugoning bay.
Ref. Annual Report, xxii, page 9.

Meg. Upper portion of the Wauswaugoning quartzyte, gray, fine grained, somewhat colored like the slates, spotted with light red, pink, or even green, depending on the character of the incipient re-crystallization.

Mic. Consists very largely of *quartz*, which has lost its clastic characters under the influence of the basic intrusives of the place, only showing the original outlines of the grains by curving bands of opaque inclusions. The red material is *feldspar*, as shown by an occasional interference figure of a biaxial character. This material composes perhaps one-fifth part of the whole, while *hornblende*, *pennine* and *epidote* are occasional, the first most common. Two sections.

Age. Animikie. N. H. W.

No. 1839. Quartz-Porphyry.

Same place as Nos. 1837 and 1838, appearing in patches in No. 1838.
Ref. Annual Report, xxii, page 9.

Meg. Very fine-grained, reddish rock, with phenocrysts of quartz and pinkish feldspar. No section.

Age. Cabotian. U. S. G.

No. 1841A. Quartzyte. *(Spotted.)*

From the beach near the head of Morrison bay, Pigeon point; N. E. ¼ sec. 32, T. 64–7 E.
Ref. Annual Report, xxii, page 9.

Meg. There are several specimens, varying somewhat, but in general they are fine-grained, hard, gray quartzytes, with spherical areas, one-fourth to one-half inch in diameter, which are green, rather soft and weather out more rapidly than the rest of the rock. No section.

Age. Animikie. U. S. G.

No. 1842. Quartzyte. *(Metamorphosed.)*

Pigeon point, one-half mile west of Little Portage bay (*i. e.*, where Pigeon point is narrowest).
Ref. Annual Report, xxii, page 9.

Meg. At this point the axis of the peninsula is composed of a dark-greenish, but spotted, modified quartzyte, the spots being coincident with or caused by poikilitic crystals of some rock-making mineral, apparently some feldspar.

Mic. While interlocking quartz makes up the greater portion of the slide, a considerable area is also occupied by *delessite*, by *feldspar (orthoclase)*, by *actinolite*, and by a yellowish-brown mineral which has the form represented by the figures attached. This mineral has an irregular cleavage or lamello-fibrous structure in the plane of which lies the axis n_g. It affects hexagonal outlines when entire, but is frequently elongated in the direction of n_g. Its absorption is faint but distinct, and is greatest when the lower nicol coincides with n_g. In the identifiable optic characters, except coloration, it well agrees with the usual characters of *biotite*.

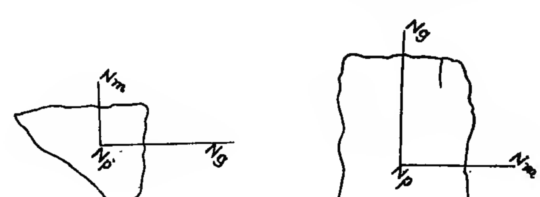


FIG. 47. YELLOWISH-BROWN BIOTITE IN NO. 1842.

Quartz is sometimes in micro-pegmatitic relation with the feldspar, and the latter in large reddened crystals sometimes embraces all the other minerals poikilitically. One section.

Age. Animikie. N. H. W.

No. 1845. Quartzyte. *(Metamorphosed.)*

From the red knob rising near the south shore of Pigeon point a little west of Little Portage bay.
Ref. Annual Report, xxii, page 9.

Meg. Quartz keratophyre (Bayley). The knob exhibits various conditions of this quartzyte.

Mic. The section shows granular *quartz* and spherulites of *orthoclase*, with *hornblende* and *delessite*. One (thick) section.

Age. Cabotian.

Remark. This is a phase of the "red rock," and acts like a Cabotian intrusive, and at other places forms lava flows under favorable conditions. N. H. W.

No. 1846. Calcite. *(Cone-in-cone.)*

From the slates on the south side of the tongue which divides Pigeon bay into north and south arms.
Ref. Annual Report, xxii, page 9.

Meg. Septaria-like masses, weathering from the slates, having a cone-in-cone vertical structure.

Mic. The *calcite* stands with its vertical axis about in agreement with the directions of the cone structure, but it is clouded by dark impurities which are abundant along the cleavages and are much thickened along the undulating or mammillated planes of separation between the individual cones. Two (thick) sections.

Age. Animikie.

Remark. When collected this substance was presumed to show possibly some trace of organic structure. It was submitted to Profs. John M. Clark and G. F. Matthew, and they concur in the opinion that no organic structure is visible.

N. H. W.

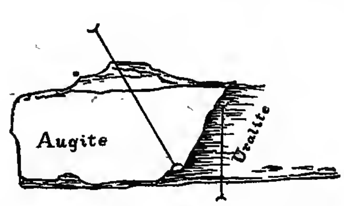
No. 1847. Pseudamygdaloid.

At the eastern end of the outer and eastern of the Lucille islands (Magnet island).
Ref. Annual Report, xxii, page 9; Final Report, vol. iv, page 516.

Meg. The green spots give this rock an amygdaloidal aspect. It is rather coarse grained.

Mic. It is due to alteration that this rock has acquired conspicuous *delessite* areas and a partial uralitization of the *augite*. This *uralite* appears as a sharp fringe, with fine fibrous structure, growing out from the augite in precisely the same manner as the fringes of secondary growth, so-called, in the hornblendes of the porphyry at Kekequabic lake, and in several other similar hornblendic rocks. It is particularly well illustrated in the description of some dikes on Stuntz island (Nos. 380, 872), where some figures may be seen. It has already been suggested that these fringes are neither "frayed-out" ends of the hornblende as suggested by Williams, nor secondary growths as supposed by Van Hise, but that they show the growth of the hornblende beyond the original limits of the augite grains, the difference of absorption and of polarization colors being due in some way to the effect of the augite form in the body of the resultant hornblende.

In rock No. 1847 this hypothesis is demonstrated, for many of the augites have this fringe, while they are not yet wholly converted into hornblende, each mineral having its characteristic extinction, angle and colors of double refraction, as illustrated by the diagram below. This shows that a fringe of hornblende is formed about the augite before the augite is changed materially, and that the fringe is older than the hornblende which later replaces



Growth of Hornblende upon Augite.
FIG. 48. HORNBLENDIC FRINGE ON AUGITE.

the augite itself, and that instead of being later formed, as presumed by either of the above hypotheses, it is really first formed. At the same time the augites in this rock are occasionally somewhat zoned. One section.

Age. Cabotian(?) N. H. W.

No. 1848. Gabbro.

Same place as the last.
Ref. Annual Report, xxii, page 9.

Meg. Massive, pyroxenic rock, apparently in form of a dike cutting No. 1847.

Mic. This rock is quite like the last, which indicates it was cotemporary with it. The *augite* is partly altered to *hornblende,* showing narrow fringes of the latter extending beyond the augite boundaries. There are also small areas of hornblende isolated wholly from all augite. Such are frequently ensconced in a patch of green alteration products which may be *delessite,* and narrow needles are scattered in the same material, accompanied by *epidote.* The augite is frequently twinned on 100. *Olivine,* which is wholly changed, remains only in the shape of sub-rounded masses of green (*antigorite?*), which are often wholly surrounded by a single augite crystal. The feldspars are likewise so altered that they can hardly be discerned. It is apparent that there were no feldspars of the first consolidation, the only feldspathic forms visible being quite small, and mingled with the alteration products. As the augites are substantially idiomorphic, embracing only the older olivines, and impinging only on each other, they seem to have been earlier to form than any feldspars, which gives the rock one of the characters which, by some, has been considered essential to the rock gabbro. It certainly was not ophitic. One section.

Age. Cabotian(?) N. H. W.

No. 1849. Gabbro.

Dike cutting the same island diagonally.
Ref. Annual Report, xxii, page 10.

Meg. Porphyritic with feldspar.

Mic. The older *feldspars* are not abundant, and the small *augites* were about cotemporary, or slightly earlier than, the second generation of feldspar. In the older crystals, sections perpendicular to n_g have an angle of extinction on the basal cleavage of 9° to 12°, n_g being the acute bisectrix, indicating an *andesine,* with a tendency toward labradorite. Such crystals are in general clouded by alteration, and occasionally indistinctly zoned. The small feldspars, however, are almost without exception zoned, the central parts being charged with *sericite.* The *augite* is very largely uralitized and the *olivine* serpentinized, and magnetite accompanies these alteration products. This rock was in part ophitic, as now revealed by the distribution of the alteration products of the augite, showing also two periods of formation of augite. One section.

Age. Manitou(?) N. H. W.

No. 1852. Quartzyte and Black Slate.

Governor's island, at the mine (or shaft) of the Pigeon Point Silver and Copper Mining company; south side of the island.
Ref. Annual Report, xxii, page 10.

Meg. Quartzyte and slate in sedimentary succession. It is apparent that while the shaft started in hardened slate at the surface, the excavation struck red quartzyte and finally red granite.

Mic. The quartzyte is wholly recast into an interlocking, almost granitic, reddish rock, largely composed of *quartz*, but holding, in the interstices between the grains, occasionally a dirty feldspathic element, which probably is accountable for the reddish color of the rock. This element composes in some places nearly one-quarter of the rock, and it is interlocked with the secondary quartz grains. It is so crowded with fine inclusions that it cannot be determined specifically. Its extinctions are vague and not to be measured. Its inclusions are *hematite*, fine and dust-like, *actinolite*, *tourmaline* and a highly refractive, glassy-transparent mineral in isolated occasional grains resembling sphene in all respects, so far as determinable, except in having a double refraction much lower than that of sphene. One of the larger grains, giving an axis of elasticity perpendicular, thus showing the direction of the axial plane, indicates *epidote*. Still other scattered grains are undoubtedly *sphene*. These characters appertain to the quartzyte portion of the rock.

The "black slate" portion is colored by very fine *biotite*, but also contains *sericite*. These lie in a very fine background of micro-granulitic feldspar which is only occasionally discernible by reason of the great number of the little biotites. With the biotites are seen occasionally *tourmalines* almost equally small, distinguished easily between crossed nicols by their lower birefringence, and with the upper nicol removed by their greater absorption in a direction the opposite of that of the biotites. Two sections.

Age. Animikie.

Remark. This rock is wholly recrystallized, the sandstone is a quartzyte granitized, and the black slate is a mica schist. N. H. W.

No. 1853. Red Granite.

From the bottom of the shaft, same place as No. 1852.
Ref. Annual Report, xxii, page 10.

Meg. Red granite, medium grained.

Mic. This rock is like the quartzitic portion of the last, except in being more coarsely crystalline, and hence more easily examined. The feldspar is prevailingly of *orthoclase*, and zoned, but some of it shows both albite and pericline twinning. The central portions of the larger crystals are frequently more affected by alteration than the peripheral, and in the peripheral portion quartz shows itself in vermicular outlines. The slate shows no tourmaline, but there is a little *sphene*, *leucoxene* and *epidote*. One section.

Age. Cabotian.

Remark. In this red granite, as is frequent, there are visible traces of the elements of the basic intrusives (gabbro, etc.). These consist of sphene, leucoxene and the triclinic feldspars, and this fact seems to illustrate the principle which is common in these contact rocks that the acid elements of the clastic rocks permeate and easily destroy the elements of the gabbro, while the gabbro elements are more slow to enter the acid rock. N. H. W.

No. 1855. Gabbro.

About one mile west of the west point of Grand Portage bay. From a dike forming a little point at the Lake Superior shore.
Ref. Annual Report, xxii, page 10.

Meg. Evidently a basic and diabasic rock.

Mic. The *augites* and *olivines* were earlier than the *feldspars*. The rock has somewhat decayed, so that the olivine is principally changed to a yellowish serpentine or *antigorite*, and *leucoxene* appears in small quantity, while *calcite* and *quartz* have entered, the latter in form of a somewhat vermicular micro-pegmatyte in the feldspar. One section.

Age. Manitou(?) N. H. W.

No. 1856. Amygdaloid.

Cut by the dike No. 1855.
Ref. Annual Report, xxii, page 10.

Meg. Over large areas this rock shows a distinct cellular structure.

Mic. The slide shows simply a much altered diabase, in which the augite which was ophitic in its relation to the small *feldspars* has been entirely changed to a greenish, isotropic so-called chloritic, substance, while much calcite has been isolated in abundant, irregular bunches, and larger, irregular spaces are occupied by a finely granular material which cannot be completely separated, but apparently consists of the same chloritic substance in large part, through which are disseminated minute polarizing grains resembling *feldspar* and *quartz*, with *leucoxene* and *magnetite*. One section.

Age. Cabotian(?) N. H. W.

No. 1860. Aporhyolyte. (*Amygdaloidal.*)

South town line of T. 62-1 E., where the new road from Grand Marais crosses it.
Ref. Annual Report, xxii, page 10.

Meg. Porphyritic with quartz, and also amygdaloidal.

Mic. A part of the slide is occupied by interlocking fine *quartzes*, or quartz and *feldspar*, through which are disseminated a few small areas in which a multitude of fine polarizing spicules are grouped—altered hornblendes or feldspars. In this part appear the bipyramidal quartzes of the first consolidation. This part is encroached on by a spherulitic arrangement which is more stained by *hematite*, and in which is a more evident rhyolitic structure. In this part were originally phenocrysts of feldspar (and one of *sphene*) and amygdaloidal cavities, evinced by the forms now left. These forms are now occupied by secondary products, or are empty, owing to the extreme thinness of the slide. This part is wholly rusty with iron oxide, which, however, is so disposed as to reveal numerous minute skeleton crystals whose nature is unknown, as they are now evident only by the peculiar but regular distribution of the iron oxide in varying amounts. There are also lines of iron oxide which were formed by the accumulations concentrating in cracks as the glassy substance rapidly cooled. One section.

Age. Cabotian.

Remark. It is an interesting fact that here the "red rock" series, porphyritic with quartz and feldspar, probably comparable with the rock of the "Great Palisades," exhibits both porphyritic and amygdaloidal structures, showing that it flowed as a lava at the surface. The source from which the red rock supply was derived was hence a large one, and the clastic materials which supplied it were probably from a deep source, involving formations older than the Animikie. N. H. W.

No. 1863. Diabase. *(Basaltic?)*

North side of Brulé lake, at the portage north to Lost lake.
Ref. Annual Report, xxii, pages 10, 11.

Meg. Dark gray or reddish weathering, holding phenocrysts of feldspar.

Mic. The groundmass in general and especially the small feldspars are reddened by iron oxide, and the augite is wholly altered to *hornblende*, but these hornblendes are long and needle-shaped, without any preservation of the ophitic structure, if such ever existed. At the same time many rather large spicules of *magnetite* unite with the *feldspars* and the hornblendes in giving the rock a decidedly "radiated" structure. At the same time the large phenocrysts of feldspar are so altered to kaolin that they are wholly unidentifiable specifically. One section.

Age. Cabotian. N. H. W.

No. 1864. Diabase. *(Basaltic?)*

South shore of Brulé lake; S. W. ¼ sec. 13, T. 63-3 W.
Ref. Annual Report, xxii, page 10.

Meg. Porphyritic.

Mic. This rock is quite like the last, but the *magnetite* needles are arranged rather uniformly in one direction, as if due to a prevalent original structure. This and the characters of the hornblendes, as well as the confused aspect of all the minerals interstitial between the large phenocrysts, carries the impression that this rock at first was largely composed of zirkelyte. There is no evidence of orthoclase in the rock, but the old feldspars are wholly triclinic and quite likely of labradorite. They enclose considerable epidote. One section.

Age. Cabotian. N. H. W.

No. 1867. GABBRO *(with orthoclase).*

S. E. ¼ S. W. ¼ sec. 24, T. 63-3 W.; south of Brulé lake.
Ref. Annual Report, xxii, page 10.

Meg. A medium-grained, gray, granitic rock, composed of whitish to reddish feldspar, augite, hornblende and magnetite. No section.

Age. Cabotian. U. S. G.

No. 1869. GABBRO *(with orthoclase).*

South side of the island in N. E. ¼ S. W. ¼ sec. 24, T. 63-3 W.; Brulé lake.
Ref. Annual Report, xxii, page 11.

Meg. A rock similar to No. 1867, but considerably finer grained.

Age. Cabotian. U. S. G.

No. 1870. GABBRO.

East end of the island, S. W. ¼ N. E. ¼ N. E. ¼ sec. 13, T. 63-3 W.; Brulé lake.
Ref. Annual Report, xxii, page 11.

Meg. Medium-grained rock, rich in feldspar.

Mic. The *augite* preceded or was cotemporary with the *feldspars.* *Olivine* is nearly lost in a serpentinous decay, and the feldspars, which are coarse and compose the most of the rock, are also much altered. One section.

Age. Cabotian. N. H. W.

No. 1874. GABBRO.

South side of a small lake, N. E. ¼ N. E. ¼ sec. 17, T. 63-2 W., near Brulé lake.
Ref. Annual Report, xxii, page 11.

Meg. Dark porphyry.

Mic. The large feldspars, by their extinctions, seem to approach *andesine,* but the rock is not noticeably different from No. 1870. One section.

Age. Cabotian. N. H. W.

No. 1876. KERATOPHYRE (?)

N. E. ¼ N. E. ¼ sec. 20, T. 63-3 W., Brulé lake.
Ref. Annual Report, xxii, page 11.

Meg. Dark, compact, fine grained, with a tendency to reddish color. Small dark areas of crystalline material, surrounded by a vein of red which grades into the rest of the rock, are common.

Mic. Fine, angular *quartz* grains, sometimes interlocking, and occasionally rising to larger size, representing bipyramidal crystals, lie in a finer matrix of about the same materials. There are roundish spots of larger size, with iron-stained peripheries, now occupied with *pennine* which may have the nature of amygdaloidal cavities. A few small crystals and parts of crystals of a triclinic feldspar are disseminated through the fine matrix. There are visible in the slide a few small grains of *sphene*, also others of *ilmenite*, partly altered to *leucoxene*, and of *epidote* and *apatite*. One section.

Age. Cabotian(?)

Remark. The nature and origin of this rock it is difficult to establish by the microscope alone. It may be, however, composed of a mingling of the basic and acid elements. N. H. W.

No. 1879. Basalt.

On a small island in N. W. ¼ S. E. ¼ sec. 18, T. 63-3 W., Brulé lake.
Ref. Annual Report, xxii, page 11.

Meg. Black rock, so-called.

Mic. The structure of this rock is very dense and indistinct, and is further obscured by alteration, while considerable *magnetite* is a cause of its dark color. It seems to have been to some extent a basic *glass*. With the exception of some traces of the early *feldspars*, nothing of its original composition remains, but *hornblende*, *epidote*, *sericite*, *chlorite*, have taken its place. One section.

Age. Cabotian. N. H. W.

No. 1880. Basalt.

Western outlet of Brulé lake, N. E. ¼ S. W. ¼ sec. 18, T. 63-3 W.
Ref. Annual Report, xxii, page 11.

Meg. Spotted phase of the rock No. 1879.

Mic. This rock is more altered to *epidote*, which appears in the areas formerly occupied by the supposed basaltic glass, and hornblende is almost wanting. One section.

Age. Cabotian. N. H. W.

No. 1881. Diabase. *(Coarse.)*

In a low ridge crossing the trail from Brulé lake, S. W. ¼ N. W. ¼ sec. 18, T. 63-3 W., apparently in the form of a dike.
Ref. Annual Report, xxii, page 11.

Meg. Apparently fine-grained, "pepper and salt" rock.

Mic. The *augite* is in large ophitic crystals embracing both olivine and feldspar, while the olivine in a few instances gives place to the feldspar, and is also occasionally altered to serpentine. One section.

Age. Cabotian. N. H. W.

No. 1882. Syenyte.

From the precipitous cliff on the eastern side of the hill rising at the southwest corner of sec. 8, T. 63-3 W., Brulé lake.
Ref. Annual Report, xxii, page 11.

Meg. Fine-grained, red, granitic rock, with some sub-porphyritic feldspars and hornblendes. No section.

Age. Cabotian. U. S. G.

No. 1883. Diabase.

N. E. ¼ N. E. ¼ sec. 17, T. 63-3 W., Brulé lake.
Ref. Annual Report, xxii, page 11.

Meg. Fine grained, dense, nearly black.

Mic. In a fine, much changed groundmass of secondary consolidation are a few phenocrysts of feldspar of the primary consolidation. It is only possible to say that the rock is a phase of the basic eruptives of the region, rather than a clastic, for which purpose the collection was made. One section.

Age. Cabotian. N. H. W.

No. 1884. Diabase.

N. W. ¼ N. E. ¼ sec. 16, T. 63-3 W., Brulé lake.
Ref. Annual Report, xxii, page 11.

Meg. Similar to the last, but weathering reddish.

Mic. Somewhat coarser and fresher, yet having considerable *calcite* and *epidote* and *zoisite* as products of alteration. One section.

Age. Cabotian. N. H. W.

No. 1885. Diabase.

From an island in Brulé lake, lying off the easternmost point in S. E. ¼ S. W. ¼ sec. 10, T. 63-3 W.
Ref. Annual Report, xxii, page 11.

Meg. Resembling amygdaloid, the spots sometimes being one-half an inch in diameter. The rock is also porphyritic with feldspar.

Mic. Still coarser than the last, the feldspars of the second consolidation being divergent. This rock was at first probably in part glassy, but the *glass* has been replaced by products of alteration, such as *hornblende*, *calcite*, *epidote*, *magnetite*, *hematite* and *chlorite*. One section.

Age. Cabotian. N. H. W.

No. 1888. Basalt.

N. E. ¼ sec. 18, T. 63-3 W., Brulé lake, in the hills west of the lake.
Ref. Annual Report, xxii, page 12.

Meg. Black, fine, apparently with fine quartz grains, slaty.

Mic. This rock is similar to several others collected about Brulé lake, but was evidently more quickly cooled, and at first must have contained a considerable glass, which is now replaced by some of the minerals enumerated under No. 1885. One section.

Age. Cabotian. N. H. W.

No. 1889. Basalt.

At the Temperance river outlet of Brulé lake.*
Ref. Annual Report, xxii, page 12.

Meg. A dark, heavy, fine-grained rock, with pseudamygdaloidal spots.

Mic. The dark-greenish spots are occupied by the well-known "chloritic substance," mingled with which is more or less of *magnetite, calcite, epidote, sphene*; epidote sometimes constituting the largest part. One section.

Age. Cabotian. N. H. W.

No. 1890. Diabase.

Same place as No. 1889. Cut by veins of red granite.
Ref. Annual Report, xxii, page 12.

Meg. A rather fine-grained diabase, with a little pinkish feldspar. No section.

Age. Cabotian. U. S. G.

No. 1891. Graphic Granite.

At the spur of the Port Arthur, Duluth and Western railroad, near the camp of the Gunflint Iron mine at the cut near Cross river; S. W. ¼ S. E. ¼ sec. 27, T. 65-4 W.
Ref. Annual Report, xxii, page 12.

Meg. Forms veins and patches in the gabbro.

Mic. The large crystals of quartz and of an altered feldspar form a coarse pegmatyte. The feldspar is an acid plagioclase. Illustrated by plate V, figure 2. One section.

Age. Cabotian. N. H. W.

No. 1892. Diabase.

From an eighteen-inch dike cutting the gabbro on the railroad; S. E. ¼ N. W. ¼ sec. 27, T. 65-4 W.
Ref. Annual Report, xxii, page 12.

Meg. The specimen shows nearly half the width of the dike. The rock is a black, dense diabase, which at the edge of the dike is very fine grained, almost glassy. No section.

Age. Cabotian. U. S. G.

No. 1895. Quartzyte. *(Garnetiferous.)*

At the Gunflint iron mine (Paulson's camp).
Ref. Annual Report, xxii, page 12.

Meg. Cinnamon-colored mineral, is connected with the pyrite.

Mic. The section consists of granular *quartz* and *garnet*, the former being a part of the well-known iron-bearing quartzyte (Pewabic) underlying the gabbro, and the latter an accidental accompaniment. There are secondary minerals, but the garnet surrounds the quartz, and composes nearly one-half of the slide. It is also fresh,

*Brulé lake has an outlet at each end, one passing to Brulé river and one to Temperance river. At the time of our visit, in midsummer, they were both flowing. Compare *American Geologist*, xix, pp. 407-411, 1897.

glassy, but tinted with a faint tint of rose red. It has no cleavage nor optical anomalies, but irregular fissures cross it in all directions. Apparently one crystal mass extends continuously over the whole slide. There are also a few small spherules of *delessite* or *thuringite*. One section.

Age. In the Pewabic(?) quartzyte.

Remark. It is impossible to distinguish the species of this garnet, but its most obvious characters seem to indicate either *pyrope* or *almandine*. Chemical analysis only will determine the species. N. H. W.

No. 1896. Black Slate.

S. W. ¼ sec. 21, T. 65-4 W., near Paulson's camp.
Ref. Annual Report, xxii, page 12.

Meg. Fine grained, magnetited, much crumpled, bedded, or sheeted. This is an isolated ridge of the Animikie(?) separated from the main mass by a high greenstone range of Keewatin rocks.

Mic. In a background of fine interlocking quartz and feldspar are much *magnetite*, and considerable *cummingtonite*,* these all being in fine grains, having a tendency to globular shapes. At the same time occasional crystals of some pyroxene of much larger size embrace all the foregoing, poikilitically, including also numerous globules that appear to be of the same pyroxene, though having independent orientation. One section.

Age. Perhaps jaspilitic slate of the Keewatin.

Remark. While this rock is supposed to be a part of the Animikie, and grades petrographically into the iron-bearing quartzyte at the mine about a mile further south, which is the ore of the region, yet it grades into the rocks (in the field work often called muscovado) that resemble muscovadyte, and apparently into the true muscovadyte which is a phase of the gabbro. Further study is needed in order to separate, in this case, the modified Animikie from the modified Keewatin. N. H. W.

No. 1898. Diabase.

From the hill at the west side of the outlet from South Fowl lake.
Ref. Annual Report, xxii, page 12.

Meg. From the central part of the well-known dike which cuts the hill vertically, visible in the cliff.

Mic. The original *augites*, which preceded the feldspars, have been altered in large part to a greenish, obscure, hornblendic substance. In general, however, throughout the slide, there is a curious intergrowth of *hornblende* and *pyroxene*, each having its characteristic extinction angle, the pyroxene being most frequently plainly enveloped by the hornblende, as described in No. 1899. One section.

Age. Manitou(?) N. H. W.

* This is the mineral frequently known as grünerite, after the determination of Lane and Sharpless, but which, according to the comparative analyses, as given by Hintze, should be called cummingtonite.

No. 1899. Zirkelyte.

At the west side of the outlet of South Fowl lake, from the hill at the creek.
Ref. Annual Report, xxii, page 12.

Meg. From the margin of the conspicuous dike which cuts vertically the trap hill.

Mic. The section consists largely of devitrified magma *glass*. But, arranged in a divergent manner, are fine, elongated crystals of a feldspar and of a composite element, which, according to its extinction angles, consists of *hornblende* and *pyroxene*. These fine elongated crystals, when viewed with high power, have two angles of extinction, viz., the central portion, which is somewhat dimmed by decay, at 5° to 10°, and the peripheral portion, which is fresh, at about 45°. The elongation and general habit are amphibolic, and it may be supposed that after the formation of the hornblendes, which was about cotemporary with that of the feldspars (as they mutually cut each other), a change in the environment and in the composition of the magma caused a zone of pyroxene to envelop them. On the other hand the hornblendic cores may be due to alteration of original pyroxene. One section.

Age. Manitou(?) N. H. W.

No. 1900. Diabase.

Same place as the last.
Ref. Annual Report, xxii, page 12.

Meg. Sample representing the rock of the hill, remote from the dike.

Mic. The ophitic structure is evident in some parts, but at the same time some of the *feldspars* were later than the final crystallization of the *augite*, for they are broken about their margins by the augite. There is no visible olivine, probably because of alteration by weathering, which is apparent in all the minerals. One section.

Age. Cabotian(?)

Remark. This is called diabase, because of the ophitic structure, but it is supposed to be a portion of the great gabbro mass of the Cabotian, which frequently does not show the ophitic structure. N. H. W.

No. 1901. Diabase.

Same place as the last.
Ref. Annual Report, xxii, page 12.

Meg. Sample of the rock of the cliff near the dike.

Mic. This rock is much finer grained than No. 1900, but is not essentially different. It is likewise much weathered. One section.

Age. Cabotian. N. H. W.

No. 1902. Conglomerate. *(Quartzose.)*

Valley of the Puckwunge, about at the centre of the N. W. ¼ sec. 25, T. 64–4 E.
Ref. Annual Report, xxii, page 12. Compare No. 2069.

Meg. Rather fine, quartzose, but containing some colored pebbles and grains, *Mic.* The rounded *quartzes* are not supplied with an interlocking border, but they frequently show a shadowy extinction due to dynamic fracturing, as well as lines of inclusions. *Microcline*, as shown by the characteristic twinning, is not uncommon. Other grains are of orthoclase. A single grain of *zircon*, cut perpendicular to its vertical axis, shows two sets of cleavages, as shown in the figure. In the spaces between the quartzes is a finer debris, largely of quartz, but also containing *hornblende* and *mica*. There are also quite a number of pebbles consisting of quartzyte, of which the constituent grains are interlocking in a manner similar to much in the bottom of the Animikie. These grains vary in size, in some of the pebbles being very fine, as in the taconyte, and in others as coarse as in the Pewabic quartzyte.

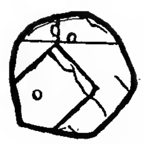


FIG. 49. ZIRCON.

The slide represents the finer portion of the conglomerate. One section.

Age. Bottom of the Potsdam. N. H. W.

No. 1905. Zirkelyte.

From the top of the same hill as No. 1902, lying about 200 feet above the gritstone No. 1902.
Ref. Annual Report, xxii, page 13.

Meg. A nondescript rock of green color. Compare No. 2066.

Mic. In a groundmass of microlitic devitrified glass are numerous idiomorphic fine feldspars and amygdaloidal spaces. The groundmass is mostly chloritized and the amygdaloidal spaces are occupied principally by *quartz*, some of which shows the optic elongation of *quartzine* and some of *chalcedony*, and by *calcite*. One section.

Age. Manitou. N. H. W.

No. 1906. Graywacke. *(Grit.)*

"A fine-grained member of the gritstone, from an exposure further east [than Nos. 1902 to 1905]."
Ref. Annual Report, xxii, page 135.

Meg. Fine-grained, compact, hard graywacke. No section.

Age. Potsdam. U. S. G.

[Note. Nos. 1907 to 1941, inclusive, were collected outside of Minnesota. Of these only those of which there are thin sections are here described. Notes on these rocks, Nos. 1907 to 1941, can be found in the Twenty-second Annual Report, pages 13–15.]

No. 1915. Greenstone.

Sample of the more massive portions of the greenstone, Lower Quinnesec falls, Menominee river, Michigan.
Ref. Annual Report, xxii, page 13.

Meg. Apparently a massive rock.

Mic. *Hornblende*, composing the larger part, in overlapping, angular, confused fragments, is abundantly mingled with *epidote*, *magnetite* (in larger grains), partially altered to *leucoxene*, some *chlorite*, some *quartz*. These lie in a groundmass of fine interlocking secondary feldspar, in which quartz also takes some part.

These are all (except magnetite) secondary minerals, derivable from a decay and rearrangement of the elements of a basic rock, or from basic volcanic tuff, as often illustrated in Minnesota. One section.

Age. Keewatin. N. H. W.

No. 1918. Diabase.

Lower Quinnesec falls; excavated for the channel for running logs; forms the barrier of the falls.
Ref. Annual Report, xxii, page 13.

Meg. Coarse, gabbro-like, but much altered, often spotted with white; perhaps as a dike.

Mic. The rock shows an ophitic relation between the *hornblende* (altered from augite) and the original *feldspars,* the latter being too much decayed for specific determination. There were some larger feldspars, but they are altered to *zoisite* and *calcite,* and otherwise obscured so that they cannot be determined. A part of the amphibolic mineral is fibrous *actinolite. Apatite* is in crystals of the first consolidation. One section.

Age. Keewatin (dike in?) N. H. W.

No. 1919. Amphibolyte. *(Garnetiferous.)*

At a point in the first hill just south of the Republic mine, Michigan.
Ref. Annual Report, xxii, page 13.

Meg. Structure dips north about 75°. So-called actinolite-magnetite schist, from the "lower Huronian."

Mic. Many of the grains of the amphibole are multiple-twinned, but not all of them. Mingled with them is much *garnet.* The *magnetite* in the slide is so small in amount as to be negligible in giving name to the rock, there being but two or three insignificant grains. One section.

Age. *(?)*

Remark. Named actinolite-magnetite-schist and anto-phyllite-schist, the predominant mineral of this rock was carefully examined by Lane and Sharpless, and pronounced grünerite, and it has latterly been called grünerite-schist. Yet, according to the analysis of Lane and Sharpless, it is placed recently by Hintze under cummingtonite. (Handbuch der Mineralogie, II, page 1230.) N. H. W.

No. 1939. Tuff.

From the dump of the Palms mine, Gogebic iron range, Michigan.
Ref. Annual Report, xxii, page 15.

Meg. A rather fragile, greenish-gray rock, with quartz.

Mic. A *chloritic,* isotropic substance forms the cement and background of this rock. It has a varied aspect as to light and dark because of apparent small fragments of different composition, with varying amounts of iron oxide. Sometimes a rusty mesh of a spongy appearance is filled with a reciprocal mesh of this greenish chloritic material, but most usually the greenish material predominates largely over the rusty. These two, and a little *hornblende*, and numerous sub-angular *quartz* grains, compose the rock. One section.

Age. "Upper Huronian," *i. e.,* Taconic. N. H. W.

No. 1940. Quartz Schist.

South of the Aurora mine, Gogebic iron range, Michigan. Contact of the granite.
Ref. Annual Report, xxii, page 15.

Meg. Siliceous, slaty.

Mic. Interlocking *quartzes,* with a few feldspars *(microcline),* compose the most of this rock, but between the quartzes, running in more or less continuous sheets, and sometimes not in sheets, is an *actinolitic* schist which gives a prevalent structure to the rock. As an inclusion in the granite, or as a schist at an intrusive granite contact, it is perfectly explicable, but as the bottom of the upper iron-bearing series at the place where it occurs it would be an anomaly. One section.

Age. Archean (Keewatin).

Remark. The bottom of the iron-bearing series at the Aurora mine is a rather crumbling sandstone, which forms the foot-wall of the mine (or runs through the mine east and west), which is but a few feet thick. The hard, grayish-green, siliceous slates lying to the south of the mine, having a thickness of several hundred feet (Twenty-sixth Annual Report, page 58), belong to the Keewatin; and it is on these slates that the granite forms an intrusive contact, as in many places along the Mesabi range in Minnesota. Still, these green slates have been included frequently in the Penokee-Gogebic series. N. H. W.

No. 1942. Diabase.

Short Line park, St. Paul and Duluth railroad. At the east end of the first cut in the gabbro.
Ref. Annual Report, xxi, page 15.

Meg. Some of the most coarsely crystalline portions of the "gabbro" as seen at this place. Evidently ophitic.

Mic. The augite, which formerly was in very large crystals, has been weathered to a *uralite,* and then almost wholly chloritized, but the ophitic structure is perfectly preserved. One section.

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

No. 1949. Diabase. *(Amygdaloidal.)*

From a detached amygdaloidal mass, lying on the ancient flood plain of the St. Louis, between the depot and the river at Cloquet.
Ref. Annual Report, xxii, page 15.

Meg. Coarsely crystalline, amygdaloidal, and spotted with red, as if by orthoclase derived from contact on the clastics as at Duluth, *Mic.* The slide only shows a coarsely ophitic diabase or gabbro, like that at Short Line Park. Owing to weathering decay, numerous secondary minerals of the usual species have been developed, in which *epidote* is most conspicuous. Red hematitic spots are loosely disseminated, but there seems to be no difference in the essential mineral composition. One section.

Age. Cabotian (boulder). N. H. W.

No. 1951. Diabase.

First hill range of gabbro, *i. e.*, most westerly, at Short Line park, at the railroad cut of the St. Paul and Duluth railroad.
Ref. Annual Report, xxii, page 15.

Meg. Intended to show the average amygdaloidal structure.

Mic. The green spots supposed to be due to amygdaloidal structure are occupied by chloritic and actinolitic fine aggregate, or by this aggregate more or less replaced by fine interlocking secondary feldspars (or quartz). One section.

Age. Cabotian (probably Beaver Bay diabase). N. H. W.

No. 1952. Diabase.

"One of the narrow amygdaloidal dikes cutting this hill, with contact on the gabbro; same place."
Ref. Annual Report, xxii, page 15.

Meg. The country rock, with which the dike is in contact, is a rather fine grained, gray diabase with white feldspars. The dike rock is a very fine-grained, dark-gray diabasic rock. No section.

Age. Dike cutting Cabotian (Beaver Bay diabase?). U. S. G.

No. 1956. Breccia.

"A breccia, embracing some green fragments of the schist." West Breitung mine, Soudan.
Ref. Annual Report, xxii, page 16.

Meg. A rough breccia of green schist and hematite cemented by hematite. No section.

Age. Archean (Keewatin). U. S. G.

No. 1957. Feldspar Schist. *(Calcareous.)*

North side of Ely island, Vermilion lake.
Ref. Annual Report, xxii, page 16.

Meg. Light colored, nearly white, not very siliceous.

Mic. The slide is very largely composed of *feldspar* and *calcite*, with only one small *quartz* grain, so far as discoverable. This feldspar is in two conditions, viz., old crystals now almost entirely lost by alteration, and fragments of crystals. These are thickly strewn with calcite and with feldspar of the second form, viz., micro-granulitic interlocking grains. This feldspar seems to have formed *pari passu* with the decay and disappearance of the older grains of the other feldspar. Fine *sericite* scales also are abundant, but they are uniformly distributed, without forming any schistosity. One section.

Age. Archean (Upper Keewatin).

Remark. With the exception of a little argillyte at the west end of this island, the whole north shore of Ely island consists of rock of this kind. N. H. W.

No. 1959. Feldspar Schist. *(Chloritic.)*

On the mainland southeast from Ely island.
Ref. Annual Report, xxii, page 16.

Meg. Fine grained, slightly greenish. At the "contact" or transition to jaspilyte.

Mic. This rock differs from No. 1957 in having better-preserved old *feldspars* (though still replaced by the same micro-granulitic alteration) and a notable amount of a green isotropic substance which is the same as frequently appears in the greenwackes, and also large grains of quartz. One section.

Age. Archean (Keewatin). N. H. W.

No. 1960. Jaspilyte.

North side of the North ridge at Soudan.
Ref. Annual Report, xxii, page 16.

Meg. Showing a distribution of iron ore in such a manner as to give the appearance of squeezed pebbles of different colors.

Mic. While the rock consists essentially of interlocking *quartz* grains in the well-known manner of jaspilyte, it is colored by *magnetite* in such a manner as to bring out more or less roundish outlines. Where the iron ore is abundant, or even present in any amount, the fineness of the quartz grains is greater. One section.

Age. Archean (Lower Keewatin).

Remark. The variation in the size of the quartz grains where the iron ore appears, indicates that the ore was present in some form at the date of formation of the quartz, and has not been infiltrated since, and hence that it is not the result of later concentration. N. H. W.

No. 1961. Jaspilyte.

Same place as the last.
Ref. Annual Report, xxii, page 16.

Meg. Apparently pebbles, pressed, enclosed in hematitic jaspilyte.

Mic. The pebble-like appearance is due, as in the last, to the peculiar manner of distribution of iron ore in the siliceous mass. This slide, being more abundantly supplied with iron ore, does not exhibit the same variation in the fineness of the quartz grains. It shows, however, that the iron was present even before the micro-granulitic structure was taken by the quartz, and that it also crystallized as hematite before that structure was acquired. Thus, within a triangular space filled otherwise by interlocking grains of quartz, surrounded by what appears to be amorphous iron ore, there are several crystals of hematite standing on the surrounding hematite border. These crystals are sufficiently long to reach about half way across the triangular space, and they cut through the quartz grains idiomorphically, each crystal thus penetrating from two to four of the quartz grains. In the slide are a number of illustrations of this priority of the hematite. One section.

Age. Archean (Lower Keewatin).

Remark. This priority of the iron ore, in its present form, over that of the quartz, in its present form, may be united with notes on the condition of the jaspilyte where it has been modified by the gabbro contact at Disappointment lake (Nos. 2199–2201). N. H. W.

No. 1962. Greenwacke.

North slope of the North ridge, Soudan.
Ref. Annual Report, xxii, page 16.

Meg. The rock has an approach toward argillyte.

Mic. The slide, however, shows a rock much too coarse for argillyte. It is essentially made up of basic debris, perhaps tuffaceous, in which great decay has taken place. The old feldspars (and augites, if any existed) are hardly discernible, but a *chloritic* and *amphibolic* and *epidotic* confused secondary product has taken their places, showing a sprinkling also of *hematite.* One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 1966. Greenwacke *(with cordierite?)*

Crossing of Lake street and Piedmont avenue, Duluth.
Ref. Annual Report, xxii, page 16. (Compare Nos. 44 and 1708.)

Meg. Typical homogeneous specimen of the "black rock," so-called. Appearing like a basalt.

Mic. The rock is very fine grained, but in high powers it is seen to be composed of the same elements as a greenwacke, *i. e.*, *amphibole,* old *feldspars* nearly destroyed, *magnetite* (or hematite) *quartz* in angular and subangular grains, all more or less enshrouded in an isotropic mantle of *chlorite.* The rock might pass for an Archean greenwacke, or even for a volcanic tuff. One section.

Age. Animikie.

Remark. The supposed "old feldspars" are possibly not feldspar, but *cordierite.* They frequently have parallel extinction and are crowded with inclusions, but being very small and indefinite, it is not safe to rely on them as cordierite. N. H. W.

No. 1967. Greenwacke. (*Tuff?*)

Same place as No. 1966.
Ref. Annual Report, xxii, page 17.

Meg. Sample of the roughly conglomerate-appearing portion of the same rock mass as No. 1966.

Mic. There are certain spots in which the green *amphibole* prevails over all the other minerals, even to their entire exclusion, and others in which *magnetite* plays the same rôle. The former are sometimes irregularly angular, and bordered by a band of greater abundance of granular magnetite; in other places the magnetite simply fades out and leaves a somewhat roundish area in which none is found. On the other hand magnetite sometimes suddenly increases in innumerable fine grains, forming a *tache* something like lapillitic magnetited fragments seen in old volcanic ash. One section.

Age. Animikie(?) N. H. W.

No. 1968. Aporhyolyte.

Same place as the last but a short distance further west, near the creek crossed by Piedmont avenue, Duluth.
Ref. Annual Report, xxii, page 17.

Meg. Red rock, associated with the foregoing black rock.

Mic. Poikilitic *quartz* spreads irregularly throughout the fine mass, embracing the red (feldspathic?) material. It consists of numerous crystal orientations. *Magnetite*, *hornblende* and *epidote* are likewise more or less abundant, the hornblende being quite scant. One section.

Age. Cabotian. N. H. W.

No. 1976. Pebbles.

Pebbles from the crumbling red conglomerate which overlies the green shale (No. 1974) and the quartzose conglomerate, at the mouth of the creek entering the St. Louis river on S. W. ¼ sec. 1, T. 48-16 W.
Ref. Annual Report, xxiii, pages 239, 240.

Meg. The pebbles are not usually more than an inch in diameter. They are of various kinds of rocks, among which are: greenish-gray shale; gray, flinty rock; reddish, banded, flinty rock; pyrite; vein quartz; fine-grained, red granite; red quartzyte; fine-grained, decayed, reddish, igneous rocks.

Age. Potsdam conglomerate. U. S. G.

No. 1980. Granite.

Ortonville, near Big Stone lake. Much used for construction.
Ref. Annual Report, xxiv, page 1.

Meg. Rather coarse, reddish, sometimes porphyritic.

Mic. *Microcline* and *orthoclase* form large crystals. *Quartz* is abundant; *biotite* is rather sparse but preceded both feldspars. The orthoclase sometimes enters the microcline in a pneumatolitic manner, and also itself is converted to a *microperthite* by the intergrowth of a secondary feldspar along its cleavages. In small amount a vermicular micropegmatyte and other inclusions are formed by the quartz in the microcline, but generally the quartz is grouped by itself in roundish interlocking grains.

The rock is quite fresh, but that it is a reconstructed rock is indicated by the remains of "old feldspars," though not so evidently as in the granite of Kekequabic lake. These remains are of three sorts: (1) Decayed areas isolated in the midst of otherwise fresh feldspar (quite rare in this rock); (2) Remains of a triclinic feldspar in the midst of orthoclase. These consist of scattered grains having their extinction directions the same and simultaneous; (3) Lines of iron rust (limonite) as inclusions running parallel through the orthoclase, simulating albite twinning bands of a triclinic feldspar from which everything is lost except these lines, which were probably accumulated along the planes of separation between the albite macles, or within the macles themselves. The microperthite itself may be mentioned as a fourth trace of an older state of the feldspars of this granite. Two sections.

Age. Archean granite. N. H. W.

No. 1986. Granite.

Menan island, Vermilion lake. The older of two granite dikes.
Ref. Annual Report, xv, pages 288–290; Annual Report, xxiv, page 1.

Meg. Two granite dikes, one cutting the other.

Mic. The rock is made up of "old feldspars," much broken and corroded by the surrounding matrix, lying in a micro-granulitic groundmass, quite resembling the granite already described at Kekequabic lake. These old *feldspars* never interlock with each other, but they are intimately interlocked about their borders by the secondary fine interlocking groundmass. If two are in contact they have the appearance of having been brought accidentally into that position, and sometimes a broken line of glassy small feldspars, or perhaps only one or two grains or a few scales of mica, have been developed along their contact edges. These old feldspars also frequently have isolated, small, fresh and glassy feldspars and *quartz* scattered irregularly through them, having independent orientations. The most of them are plainly triclinic and approach *oligoclase.* Extinction on n_p is about 85°, n_g being apparently the bisectrix, thus indicating *oligoclase-albite. Microcline* appears as one of the fresh feldspathic growths. The small granular and interlocking feldspars are mingled with interlocking quartz; it is impossible from the slide at hand to determine them specifically, for they show no crystallographic characters on which to measure extinction. The section contains a little *epidote* and *sphene* and a few scales of *mica,* but is nearly free from the colored silicates. One-section.

Age. Archean dike. N. H. W.

No. 1987. Granite.

Same place as the last.
Ref. Annual Report, xxiv, page 1.

Meg. A later granite dike, cutting No. 1986.

Mic. This rock is like the last, but having less contrast as to size between the old and the fresh feldspars, the latter also being more numerous as compared with the interstitial new growths, and thus coming occasionally into contact; but such contacts are characterized, as in No. 1986, by the same appearance of apposition rather than crystalline intergrowth, except that usually a fresh deposition of clear glassy feldspar or of *quartz* cements them by a continuous line or by several nearly adjacent grains. Quartz also enters the old feldspars as a vermicular micropegmatyte. One section.

Age. Archean dike.

Remark. There is no way of knowing whether much or little time separated the dates of formation of these dikes. They are petrographically so similar that they seem to have had nearly the same date and the same origin. N. H. W.

No. 1990. Granite.

Menan island, near the last.
Ref. Annual Report, xxiv, page 1.

Meg. This is a light-gray, rather fine-grained dike six inches wide, showing contact on schist, apparently the youngest of the dikes.

Mic. The larger old *feldspars* are quite scarce in this rock, but very many of the grains in the finer matrix are surrounded by a rim of secondary growth which interlocks with rims that likewise surround adjacent grains, the centres of the grains being crowded with mica scales and sometimes containing secondary silica. *Epidote* is quite common, and is lodged within the old feldspars, or in the finer groundmass. Green *hornblende* also forms a conspicuous part of the slide, being later than the few *biotite* scales which it encloses. One section.

Age. Archean dike. N. H. W.

No. 1991. Granite.

N. W. ¼ S. E ¼ sec. 26, T. 63-17, northern part of Vermilion lake, where the canoe route turns north on the east side of the channel.
Ref. Annual Report, xxiv, page 1.

Meg. Resembling outwardly the rock No. 1990, this forms a laccolith or spreading mass in the midst of the schists and granites, constituting the highest part of a knob a little back from the lake, supposed to be of the same origin and age as No. 1990.

Mic. This rock shows well the contrast between the old feldspars and the new. The old form cores which are surrounded by fresh rims, as already mentioned, and the rims interlock with their neighbors, but the old forms are seldom so thickly set as to come into contact with each other. Some *biotite*, *epidote*, *sphene* and *hornblende* are scattered through the slide, while *quartz* is abundant. One section.

Age. Archean. N. H. W.

NO. 1992. GRANITE.

Same place as No. 1991.
Ref. Annual Report, xxiv, page 2.

Meg. Coarse, granitic or pegmatitic, vein-like rock, enclosing areas of No. 1991, much lighter colored than No. 1991.

Mic. The large feldspars have a micro-perthitic structure, the later feldspar having insinuated itself along the cleavages and in other irregular fissures or points of weakness. From this microscopic form the secondary growth spreads into larger patches, and in several such it shows the *microcline* quadrillage. Microcline is also in independent larger grains. It thus appears that microcline forms a refilling for a semi-decayed or crushed feldspar. Frequently thus an old feldspar, with ragged remnants, is filled in and surrounded by a microcline border, about one-half of the area showing the quadrillage and the other not. Still it is not always plainly microcline which forms the secondary ingrowths, but a fine, thread-like feldspar scattered in minute films which become visible because of their different orientation. They extinguish simultaneously and lie approximately parallel, in two series, one of which is in the direction of the basal cleavage. The older crystal, in this case, is apparently *andesine-oligoclase*, having an extinction of 3° on n_g. The slide is entirely free from the colored bisilicates. The quartz has been much fractured and has a shadowy extinction. One section.

Age. Archean.

Remark. The old feldspars here are not so much decayed, but crushed and recemented. N. H. W.

NO. 1994. GRANITE. *(Red.)*

N. W. ¼ sec. 23, T. 63–17, north part of Vermilion lake.
Ref. Annual Report, xxiv, page 2.

Meg. Dike, three inches wide, cutting mica schist.

Mic. The rock shows but little contrast between old and new feldspars, but the whole is an interlocking mass of *feldspar* and *quartz*, with a trifling amount of chloritized *hornblende*. The feldspar is slightly colored by hematite, by weathering, and consists of *microcline*, *oligoclase* and *orthoclase*. One section.

Age. Archean dike. N. H. W.

NO. 1995. GRANITE. *(Granitized schist.)*

Same place as No. 1994.
Ref. Annual Report, xxiv, page 2.

Meg. This rock, as observed in the field, is a mica schist permeated by granitic elements.

Mic. It is not distinguishable from the last, except that it contains more chloritized hornblende. One section.

Age. Archean (granitized schist). N. H. W.

No. 1996½. Mica Schist. (*Subgranitized.*)

Same place as the last.
Ref. Annual Report, xxiv, page 4.

Meg. With many granitic segregations within the mica schist, there are also intermediate rocks, or stages of transition from schist to gneiss, and apparently to granite. This represents one of the intermediate stages.

Mic. The rock is completely crystalline, but not with a new interlocking structure; on the other hand the grains are subround and small, though exactly fitting and filling all the spaces in which they lie. The *feldspars* are much decayed by weathering, but the decay has attacked their borders first, leaving the central portions fresh, when any portion is left unaltered. In general, this decay is uniform throughout the whole grain. Thus their appearance in this respect is the reverse of that presented by the "old feldspars" already mentioned in several granites. The rock contains much *quartz* and a considerable quantity of chloritized *hornblende.* One section.

Age. Archean (schist). N. H. W.

No. 1997. Albite and Microcline.

Same place as No. 1994.
Ref. Annual Report, xxiv, page 4.

Meg. Coarse pegmatyte, consisting of pink and white feldspars and of quartz.

Mic. In a zig-zag course forms a vein in the schist, ascending a bluff twenty feet high. The pink feldspar is clearly *microcline,* and extinction on the basal cleavage of the white is 3°. Specific gravity being 2.61, in Thoulet's solution, may be somewhat increased by micaceous inclusions. It is probable, however, that the white feldspar is either *albite* or *oligoclase albite.* The long, fine, twinning striations are more like those of oligoclase than those of albite. One section.

Age. Archean (pegmatyte). N. H. W.

No. 1998. Gneiss.

N. E. ¼ sec. 22 (north side), T. 63-17, Vermilion lake, near the same place as No. 1994, about four rods west of the north-south section line between sections 22 and 23.
Ref. Annual Report, xxiv, page 4.

Meg. Forms a knoll at the lake shore, a dark gneiss, dipping north, evidently a more massive condition of the schists of the vicinity.

Mic. The darker color is due to the presence of more *hornblende,* which is also accompanied by *epidote.* The alteration of the mostly non-interlocking *feldspars,* which is prevalent, spreads irregularly over their surfaces, as exposed by the section, but still it is frequently mostly confined to the central parts, and occasionally a grain shows a distinct bordering secondary growth. The abundant *quartz* has a shadowy extinction and forms the cement for the feldspars. One section.

Age. Archean. N. H. W.

No. 1999. Granite.

Same place as No. 1998.
Ref. Annual Report, xxiv, page 5.

Meg. Granitic boss underlying No. 1998, its structure rudely conformable with it, having inclusions of schist and gneiss.

Mic. The *feldspars* are mostly distinctly interlocked with each other, but the *quartz*, which is of later origin, fills the angles and often isolated spaces within the feldspars. The weathering effect is spread uniformly through the feldspars. *Epidote*, *sphene* and *hornblende* are in small amounts. One section.

Age. Archean.

Remark. Some discussion of the structural relations of the granites and schists at this point, on Vermilion lake, may be found on pages 2–11 of the Twenty-fourth Annual Report, based on the facts of field observation. N. H. W.

No. 2001. Diabase.

From a dike, sec. 14, T. 63–18, two and a half feet wide, cutting the face of the bluff and running E. N. E., Vermilion lake.
Ref. Annual Report, xxiv, page 8.

Meg. Fine grained near the centre of the dike.

Mic. The *augite* has so small an optic angle that the interference figure in convergent light has an action and appearance resembling that of a uniaxial mineral, thus allying this diabase with some of the gabbros of the Keweenawan (Nos. 291, 297). It gives the positive sign with the mica plate, n_g being in the acute optic angle, but its elongation is negative, *i. e.*, n_p forms a smaller angle with the vertical crystallographic axis than n_g, a fact which shows that it is allied to *ægyrine*.* This augite is rarely ophitic with respect to the feldspars of the second generation, the first feldspars having evidently also preceded, but being so few as to not come into contact with the augite. *Magnetite* in scattered grains, *sphene* in a few irregular grains, calcite and *pennine(?)* filling large idiomorphic crystal spaces which may have been once occupied by olivine, are the only other ingredients. One section.

Age. Keweenawan (?)

Remark. The slide presents the appearance of a rock whose individual crystals, probably once in ophitic relation, have been broken up into many angular individuals with varying orientation, this being due apparently to the exigencies of flowage

* *Minéralogie de France*, vol. 1, p. 568.

in a narrow fissure. The angularity of these individual grains is in marked contrast with the roundness of the grains in muscovadyte or noryte, which have been attributed to the peripheral flowage and contact of the gabbro on the older rocks.

N. H. W.

No. 2002. Zirkelyte.

From the contact edge of the same dike as No. 2001.
Ref. Annual Report, xxiv, page 8.

Meg. Fine, dark, somewhat rusty on the contact surface.

Mic. The grain is so fine that much of it appears to be simply a devitrified glass. The *augites* are separated into several parts, though lying adjacent, the parts having separate orientations, and similar parts, though smaller, and globular, are thickly disseminated everywhere in the slide, so fine that their united marginal reflections produce the darkness that the slide presents between the nicols. One section.

Age. Keweenawan(?) N. H. W.

No. 2005. Gneiss.

N. E. ¼ sec. 13, T. 63–18, opposite the two small islands at seventy-five feet above Vermilion lake, near the shore.
Ref. Annual Report, xxiv, page 9.

Meg. Gray gneiss.

Mic. With a sprinkling of *biotite* and *hornblende,* this rock consists of considerably altered *feldspars* and of *quartz,* the distribution of the alteration being irregular, due in large part to recent weathering. There is no general distinction between old and new feldspars, though some are much more decayed than others. One section.

Age. Archean. N. H. W.

No. 2006. Amphibolyte.

Associated with No. 2005.
Ref. Annual Report, xxiv, page 9.

Meg. Hornblendic, dark.

Mic. More than one-half of this rock is composed of green *hornblende.* The rest is composed essentially of a feldspathic element which is so crowded with impurities that its crystalline structure is wholly lost. This substance fills the angles between the hornblendes and occasionally enters them after the manner of corrosion bays in quartz of a quartz-porphyry. There are several pieces of *sphene* and one corroded crystal of a *pyroxene.* One section.

Age. Archean. N. H. W.

No. 2008. Amphibolyte.

From large boulders, evidently derived from rock in place not far distant. N. E. ¼ sec. 13, T. 63–19, same place as No. 2005.
Ref. Annual Report, xxiv, page 10.

Meg. Dark, coarse, the conspicuous hornblendes lying in a sparse, fine, pinkish feldspathic matrix.

Mic. The *hornblende* is so abundant as to interlock with itself and with the *microcline.* It embraces grains of *epidote* and of *sphene,* and a small amount of crumpled *biotite.* One section.

Age. Archean(?) (boulder). N. H. W.

No. 2010. QUARTZ-PORPHYRY. *(Esterellyte?)*

Small island, east side of sec. 20, T. 62–15, south side of Vermilion lake.
Ref. Annual Report, xxiv, page 12.

Meg. Two pebbles (Nos. 2010 and 2011) in the conglomerate forming this island, lying adjacent, have different outward appearance, this being finer than the other.

Mic. In a fine groundmass lie large crystals of *feldspar* and a few of *quartz.* The feldspar crystals are uniformly triclinic and conspicuously twinned on the albite and pericline plans, and on the Carlsbad(?), the last consisting of the connection of one or two small crystals apparently on the plane 010 of a larger one, in a manner similar to the twinning of some of the feldspars in the schist of Kekequabic lake. These feldspars are all much and evenly decayed, and are thickly sown with particles of *calcite* and of *sericite.* They frequently have their own crystalline forms, but there are many parts of crystals of all sizes, running down to the matrix, and in the matrix can be seen forms that show a gradual disappearance of some of the smaller feldspars by the growth of a fine granular secondary substance identical with that seen in the schists of Kekequabic lake, but usually somewhat less observable. This secondary growth has slightly affected the borders of the larger feldspars, giving them a differently extinguishing narrow fringe which is interlocked with the contiguous fine groundmass; and it is evident that the groundmass or finer cement consists very largely, if not entirely, of this secondary generation of a granulitic matrix, as it is intimately and universally interlocked, the small grains not being round altogether, but sometimes elongated in a feldspathic manner. It contains very little if any quartz; indeed, it is impossible to affirm that it contains any quartz. The larger grains of quartz, comparable with the larger feldspars, are quite evident, but quite few. One section.

Age. Upper Keewatin (pebble in). N. H. W.

No. 2011. QUARTZ-PORPHYRY. *(Esterellyte?)*

Same place as the last.
Ref. Annual Report, xxiv, page 12.

Meg. Granular, coarser than No. 2010.

Mic. This rock is coarser, has larger and more numerous *quartzes,* and larger feldspars, and a finer cement, but in all other respects it is quite similar to rock No.

2010. The large quartzes are much broken and the fragments lie adjacent, while a wavy extinction passes over them all. Between these parts is a granular cement appearing to be of quartz or quartz and feldspar, but a little coarser than the cement of the rock at large. This pebble, as seen in the thin section, has a distinct schistosity in the direction in which the fragments of the broken quartzes are separated from each other, and it has more abundant and coarser scales of *sericite*. One section.

Age. Upper Keewatin (pebble in).

Remark. These rocks may be compared with others of the Stuntz conglomerate, Nos. 2017 and 2018. These are pebbles that lie in and form parts of that conglomerate. They have a strong resemblance (especially No. 2010) to rocks Nos. 1789 and 2095 (seen at Ely), which are intrusives in the Lower Keewatin. No. 2011 itself appears to be a clastic rock. N. H. W.

No. 2012. "Quartz-Porphyry." *(Graywacke.)*

From the extremity of the point nearest the same small island, Vermilion lake. The rock in general is a conglomerate.

Ref. Annual Report, xxiv, page 12; Final Report, vol. iv, pages 530–532.

Meg. Fine grained, light colored, apparently "quartz-porphyry."

Mic. This rock is like No. 2011, except that it contains much more *calcite*, through greater alteration of the *feldspars*. It also shows remnants of *hornblende* in form of *actinolite* in fibrous, lengthened shreds, and some brightly polarizing scales of *sericite*. Fine particles, and groups of particles, resembling dark *leucoxene*, are visible in ordinary light. One section.

Age. A stratum of the Stuntz conglomerate. N. H. W.

No. 2013. Quartz-Porphyry. *(Sheared.)*

On the point, in section 20, a little further west than No. 2012, Vermilion lake.

Ref. Annual Report, xxiv, page 12; Final Report, vol. iv, page 531.

Meg. In contrast with No. 2014, the two being pebbles in the conglomerate.

Mic. Owing to shearing pressure the feldspars and quartzes are considerably broken and separated. There seems to have been formerly a hornblendic element in this rock, but it is lost by the dynamic action to which the conglomerate has been subjected, only traces remaining in the form of elongated chloritic streaks which are isotropic. These are frequently associated with greater amounts of *sericite*. *Leucoxene* appears in formless clusters of particles as in the foregoing. One section.

Age. Pebble in Upper Keewatin. N. H. W.

No. 2014. Feldspar Schist.

Same place as No. 2013.

Ref. Annual Report, xxiv, page 12; Final Report, page 531.

Meg. This pebble lies in contact with No. 2013. It is finer grained than No. 2013 and schistose.

Mic. This is so micaceous and fine and so charged with *calcite* that it might almost be styled a sericitic schist. Still there are crystal forms of feldspar as well as quartz well preserved. One section.

Age. Pebble in Upper Keewatin. N. H. W.

No. 2016. Graywacke.

From the same place as No. 2013, but further south on the point.
Ref. Annual Report, xxiv, page 12.

Meg. From the country rock at large.

Mic. This is a clastic made up of small pebbles of rock like the foregoing pebbles, and of feldspar and *quartz* crystals, embraced in a finer debris of the same kind, the whole much altered. This rock presents an interesting contrast with the foregoing pebbles which have a general similarity and can be referred to the same general source. This is plainly a composite rock. One section.

Age. Upper Keewatin.

Remark. The feldspars in this fragmental are obscured and often nearly lost by the introduction of fine granular substances. This change is akin to that seen in the alteration of feldspars in the Ogishke conglomerate. N. H. W.

No. 2017. Quartz-Feldspar Schist.

From the same place as No. 2016.
Ref. Annual Report, xxiv, page 13.

Meg. A pebble from the conglomerate.

Mic. This slide is like No. 2013, etc. The feldspars, however, are not so well preserved. The rock is evidently of the same nature and origin. Appears to be a clastic rock. One section.

Age. Pebble in Upper Keewatin. N. H. W.

No. 2018. Quartz-Feldspar Schist.

Same place as No. 2016.
Ref. Annual Report, xxiv, page 13.

Meg. Pebbles from the same.

Mic. This pebble has considerable *quartz* in the fine matrix surrounding the *feldspars*, and the feldspars are nearly destroyed. There are areas evidently once occupied by feldspars that are hardly separable from the surrounding rock material. They show sometimes a greater or a smaller number of microlitic secondary particles, or the particles are larger, or arranged in lines at variance with the surrounding rock; and sometimes such secondary particles appear as if somewhat dependent on the direction of original cleavages in the feldspar which has been lost. One section.

Age. Pebble in Upper Keewatin. N. H. W.

No. 2019. Pebbles.

"Pebbles in contact near the lake, on the east side, showing remarkable differences; one lot (a) are coarse and specked by white feldspars in a greenish matrix, and another lot (b) are very fine grained." Near the same place as No. 2016.

Ref. Annual Report, xxiv, page 13.

Meg. "The first specimen (a) appears to be a quartz-porphyry with small porphyritic quartzes and numerous feldspars. The matrix is very fine grained and dark colored. The second specimen (b) is a very fine-grained, gray, siliceous rock. No section.

Age. Pebbles in Upper Keewatin. U. S. G.

No. 2020. Graywacke.

Same place as No. 2016.

Ref. Annual Report, xxiv, page 14.

Meg. Fine grained layer ten feet thick, overlying a bed of conglomerate conformably.

Mic. Even grained assemblage of *feldspar* and *quartz* fragments, lying in a scant matrix of *sericite* and debris of the same sort. Much of the apparent matrix has resulted from a granulitic alteration of some of the finer feldspars, as in No. 2018. One section.

Age. Upper Keewatin. N. H. W.

No. 2021. Graywacke.

The same place.

Ref. Annual Report, xxiv, page 14.

Meg. At ten feet from the conglomerate. Forms a bed ten feet thick.

Mic. Essentially the same as No. 2020; more evidently some of the feldspar fragments have taken on the fine granulitic alteration structure seen in many cases in the feldspar grains of the Ogishke conglomerate, thus resembling devitrified glass. One section.

Age. Upper Keewatin. N. H. W.

No. 2022. Greenwacke. *(Sheared.)*

Same place as No. 2016.

Ref. Annual Report, xxiv, page 14.

Meg. Forms a conformable layer two feet thick. Greenish, slightly fibrous, but containing pieces or pebbles of rock like No. 2013, etc.

Mic. This is one of the sheared, altered fragmentals which at first must have contained a considerable amount of some ferromagnesian mineral which now is altered to a chloritic mineral. In the midst of this are some evident feldspar forms and many not so evident, since they are replaced by the usual finely granulitic secondary growth already mentioned, and at the same time very much *calcite* has been deposited. One section.

Age. Upper Keewatin. N. H. W.

No. 2023. Graywacke.

Same place as No. 2016.
Ref. Annual Report, xxiv, page 14.

Meg. Overlies No. 2022; one of the series of clastic material.

Mic. This is also slightly greenish, much altered, sheared and calcified. It contains a few old feldspar forms, but in general the whole rock is darkened between the nicols by chloritic alteration. One section.

Age. Upper Keewatin. N. H. W.

No. 2024. Graywacke.

Same place as No. 2016.
Ref. Annual Report, xxiv, page 14.

Meg. Overlies No. 2023; twenty or more feet thick.

Mic. This rock is like No. 2020, a rather even-grained graywacke, but there were evidently pebbles of feldspar that have disappeared as feldspar by the formation of the same granulitic fine secondary substance (micro-granulitic) seen in numerous cases in the Ogishke conglomerate. One section.

Age. Upper Keewatin. N. H. W.

No. 2025. Argillyte and Graywacke.

Across the little bay in sec. 20, T. 62–15 (*i. e.*, on the east side of the bay), Vermilion lake. Sinuous alternations of black slate with graywacke, a little southwest from the cliff near the extremity of the point.
Ref. Annual Report, xxiv, page 15.

Meg. Black slate, rigid, and graywacke in contact.

Mic. The graywacke consists, as usual, of a rather uniform grain of feldspar and quartz, the former much altered, lying in a finer debris of the same, which debris is now changed, with much of the larger feldspar grains, to an interlocking fine plexus. There are a few of the larger grains of this feldspathic material embraced within the slaty portion of the slide near the line of separation. The slaty portion is quite different when viewed in natural light. While it is apparent that there is a small amount of the same feldspathic material running through this dark mass, even including a few scales of *sericite,* the slate consists essentially of a single other substance, which it is difficult to determine. It has a high refractive index, and being very fine and granular, it gives a darkness to the microscopic field which, with low power, is almost that of an isotropic substance. It may be a mixture of *epidote, chlorite* and *hornblende* with *leucoxene.* One section.

Age. Upper Keewatin.

Remark. This "black slate" was supposed, when collected, to be allied to the jaspilyte, and to be a large fragment from the Lower Keewatin involved with the graywackes of the Upper Keewatin, but its composition is rather like the graywackes, and it is hence a portion of the Upper Keewatin, considerably broken and folded. It has not a single element of the jaspilyte. N. H. W.

No. 2026. Graywacke.

Stuntz island, Vermilion lake.
Ref. Annual Report, xxiv, page 15.

Meg. Pebble from the conglomerate, lying in contact with No. 2027.

Mic. This rock is like that numbered 2016, and the description need not be repeated. One section.

Age. Pebble in Upper Keewatin.

Remark. This being a pebble in the Stuntz Island conglomerate, and itself apparently a clastic rock, is an indication that the Stuntz Island conglomerate is nonconformable on some graywackes. N. H. W.

No. 2027. Graywacke.

Stuntz island, Vermilion lake.
Ref. Annual Report, xxiv, page 15.

Meg. Pebble lying in contact with No. 2026.

Mic. This pebble is a graywacke and consists almost entirely of distinct coarse fragments of *feldspar* of different kinds and of *quartz*, the cement between them being *calcite* and *sericite*, with less of the debris that appears in the graywacke on the point in section twenty, which is simply a downward gradation in size of grains like the coarser fragments. In that respect it is like No. 2026. One section.

Age. Pebble in Upper Keewatin. N. H. W.

No. 2030½. Tuff.

On the International boundary, at the ridge over which the trail passes between Otter Track and Oak lakes.
Ref. Annual Report, xxiv, page 18.

Meg. Green, coarse, appearing somewhat like a graywacke. This ridge prevents Hunter's island from being an island. It is apparently only a variation of the rock that forms the shores of Knife lake and Otter Track lake, but differs from ordinary graywacke.

Mic. This interesting rock has an alliance with the tuffs of Kekequabic lake, but it is more characteristically a tuff than any yet seen from that region. It contains large pieces (microscopic) of zirkelyte, in which, however, are idiomorphic crystals of green *hornblende*, faintly zoned by a narrow rim visible occasionally, and of *pyroxene*. Throughout the slide, in which is also much zirkelyte, are isolated pyroxenes (*augite*) and *quartzes*, and occasionally an area of feldspar in which there is plainly a coarse fibrous and radiated structure, the elongation being negative, *i. e.*, parallel to n_p. There are also sub-round masses apparently of diabase porphyryte in which the little feldspars stand in divergent positions. One section.

Age. Archean (Upper(?) Keewatin). N. H. W.

No. 2031. GRAYWACKE. *(Arkose.)*

N. E. ¼ sec. 24, T. 66–6, Oak Lake portage to Saganaga lake.
Ref. Annual Report, xxiv, page 18.

Meg. Coarser-grained portion of the rock near the landing at Saganaga lake. Appears like granite, but varies from coarse to fine in not very evident alternations. Greenish gray and gray. (Compare No. 322.)

Mic. *Feldspar* and *quartz* in a mixture like a graywacke with a cement like that of No. 2027, *i. e.*, largely of *sericite* and *calcite*. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 2032. GRAYWACKE. *(Arkose.)*

Same place as No. 2030.
Ref. Annual Report, xxiv, page 18.

Meg. Some of the finer portion of the same rock.

Mic. This rock differs from the last in having fewer of the entire crystals, or large fragments, and a very abundant supply of the finer detritus. One section.

Age. Archean (Upper Keewatin).

Remark. The rock at this portage has been mentioned as granite by several geologists. N. H. W.

No. 2033. GRAYWACKE.

Apparently as fragments in rock like Nos. 2031 and 2032. In Ontario, about two rods north of the portage (which is in S. E. ¼ N. E. ¼ sec. 24, T. 66–6 W.) between Oak and Saganaga lakes.
Ref. Annual Report, xxiv, page 19.

Meg. Apparently similar to Nos. 2031 and 2032, but very much finer grained. The rock is of a light yellowish-green color, but weathers to a brown. One side of one of the specimens shows a small area of coarse-grained rock. No section.

Age. Archean (Upper Keewatin). U. S. G.

No. 2035. GRAYWACKE.

About five rods east of No. 2034; in Ontario. From a surface which appears to be ripple marked.
Ref. Annual Report, xxiv, page 20.

Meg. Similar to No. 2032, but more weathered and consequently yellowish in color. No section.

Age. Archean (Upper Keewatin). U. S. G.

No. 2037. GRAYWACKE.

Below the ripple marks; same place as No. 2035.
Ref. Annual Report, xxiv, page 20.

Meg. Similar to the general rock here (Nos. 2031 to 2036), but somewhat finer grained than usual, and showing rusty specks. No section.

Age. Archean (Upper Keewatin). U. S. G.

No. 2038. CONGLOMERATE.

East shore of Oak lake, in Ontario, and about 200 paces north of the portage mentioned under No. 2033.
Ref. Annual Report, xxiv, page 20.

Meg. Coarse, gritty rock, similar to No. 2031, but containing a few sub-rounded quartz pebbles about half an inch in diameter. No section.

Age. Archean (Upper Keewatin). U. S. G.

No. 2043. GRAYWACKE. *(Slaty.)*

East side of the little bay in sec. 24, T. 66-6, Saganaga lake.
Ref. Annual Report, xxiv, page 21.

Meg. Fine grained, gray, weathering yellowish, in conformable contact with recomposed granite, and interstratified with it, appearing slaty.

Mic. A fine fragmental slate or graywacke. With a few angular grains of *quartz* is much of *calcite* and still more of an ill-defined, dirty-gray substance whose nature it is difficult to determine, but which is a common product of fine trituration of the debris of crystalline rocks, embracing apparently more of the ferromagnesian elements than the lighter colored strata adjacent. In higher power this is somewhat resolved into *quartz*, *mica*, *calcite* and apparently some iron oxide, the last giving color to the rock. One section.

Age. Archean (Upper Keewatin). N. H. W.

No. 2044. GRANITE.

Northeastward from the last across the strike; N. E. ¼ S. W. ¼ sec. 19, T. 66-5.
Ref. Annual Report, xxiv, page 21.

Meg. In a ridge of granite, evidently the source of the debris of Nos. 2032 and 2043.

Mic. The grains all interlock, but the feldspars are all much altered by weathering. It is noticeable that this decay is uniform throughout the large crystals, and consists in the formation of myriads of scales of mica and irregular forms or clusters of *calcite*. This decay thus contrasts with the decay seen in the "old feldspars" seen in the granite of Kekequabic lake. Still there is occasionally a narrow zonal band about some of these feldspars which is less affected by the prevalent decay. One section.

Age. Archean (granite). N. H. W.

No. 2045. GRANITE. *(Weathered.)*

Same place as the last, but nearer the graywacke.
Ref. Annual Report, xxiv, page 22.

Meg. Granite, which shows the ferromagnesian mineral altered to a straw yellow, laminated nacreous mineral.

Mic. This mineral is not pleochroic perceptibly, and has n_p perpendicular to the lamellæ, which are numerous and not entirely parallel, some of them being hardly transparent. It seems to be *muscovite* altered from *biotite*, a condition of the dark element of the granite. One section.

Age. Archean (granite). N. H. W.

No. 2046. Granite *(with fluor)*.

From Fluor island, in Saganaga lake, near the centre of sec. 14, T. 66–5. On the east side of the island, south of the large quartz vein.

Ref. Annual Report, xxiv, page 22.

Meg. Blue *fluorite* is disseminated more or less in the mass of the granite, which is red, some of the cubes being half an inch on the side. The cubic form does not, however, generally appear.

Mic. The section does not happen to cut any of the large fluorite grains, but a few small irregular ones are visible. The rock in general is highly feldspathic and contains *hornblende* and *quartz*. The feldspars have been much altered and reconstructed by secondary feldspars, both in the form of zonal and of micropegmatitic interpositions, and occasionally by *microperthitic*, accompanied by the development of some *microcline*. Later a weathering decay has developed *calcite* and *muscovite*. The small *fluorite* grains are of a faint amethystine color, and frequently are included within the feldspars in specks and in spreading, spider-like forms. A few grains of *sphene* are also in the feldspars. One section.

Age. Archean (granite). N. H. W.

No. 2047. Greenstone and Granite.

Greenstone ridge on the south side of West Sea Gull lake, N. W. ¼ N. E. ¼ sec. 17, T. 65–5 W. The greenstone is cut by granite dikes.

Ref. Annual Report, xxiv, page 23. See, also, Annual Report, xx, page 83, Nos. 648G to 650G.

Meg. The hand sample shows the contact between the greenstone country rock and the granite dike. The two rocks are firmly cemented. The greenstone is a compact rock appearing like a fine-grained diabase. The granite is a white, fine-grained aplýte, composed of quartz and feldspar with a very little biotite and probably also muscovite. No section.

Age. Lower Keewatin cut by granite. U. S. G.

No. 2048. Quartzyte. *("Chalcedonic.")*

At the portage in sec. 12, T. 65–4, Saganaga lake.

Ref. Annual Report, xxiv, page 23; American Journal of Science, series 3, vol. xli, pages 386–390.

Meg. So-called chalcedonic silica; appearance like that at Tower, embraced in the granite.

Mic. The quartz grains are very fine, but they have a structure of elóngation, so that the mass has a roughly fibrous aspect. Within the quartzyte mass, however, are a few feldspathic grains, one being distinctly of *microcline*, while other grains are of *calcite*. The appearance of elongation is due not so much to the elongation of the individual *quartz* grains as to their rather uniform orientation in belts that run roughly parallel, causing light and dark to alternate in belts on rotation. One section.

Age. Inclusion in the Archean granite of Saganaga lake. N. H. W.

NO. 2049. QUARTZ. *(Vein.)*

Within a few feet of No. 2048, in the Saganaga granite.
Ref. Annual Report, xxiv, page 23.

Meg. Vitreous quartz from a vein.

Mic. This has a remarkable contrast with No. 2048, being in large plates that have the characteristic uniform polarization and extinction. One section.

Age. Vein in Saganaga granite.

Remark. The differences which these quartzes present indicate different origins or different histories, and perhaps both. No. 2049 is plainly from an ordinary vein of quartz, and so it appears in the rock in place. No. 2048 has not the form nor manner of a quartz vein in the rock, but rather of an irregular patch, and under the microscope it has none of the characters of vein quartz. N. H. W.

NO. 2050. GRANITE.

Same place as Nos. 2048 and 2049.
Ref. Annual Report, xxiv, page 23.

Meg. Granite in which occur the foregoing quartzes.

Mic. This is an ordinary, but considerably altered, granite, containing *epidote* (included occasionally within the feldspars), *hornblende*, *sphene*, with the usual *feldspars* and *quartz*. One section.

Age. Archean (granite). N. H. W.

NO. 2051. DIABASE. *(Porphyritic.)*

S. E. ¼ sec. 24, T. 65-4 W., west from Gunflint lake. From the high, isolated hill north of the railroad: forms a sill.
Ref. Annual Report, xxiv, page 26. (Compare Part I, page 66.)

Meg. Diabase with coarse, sporadic feldspar crystals and with larger groups of finer crystals which form feldspar rock or anorthosyte.

Mic. The *pyroxene* is converted mostly, but not wholly, to *hornblende*, which shows still the ophitic relation to the smaller feldspars. The large feldspars are considerably affected by the development of mica. The specimen collected is illustrated by plate IV, figure 2. One section.

Age. Cabotian. N. H. W.

No. 2052. Siderytе.

From the prominent hill near the centre of sec. 24, T. 65–4 W.; west of Gunflint lake.
Ref. Annual Report, xxiv, page 27.

Meg. A medium-grained, gray rock, in places showing fine bandings; effervesces freely in cold hydrochloric acid; weathers rusty. Is apparently composed of siderite, calcite and actinolite, the first in large amount and the last in fine star-like rosettes. Compare Nos. 437 and 1289.

Mic. A thin section made by Dr. Otto Kuntze shows this rock consists apparently only of *siderite* and *actinolite* (or cummingtonite). In the former are many globular grains of siderite, a feature that has been seen to characterize several of the secondary minerals generated by metamorphism. The latter mineral is prevailingly in sheaves that spread at each end, but sometimes from one end a ramifying lot of fibres extend further and make connection with similar extension from some other sheaf. The rock is like No. 1289, and is allied to No. 437, and both are from the iron-bearing member of the Animikie. *Magnetite* dust is thick in spots, rendering some of the siderite nearly opaque.

Age. Animikie (iron-bearing member). N. H. W.

No. 2053. Actinolyte. *(Rock; zirkelyte.)*

N. W. ¼ S. E. ¼ sec. 24, T. 65-4 W.; west of Gunflint lake.
Ref. Annual Report, xxiv, page 27.

Meg. The rock is full of spherical masses which vary from one-eighth to one-half inch in diameter. They are very distinct on weathered surfaces, but on fresh fractures are hardly discernible. The spherical masses resist the effects of weathering much better than the interstitial material. The whole rock is quite fine grained and is greenish-gray in color, the spherical masses being a little darker colored than the rest of the rock. There is some carbonate present, probably calcite, as the rock effervesces a little in cold hydrochloric acid, and probably also siderite, as the rock on weathering turns yellowish with iron oxide. This rock is developed in the Animikie in connection with a horizontal fault plane or slip in which is a coarse breccia.

Mic. In ordinary light the spherical masses in the slide are quite distinct, and sometimes they are partially outlined by an area which contains considerable yellow iron oxide. The interstitial material, which is not abundant, is lighter colored than the spherical masses, and seems to have lost considerable in the grinding of the slide. Under crossed nicols the spherical masses are not very distinct, and the whole section breaks up into a closely matted mass of minute amphibole fibres, which appear to be grünerite-cummingtonite. One section.

Age. Animikie (iron-bearing member). U. S. G.

Remark. In some parts this rock is finely scoriaceous; indeed, the interstitial areas between the spherical masses are uniformly porous. The balls that present their outlines on the weathered surfaces resemble the balls that weather out from the lava sheet seen on Grand Portage island (No. 544), which is more or less glassy. There seems more reason to refer this rock to the igneous parts of the Animikie than to the fragmental. Its intimate connection with the iron-bearing member of the Animikie, into which it passes, is very significant. The spherical masses in this rock, consisting largely of actinolite, are comparable to the rosettes of actinolite in No. 2052.

Two additional sections of this rock were made by Dr. Otto Kuntze, one (a) from the balls, in such a manner as to cut two or three balls, showing at the same time some of the intervening rock-matter, and (b) from a part of the rock forming a thin layer (one-fourth of an inch) not embracing the balls, but immediately in contact with the balls. The former shows the intervening rock-matter is isotropic, with a few isolated grains that are evidently rusty siderite, greenish and apparently resulting from devitrification and alteration of a basic glass; the latter (b) is in part of the same material as that intervening between the balls but also contains a notable amount of siderite, and apparently fibres of some amphibole. The glassy part of (b) is in detached masses, which are so crowded with irony oxides as to be nearly opaque. These detached glassy masses also contain a few minute translucent spots that, so far as determinable, appear to be of siderite.

It hence appears that the balls are globules originating in a basic lava at the time of cooling, and the material that embraces them is a devitrified part of the same lava. It is also plain that this lava has become charged with iron, chiefly in the form of siderite. It appears also that this altered lava contains darker masses of opaque finer lava which are charged with oxide of iron rather than the carbonate. Thus the iron-bearing member of the Animikie at Gunflint lake is intimately associated with and grades into a basic devitrified lava. Compare Part III. N. H. W.

No. 2054. Gabbro.

Same rock mass as No. 2051.
Ref. Annual Report, xxiv, page 27.

Meg. Presenting large, dark, crystal surfaces.

Mic. The rock, though from the same mass as No. 2051, can here hardly be said to be ophitic, and deserves hence the name gabbro. It is not porphyritic with earlier feldspars, but all the feldspars and the augite seem to have formed nearly simultaneously. *Magnetite* forms large and conspicuous tabular crystals. Pyroxene is changed to *uralite.* One section.

Age. Cabotian. N. H. W.

No. 2055. Mica Schist *(with cordierite.)*

From the west end of Loon lake (south of Gunflint); face of an obliquely ascending cliff which faces north, at two-thirds the distance toward the top.
Ref. Annual Report, xxiv, page 27.

Meg. Fine-grained, siliceous, supposed to be a portion of the Animikie.

Mic. The groundmass is of fine interlocking *quartz*. There are two micas, viz., *biotite* and *muscovite*, the latter of later origin than the biotite and the quartz which form inclosures within it. The muscovite forms larger plates than the biotite and by its colorlessness and its high double refraction is easily remarked. The biotite is usually older than the quartz. *Pyrite* in scattered small grains is quite abundant. Among the interlocking quartzes is occasionally a grain of a striated *feldspar*, while larger grains of low birefringent power have characters that show *cordierite*. One section.

Age. Animikie. N. H. W.

No. 2056. Quartz Schist.

Same place, same bluff, but higher up, toward the gabbro.
Ref. Annual Report, xxiv, page 27.

Meg. Siliceous, but fine grained.

Mic. Mostly quartz, but much coarser than in the last. There are many feldspathic grains indistinctly triclinic, but so much weathered that they are completely dimmed by microscopic inclusions. They sometimes lie within the quartzes, but usually they share in the interlocking plexus. *Biotite* is not very conspicuous, but varies from brown to greenish gray in small scales. One section.

Age. Animikie. N. H. W.

No. 2057. Quartzyte.

Same place, same cliff, still higher, 150 feet ± above the lake, near the top of the ridge, dipping 60° to 70° southerly.
Ref. Annual Report, xxiv, page 28.

Meg. Fine grained and gray, siliceous.

Mic. *Quartz*, principally, but mingled with *plagioclase* and with *biotite*, composes this rock, including also a little pyrite. The feldspars are decayed by weathering. One section.

Age. Animikie. N. H. W.

No. 2058. Gabbro. *(Ophitic.)*

Same place, 150 feet south of the foregoing, but not much higher.
Ref. Annual Report, xxiv, page 28.

Meg. Coarse, gray.

Mic. The *magnetite* in one instance is surrounded by a fringe of brown *biotite* which penetrates the surrounding feldspars as if it were of older date. The *olivine* is quite fresh, about cotemporary with the feldspars and apparently *fayalite*. The *augite* shows a diallage structure in a few grains, and frequently surrounds the olivines. One section.

Age. Cabotian. N. H. W.

No. 2059. Quartzyte.

Same place as No. 2057.
Ref. Annual Report, xxiv, page 28.

Meg. Another phase of the fragmental rock.

Mic. As in the other contact rocks at this place the original *quartz* is entirely re-wrought, so that no clastic structure remains. There are a few *feldspars*, but dimmed by inclusions presumed to be due to weathering, and a subordinate amount of *biotite*. One section.

Age. Animkie.

Remark. It is worthy of remark that the clastic structure of the quartz has given place universally, as in the Pewabic quartzyte, to an interlocking granular plexus, in which are a few grains of triclinic feldspar. Instead of pyroxenic minerals the contact here has produced mica. Whether at points near the gabbro the same or similar ferromagnesian minerals would make their appearance at this place, there is no means of stating, as the immediate contact was not seen. N. H. W.

No. 2060. Quartzyte. *(Gneissic.)*

Same place.
Ref. Annual Report, xxiv, page 29.

Meg. A coarser rock, presenting a gneissoid aspect.

Mic. The rock is essentially the same as the foregoing, but it exhibits a greater variation in size amongst the *quartz* grains. The same is true also of the *feldspars*. Thus the rock approaches a perfect granitic structure. In this slide the *biotite* is associated intimately with *pennine*. One section.

Age. Animikie. N. H. W.

No. 2061. Mica Schist.

At a point a little further east (southwest end of Loon lake).
Ref. Annual Report, xxiv, page 29.

Meg. A part of the less siliceous portion of the Animikie, but very fine grained; "black rock."

Mic. The rock is in all respects like the foregoing except being finer. The *biotite* micas are older than the interlocking *quartz*, but the *muscovite* is later. One section.

Age. Animikie.

Remark. It is evident that these clastic beds belong to the upper part of the Animikie. N. H. W.

No. 2064. Gabbro *(with olivine)*.

The rock of the great sill at mount Reunion, forming the summit, Rove lake.
Ref. Annual Report, xxiv, page 30.

Meg. Medium grained, from one of the fallen blocks.

Mic. The *augite*, *olivine* and *feldspar* were formed about simultaneously, but occasionally the augite surrounds the olivine. There is considerable magnetite, which was later than the feldspars and olivine. While most of the augite is granular, some is ophitic, as if there had been two dates at which it was generated. There is also some quartz which enters the feldspar in a granophyric manner (Plate V, figure 6). One section.

Age. Cabotian.

Remark. This is one of the largest known sills and can be traced, with interruptions, as far as to Arrow river, where it seems to have its strike into Canada, although it appears (as supposed) in similar hills further east along the boundary. Its thickness is about 100 feet at mount Reunion. N. H. W.

No. 2065. Gabbro.

Eastern part of Rove lake. From a sill near the water on the south side; one and one-half miles east of mount Reunion.
Ref. Annual Report, xxiv, page 31.

Meg. Fine grained.

Mic. So far as concerns structure and composition, this rock is like that of the great sill of mount Reunion, except in being finer grained, and in having decayed so much that no olivine is preserved and the augite is mostly uralitized.

Age. Cabotian. N. H. W.

No. 2066. Diabase. *(Amygdaloidal.)*

Summit of hills just south of the conglomerate (Nos. 1902, 1903 and 1904). Probably in N. E. ¼ sec. 25, T. 64–3 E.
Ref. Annual Report, xxiv, page 35.

Meg. A fine-grained, dark-gray, diabasic rock, with chalcedonic amygdules. No section.

Age. Manitou. U. S. G.

No. 2067. Zirkelyte. *(Basalt glass.)*

Near the same place as No. 2066.
Ref. Annual Report, xxiv, page 36.

Meg. A fine-grained, light-gray, rather soft rock, looking like a decayed basic eruptive. Compare No. 1905 which somewhat resembles this rock.

Mic. The slide shows a rock that consisted very largely of basic *glass*, but now contains, along the numerous fissures by which it is parted into somewhat perlitic areas, much calcite, and frequent minute feldspar crystals which have lost their power of individual polarization by the substitution of kaolinic products of alteration. These fissure-lines are more transparent than the glass itself, which is brown, and in them are nearly all the crystal forms visible. Sometimes these fissure-lines take shapes and directions that suggest a fluidal origin at the commencement of flowage.

The brown glass, where it surrounds the little feldspar crystals, seems to be converted into a transparent glass in the immediate vicinity of the little feldspars, forming a halo of light about the crystal form, visible on the removal of one nicol, but invisible between crossed nicols. Also throughout the brown glass, when the section is quite thin, the same phenomenon is apparent, viz., the brown glass is thickly sown with spots or globules which are transparent with one nicol, and invisible with both. In both cases it is probably due to incomplete crystallization, from the glassy substance, the initial crystals or points of crystallization going no further than the globular form and remaining mono-refringent. One section.

Age. Manitou. N. H. W.

No. 2068. Diabase. *(Porphyritic and with zirkelyte.)*

Near the same place as No. 2066; a little further south.
Ref. Annual Report, xxiv, page 36.

Meg. Fine-grained, dark, diabasic rock, containing numerous large porphyritic plagioclases.

Mic. This rock is qualitatively the same as No. 2077, but its crystallization is so far advanced that as a whole it is worthy of a different name.

If it ever embraced augite, it was in coarse, ophitic crystals, but no trace of augite remains. There is, however, a nearly isotropic, greenish substance which occupies such relation to the feldspars, and may be the result of alteration of such augite. When highly magnified in strong light this green substance is resolved into a mesh of fine fibres, which are in bunches or bundles, but occasionally acquire a spherulitic radiated arrangement, with parallel extinction and positive elongation and low double refraction, all suggesting *pennine.* It is also slightly pleochroic.

The *zirkelyte* of this slide is not brown, but is blackened by segregation of specks of iron ore. One section.

Age. Manitou. N. H. W.

No. 2069. Taconyte. *(Pebbles.)*

Pebbles from the conglomerate in the hill-range south side of Puckwunge valley, south from South Fowl lake. Compare Nos. 1903 and 1904.
Ref. Annual Report, xxiv, page 36.

Meg. Reddish and somewhat taconitic in fine structure.

Mic. Two of the slides are of the peculiar quartzyte described as taconyte. The rounded pebbles that compose the main pebble are stained with *hematite*, and they vary in the fineness of the grain of the quartz of which they are composed, often seeming to be of devitrified glass or like the feldspars replaced by a fine micro-granulitic growth seen in the conglomerate of Ogishke Muncie lake. In two or three of the constituent granules are seen apparently remains of the green substance *(glauconite?)* from which the iron oxide and in part the silica are by Mr. Spurr supposed to be derived. In this case, however, these green particles are of fine *actinolite* fibres. In other cases the little rounded pebbles take elongated shapes almost inconsistent with the idea that they are of detrital beach-worn derivation. Still, the larger pebble, of which these are the minuter units, is unquestionably a pebble of such origin, constituting a part of a siliceous conglomerate.

Two other slides are of a quartz from some vein being coarsely fibrous and of positive elongation. Four sections.

Age. Pebbles in the base of the Potsdam, *i. e.*, Puckwunge conglomerate. N. H. W.

No. 2071. Graywacke.

In the valley of the Puckwunge, north of the stream, perhaps 200 feet below the conglomerate above.
Ref. Annual Report, xxiv, page 38.

Meg. Forms low outcrops on the level land. A gritty, gray rock.

Mic. *Quartz*, originally in rounded clastic grains, now made angular by secondary enlargement, and *feldspar* grains of about the same size, sometimes a plagioclase like *oligoclase*, and sometimes *microcline*, but generally unidentifiable as to species, constitute the most of this rock. These feldspars are frequently composed of a micro-granulitic mosaic (quartz and feldspar) substituted for the original feldspar, and thus resemble the feldspars of the Ogishke conglomerate, from which they may have been derived as pebbles. Besides the debris, of the nature of the grit itself, the cement consists largely of *calcite*, but also with a little secondary quartz, some *sericite* (or other mica) and a few spicules of *actinolite*. One section.

Age. Animikie.

Remark. There is a general resemblance between this grit and some portions of the Ogishke conglomerate, in its microscopic characters, but it is supposed to be a portion of the Animikie. It is occasionally in outcrop along the Grand Portage trail where it is cut, as here, by the great dikes of that region, and it has been named *Grand Portage graywacke*. Compare vol. iv, page 510. N. H. W.

No. 2073. Graywacke.

On the Grand Portage trail about a mile from the (north or) west end.
Ref. Annual Report, xxiv, page 39.

Meg. Similar to Nos. 2070 and 2071.

Mic. The same characters as seen in No. 2071, except that calcite plays no part in the cement. One section.

Age. Animikie. N. H. W.

No. 2074. Quartzyte.

Grand Portage island; near contact with a trap sheet.
Ref. Annual Report, xxiv, page 39.

Meg. A coarse, compact, greenish quartzyte or conglomerate with a dark, fine-grained cement in which are numerous rounded fragments of quartz, feldspar, quartzyte and "red rock." No section.

Age. Potsdam. U. S. G.

NO. 2078. GRANITE. *(Porphyritic.)*

St. Cloud; used for the new water-power dam at Minneapolis; also for monuments.
Ref. Annual Report, xxiv, page 39.

Meg. Coarse, often reddish, usually gray.

Mic. The large crystals are of *orthoclase*, but are closely ingrown with secondary *albite(?)* making a *microperthite*. The extinction angle of the former, on a section cut perpendicular to the axis n_g, which is perpendicular to the cleavage 010, is 5°; but on the associated albite measured on the same cleavage is 10°. In the same section these albite intergrowths are narrow, interrupted and yet substantially parallel with themselves, making an angle with the same cleavage of about 70°. Other triclinic feldspars are probably of *oligoclase*, but there is no favorable section for specifying them in the slide. In one of the orthoclases is a minute vermicular micropegmatyte of *quartz*. At the same time quartz in large grains constitutes an important portion of the rock. The dark element is mostly *biotite*, which has numerous inclusions of *apatite* and a few of *magnetite*, and others of *zircon*, about which are formed conspicuous dark aureoles. *Hornblende*, of which there is but little in the rock, is in some degree converted to *chlorite*. Within the feldspars are distributed irregularly multitudes of minute scales of *muscovite*. One of the feldspars presents a coarse, irregular structure characteristic of *microcline*, but it is cut quite obliquely. Within this crystal is also seen the same albitic intergrowth, constituting the *microcline microperthite*, of Brögger. One section.

Age. Archean (granite). N. H. W.

NO. 2090. DIABASE.

Fair sample of the "gabbro" at Short Line park, near Thomson, cut by a dike sixty feet wide.
Ref. Annual Report, xxiv, page 40.

Meg. A rather coarse-grained, diabasic rock, much altered and now composed largely of hornblende which in places is in areas which give a lustre-mottled aspect to the specimen.

Mic. The rock has a distinctly ophitic structure with uralitized augite and small feldspars. It also seems to have contained originally a considerable amount of zirkelyte, and at the same time some of the feldspars are so decayed that they consist of a confused lot of crystalliths, *magnetite, epidote, mica(?)*, and probably others, which gives them a resemblance to the zirkelyte as now devitrified.

Age. Beaver Bay diabase. Cabotian.

Remark. It is supposed that the alteration seen in this rock took place after consolidation, but prior to cooling. N. H. W.

No. 2099. Greenstone. *(Matrix of conglomerate.)*

Small island in Long lake near the west side of S. W. ¼ sec. 29, T. 63–12 W.
Ref. Annual Report, xxiv, page 41.

Meg. Rather light green, schistose, fine grained and rather soft. Some small hornblendes are scattered through the rock.

Mic. The most conspicuous and also the largest of the ingredients is *feldspar.* It appears to have been enlarged by secondary growths, as it interlocks with the grains adjacent, and its original (central) portions are altered, containing many *sericite* scales and *calcite*, which are wanting in the peripheral portions. *Quartz* is also secondary, forming some areas as large as the feldspars. Shreds of *hornblende* give a green cast to the rock. These are but slightly pleochroic. Running across the slide is a microscopic vein of fresh minerals. These are *quartz* and *striated feldspar.* These minerals interlock in the adjoining rock mass. There is much calcite and sericite in the adjoining rock, but none (or almost none) in the vein. One section.

Age. Upper Keewatin, probably of the age of the Stuntz conglomerate.

Remark. This is a wholly crystalline rock, even in its interlocking structure, and would pass for an "altered diabase," were it not for the field relations, which demonstrate beyond question that it was at first fragmental. N. H. W.

No. 2101. Conglomerate.

West shore of Long lake; S. E. ¼ sec. 30, T. 63–12 W.
Ref. Annual Report, xxiv, page 42.

Meg. The three specimens collected vary from rock resembling No. 2099 to a fine, almost flinty greenstone. These specimens evidently represent the matrix of the conglomerate. No section.

Age. Upper Keewatin. U. S. G.

No. 2102. Porphyrel. *(Sheared.)*

Same place as No. 2101 and rising in the midst of No. 2101.
Ref. Annual Report, xxiv, page 42.

Meg. Gray, feldspathic and evidently siliceous. Crushed and deformed, medium grained, appearing suddenly in the midst of No. 2101 in the manner of an isolated mass or intrusive, but not determinable as to its extent. Holds some pyrite and was originally interspersed with large feldspars, as if porphyritic.

Mic. The large feldspars, which are polysynthetically twinned, seem to be *albite*, as they have n_g in the acute angle of the optic axes and an extinction angle of 76° in a section nearly perpendicular to n_p, and $15\frac{1}{2}$° on a section nearly perpendicular to n_g. They show much fracturing and alteration, being filled with fine grains of *calcite* and *sericite*, the latter sometimes taking the form of semi-rosettes. They grade downward through fragmentary grains to small sizes. There is a comparatively small amount of *hornblende* in ragged shapes, and of *chlorite*. The most of the rock is composed of an interlocking network of finer grains of *quartz*, calcite, sericite, feldspar whose specific determination is impossible, and shreds of hornblende and of chlorite, with occasional cubes of *pyrite*. These minerals are certainly all of secondary generation, and are due to the stresses of pressure and of heat, with underground moisture, to which the originals were subjected. It is not likely that this rock was ever truly molten, but was a debris which has taken on a recrystallization, the large feldspars being the only original minerals whose forms can now be identified; and it is probable that they also were at first not albite. One section.

Age. "Intrusive" amongst the Upper Keewatin. N. H. W.

No. 2104. Dioryte.

Small island near the west shore of Long lake, N. W. ¼ S. W. ¼ sec. 29, T. 63–12 W. Apparently a condition of the prevalent greenstone.

Ref. Annual Report, xxiv, page 42.

Meg. Clean, gray, medium grained, composed essentially of white feldspar and hornblende, not showing schistose structure, but having slight, irregular cloudings of darker tint.

Mic. The minerals are *hornblende*, feebly pleochroic, with sharp fibres that extend beyond the average outlines of the grains and pierce the *feldspar* and *quartz*, and also sometimes run in the same way into the fibrous portions of other hornblendes. These fibres are certainly of secondary growth and polarize less highly than the body of the grain to which they belong. The color in the same grain may run downward from blue, or the first "sensitive" violet, through all the colors to white, the last being at the terminations of the fibres. In the same way secondary growths of hornblende appear scattered throughout the grains themselves, as shown by the white areas resembling the fibrous terminations, and occasionally the sharp fibres of one hornblende pierce the older portions of another, the structure being somewhat interrupted in its passage, but on emerging on the other side such fibres extinguish in unison with the same fibres in the parent mass. It is apparent that such penetrating fibres made their way through the older hornblende at a time of general metasomatic rearrangement, more or less complete. In their passage through the body of the old hornblende they did not perfect their crystalline structure, for they are marked by light streaks that do not wholly extinguish in an entire revolution. There are also multitudes of little hornblendes more or less globular or club-shaped scattered through the matrix.

The feldspars, which are *plagioclase*, are so darkened between crossed nicols that they cannot be determined specifically. They are frequently angular and lie in a fine matrix, much fresher, of the same materials. They are not porphyritic, but imperfect or fragmentary, and they also show narrow rims of secondary growth.

There is a little secondary *quartz* which embraces and interlocks with the feldspars, and apparently *leucoxene*, which is nearly opaque, but in reflected light is white and similar to the feldspars. One section.

Age. Keewatin.

Remark. This rock in its recrystalline condition is comparable with the granites of Kekequabic and Snowbank lakes. N. H. W.

No. 2120. Dioryte.

About 200 feet above Long lake, and from the very top of the hill west side of sec. 18, T. 63-12 W.
Ref. Annual Report, xxiv, page 43.

Meg. Medium-grained, greenish gray.

Mic. This rock exhibits an ophitic relation between the feldspars and the hornblendes, showing that its constituents crystallized from a magma, and that the *feldspar* formed first. These have suffered a complete transformation, being permeated by fine, granular elements, such as *sericite, zoisite, epidote*, so that their optic characters are wholly obliterated. Subsequently they have suffered a regeneration, and have fresh, narrow veins of secondary feldspar, and inter-lamellar growths in an imperfect micro-pegmatitic form.

The *hornblende* has secondary fibrous enlargements in a manner similar to that described in No. 2104, but far less marked. The slide also contains several small areas of *quartz* which appears to be secondary. One section.

Age. Keewatin.

Remark. In all respects, except in having an ophitic structure, this rock resembles that of No. 2104. N. H. W.

No. 2125. Dioryte. *(Probably fragmental.)*

N. E. ¼ S. E. ¼ sec. 36, T. 63-13 W., west end of Long lake. From a ridge between the quartz vein and the railroad.
Ref. Annual Report, xxiv, page 43.

Meg. A medium-grained rock of greenish-gray color, composed essentially of feldspar and hornblende, the latter being conspicuous by its size. All the grain and structure indicate a much pressed and perhaps sheared rock.

Mic. The *hornblende* is in ragged, and often chloritized, grains. It has no ophitic structure, or other relation to the feldspars that would show that it crystallized from a molten magma. Its forms and sizes are consistent with the supposition that the hornblende was a fragmental ingredient in the process of accumulation of a green debris from older greenstones, and this origin is still more strongly probable from the nature of the rest of the rock, which consists of fragments of hornblendes, tending to become rods by separations along the cleavages; of secondary *feldspars, epidote, calcite* (sometimes surrounding crystals of epidote), *sericite, zoisite*, and nearly opaque *leucoxene.* One section.

Age. Probably near the bottom of the Upper Keewatin.

Remark. Such a rock might be called dioryte, and its present condition ascribed to pressure and brecciation. Its evidently fragmental origin, however, is shown by the photograph reproduced in plate W, in volume iv. Compare, also, plate Z, volume iv, both of the final report. Compare, also, rock No. 1786. N. H. W.

No. 2126. GRAYWACKE. *(Jaspilitic.)*

Northeast corner sec. 36, T. 63-13 W. From a jaspilyte belt near the west end of Long lake.
Ref. Annual Report, xxiv, page 43.

Meg. A fine-grained, purple rock composed apparently of quartz, feldspar, hornblende (or chlorite) and a micaceous mineral. The rock resembles some of the fine-grained graywackes that have been reddened by surface fires.

Mic. A great number of small magnetite cubes are scattered through a finer matrix of chloritic and hornblendic fibres and scales, fine feldspar fragments and quartz. Some of the coarser opaque ores are of pyrite. The fine sparkling appearance is caused by reflection from magnetite crystals. One section.

Age. Keewatin (probably Lower).

Remark. In places this rock varies to a distinct jaspilyte, and as such has attracted attention as an iron ore and been traced through the country for about a mile. The rock blends with the country greenstone by acquiring more and more of the hornblendic component. The structure of this belt resembles that seen at Moose lake (No. 2180), but it is less conspicuously conglomeratic. N. H. W.

No. 2127. QUARTZ. *(Gold ore.)*

S. W. ¼ S. W. ¼ sec. 30, T. 63-12 W.
Ref. Annual Report, xxiv, page 44.

Meg. White, vitreous, vein quartz, containing several minerals, as follows: pyrite, chalcopyrite or other copper sulphides, galena, sphalerite (apparently), malachite and azurite; also some granitic masses.

An assay of this sample by Sharpless and Winchell gave the following results: .24 ounce gold per ton and 6.04 ounces silver per ton, or $4.96 of gold and $3.62 of silver per ton, gold being taken at $20.67 per ounce and silver at 60 cents. This would make the ore worth $8.58 per ton. The ore (No. 2027) is a fair sample from one of the test pits at this place, the pit which showed what appeared to be the best ore. Other assays, by the same chemists, of ore from this locality, are as follows:

	I	II	III
Gold, per ton,	5.16	.76	....
Silver, per ton.	2.93	.48	.04
Totals,	$8.09	$1.24	$ .04

No section.

Age. Vein in Archean. U. S. G.

No. 2129. Grit. (*Volcanic.*)

Taylor's Falls, corner of Government and West streets, 200 feet above the river.
Ref. Annual Report, xxiv, page 44.

Meg. Granular, siliceous, greenish, in sedimentary structures.

Mic. Named in order of abundance the ingredients of this rock are *epidote, quartz, leucoxene(?)*, devitrified *glass*; these are in rounded forms, but the rounded forms are themselves composite, especially the quartz, and made up of a great many interlocking grains. The epidote is also of irregular shape in some instances, but it has the appearance, for the most part, of having been accumulated as a part of a beach sand. There are also variable amounts of *hornblende, actinolite* (secondary fibres growing from the hornblende and piercing the quartzes) and rounded pebbles of diabase. In the last are sometimes grains of epidote, which seems to show that the epidote was generated before it was made a constituent of this grit. Much of the quartz is pneumatolitic since the accumulation of the debris. Three sections.

Age. Keweenawan. N. H. W.

No. 2129A. Grit. (*Volcanic.*)

Same place as No. 2129.
Ref. Annual Report, xxiv, page 44.

Meg. Very fine and almost flinty condition of the same rock as No. 2129.

Mic. Consists of fine angular grains of *quartz* and *epidote*. One section.

Age. Keweenawan. N. H. W.

No. 2131. Grit. (*Epidotic.*)

Taylor's Falls, 250 to 300 feet above the river.
Ref. Annual Report, xxiv, page 44.

Meg. Irregularly cavernous and associated with fine-grained epidotic and quartzose rock, somewhat resembling No. 2129, but of a different composition, as it contains also much fine, fragmental feldspar. In the midst of this is a piece of volcanic glass, now changed (excepting its minute feldspars) to an isotropic chloritic substance. One section.

Age. Keweenawan. N. H. W.

No. 2132. Diabase and Grit.

Taylor's Falls, 1,030 to 1,040 feet above the river, near the summit.
Ref. Annual Report, xxiv, page 45.

Meg. Compact diabase, more or less porphyritic, seamed by a fine, greenish rock resembling No. 2129A or No. 2131, the widest seam being three-fourths of an inch.

Mic. The slide is composed of two different rocks, viz.: very much altered (weathered) porphyritic diabase and a granular mixture of fine *quartz* and *epidote*, evidently of clastic structure and origin, the latter forming thin greenish seams in the former. One section.

Age. Keweenawan.

Remark. These greenish seams are apparently of the nature of a clasolyte, *i. e.*, clastic material which has entered fissures from above.* N. H. W.

No. 2134. GRIT. *(Breccia, volcanic.)*

Taylor's Falls, one block west of the public school building, about 175 feet above the river.
Ref. Annual Report, xxiv, page 45.

Meg. Breccia of rock similar to No. 2129.

Mic. Besides the *quartz* and *epidote* this slide contains what appears to have been a fragment of lava, now nearly opaque with *magnetite*, in which are small quartzes and epidote crystals (pseudomorphs after feldspar), with a background of quartz(?) embracing the whole poikilitically. This epidote has not so much a clastic aspect as that in No. 2129. One section.

Age. Keweenawan. N. H. W.

No. 2135. IRON ORE. *(Pisolitic.)*

Republic mine, sec. 4, T. 58–18, Mesabi Iron range.
Ref. Annual Report, xxiv, page 47.

Meg. The ore is massive, siliceous, but shows in part a pisolitic structure.

Mic. Under the microscope the taconitic structure is quite apparent, some of the round grains consisting wholly of microgranulitic quartz. One section.

Age. Animikie (iron-bearing member). Compare Nos. 1294 and 1530. N. H. W.

No. 2136. IRON ORE. *(Pisolitic.)*

Mountain Iron mine, Mesabi Iron range.
Ref. Annual Report, xxiv, page 47.

Meg. Not siliceous. Compare No. 1294.

Mic. The ore grains are frequently hollow, or are formed by two shells of ore which are connected in some places, with a vacant space, or two spaces at the centre. The general shape of the ore grains is that of the taconitic greensand. The ore is loose and soft, and crumbles readily into a finer powder or dust. The centres of the grains sometimes contain quartz. Three sections.

Age. Animikie (iron-bearing member). N. H. W.

No. 2138. TACONYTE. *(Siliceous.)*

Mountain Iron mine, Mesabi Iron range.
Ref. Annual Report, xxi, page 160, rock *b*; Annual Report, xxiv, page 47. Compare No. 1295.

Meg. The quartzyte shows inclusions of darker ingredients.

Mic. The groundwork is exceedingly fine and apparently consists, as usual, of interlocking quartz. In the groundmass are the outlines of the usual taconitic granules which are frequently stained with a little *iron* as well as by *actinolite(?)*, more or less dimmed by alteration. There are irregular areas, and particularly the

*M. E. WADSWORTH. *Report of the State Board of Geological Survey (Michigan)*, for the years 1891 and 1892 [1893], p. 130.

triangular spaces embraced between the roundish taconite grains, which are filled with much coarser secondary quartz interlocked in apparently the same manner as in the grains. The difference of texture, while marking the outlines and size of the original grains, seems to indicate that the pebbles (taconyte grains) were deposited in their present places prior to the introduction of the intergranular silica. Lastly there are narrow strips or belts of fibrous silica, apparently arranged along cracks, to which they stand perpendicular, which, having a negative elongation can correctly be styled *chalcedony*, the rest of the silica, composing the interlocking mass in general, both coarse and fine, being simply ordinary quartz, so far as observed.

In this slide are also two grains of distinctly different kind, being of quartz of foreign origin, which must have accumulated when the taconitic "greensand" was brought together. One is angular and has a single orientation. It lies in the midst of fine interlocking quartz, with which it has no sympathy, but has a surrounding coating of iron ore. The other is a round pebble of coarse interlocking quartzyte. It has distinct boundaries as a pebble, and also lies in the matrix of fine interlocking quartz. It is also coated with a film of iron, and iron enters somewhat within it. It is suddenly and boldly set off from the matrix in which it lies. So far as they go these foreign grains indicate a fragmental manner of accumulation for the original globular constituents of this rock. One section.

Age. Animikie.

Remark. The roundish taconitic grains in this rock, which is now almost wholly of quartz, are of two sorts: (1) Very fine or flinty, siliceous, resembling the quartz-feldspar mosaic of devitrified glass, and undistinguishable from flinty masses in the Animikie at Gunflint lake, as those embraced in No. 312, and like the flint of Nos. 1277 and 1295. (2) Irregularly shaped, but roundish, forms that are largely opaque with iron and still more resemble devitrified glass, or lava sand. The latter is represented in figure 3, plate V. N. H. W.

No. 2139. Quartzyte.

Mountain Iron mine, Mesabi Iron range.
Ref. Annual Report, xxi, page 160, rock *c*; Annual Report, xxiv, page 48.

Meg. Greenish-gray, fine Pokegama quartzyte, clearly striped parallel with the usual sedimentary strike of the region. Lies below the iron-bearing strata.

Mic. This quartzyte appears quite different from the foregoing from this region. It is plainly of clastic origin and structure. The grains are angular, and, while they plainly have a secondary growth which forms an interlocking mass, they are not wholly of secondary date. Mingled with them are a few grains of striated *feldspar* and *microcline* and of *muscovite*. There is in this rock no visible taconitic structure. One section.

Age. Animikie. N. H. W.

No. 2140. Quartzyte.

Mountain Iron mine, Mesabi Iron range. Same place as No. 2139.
Ref. Annual Report, xxi, page 160, rock *d*; Annual Report, xxiv, page 48.

Meg. Coarser than No. 2139.

Mic. The boundaries of the original clastic grains are marked off from the secondary additions by the usual line of colored impurities. The original grains vary considerably in size and are accompanied, as in No. 2139, by a few triclinic feldspars. Between the quartzes, and sometimes staining them within, is a gray-greenish substance which appears to be chloritized hornblende. This substance, under favorable conditions, has a slight polychroism. This hornblendo-chloritic greenish substance sometimes takes the form of a spongy, gray mass in which lie many angular grains of quartz, and sometimes it forms small spaces without containing quartzes. It then suggests the possibility of its being of the nature of devitrified volcanic ash. One section.

Age. Animikie (Pokegama). N. H. W.

No. 2141. Taconyte.

Mountain Iron mine, Mesabi Iron range.
Ref. Annual Report, xxi, page 160, rock *e*; Annual Report, xxiv, page 48.

Meg. Quartzyte, with large per cent of iron ore.

Mic. This rock is wholly of secondary origin in its present condition, the quartz forming about one-half, and interlocking in the characteristic mosaic manner of taconyte. Some of the taconitic globules are nearly wholly opaque with iron, and some are composed of an exceedingly fine mosaic of quartz undistinguishable from the flint or devitrified silicified glass of Gunflint lake, and the same as seen in No. 2138. One section.

Age. Animikie (iron-bearing member). N. H. W.

No. 2145. Greenstone Schist. *(Pebbly.)*

S. W. ¼ N. E. ¼ sec. 36, T. 64-11, Saturday lake, south from the east end of the portage from Fall lake; a low bluff.
Ref. Annual Report, xxiv, page 49. Compare rock No. 175W.

Meg. Appearing greenish, pebbly and occasionally sericitic. Pebbles mostly less than three inches in diameter, but reaching eight to ten inches.

Mic. Abundant fine grains of *epidote* lie in a chloritic, hornblendic and calcareous matrix, associated with some cubes of *pyrite.* The structure is decidedly schistose. The small glassy feldspars are of secondary generation, but the larger feldspars, plainly clastic in origin, are dim and decayed. One section.

Age. Archean (Keewatin). N. H. W.

No. 2146. Greenwacke.

Straggling (dike?) cutting No. 2145.
Ref. Annual Report, xxiv, page 49.

Meg. Fine-grained, weathering lighter, with schistosity parallel with that of the enclosing rock.

Mic. This appears now like a schist. Old *feldspars*, secondary *feldspars*, *calcite*, *leucoxene*, and some *mica* compose this rock. One section.

Age. Archean (Keewatin).

Remark. Neither the field relations nor the petrographic characters are sufficient, nor both together, to determine whether this rock exists as a dike or a part of the clastics. The occasional crowding which it manifests upon the other beds, indicating an intrusive nature, may be due to crumpling and overthrust, while the microscopic characters rather favor a clastic origin. N. H. W.

No. 2148. Green Schist.

A little further south but still on the S. W. ¼ N. E. ¼ sec. 36, T. 64-11. Saturday lake; a second low bluff.
Ref. Annual Report, xxiv, page 49.

Meg. Rock is more uniform, but having scattered siliceous and calcareous spots, somewhat resembling amygdaloid, the silica areas sometimes being from two inches to two or three feet in diameter. The weathering of the calcite gives a decided aspect of porosity.

Mic. It is evident that these areas are of secondary origin, due to the replacement of some of the minerals by *calcite* and *quartz*, the latter being micro-granulitic and probably secondary after feldspar, while the calcite is the result of the same replacement, but accumulated as pseudamygdules. Calcite, moreover, is distributed widely through the rock in general. One section.

Age. Archean (Keewatin). N. H. W.

No. 2148A. Siliceous Part of No. 2148.

Same place as No. 2148.
Ref. Annual Report, xxiv, page 50.

Meg. Of irregular shape, evidently not wholly of quartz.

Mic. The *quartz* is of pneumatolitic origin and micro-granulitic structure, but the grains vary considerably in size. Nine-tenths or more are of such quartz, the rest being *calcite* and *epidote*. One section.

Age. Keewatin. N. H. W.

2158. Serpentine. *(Imperfect.)*

Southwest corner of sec. 16, T. 64-10, Bassimenan lake.
Ref. Annual Report, xxiv, page 51.

Meg. Apparently originally peridotyte.

Mic. This rock is largely serpentinized, but there are remnants of all the original minerals. The structure is wholly destroyed, apparently by decay and by crushing. One section.

Age. Archean (Keewatin).

Remark. This rock has been used by the aborigines for making pipes.

N. H. W.

No. 2159. Amphibolyte. *(Epidotic.)*

Sec. 16, T. 64–10, Bassimenan lake. At the dull, high point just west of the mouth of the river which here enters the lake.

Ref. Annual Report, xxiv, page 52.

Meg. Schistose, hornblendic, with patches that weather lighter.

Mic. The rock is largely of *hornblende* and *epidote*, with a little *sphene.* What little feldspar there was in this rock formerly has been replaced by an irregular interlocking group of secondary *feldspars.* One section.

Age. Archean (Keewatin). N. H. W.

No. 2161. Quartz-Feldspar Schist.

Midway on the portage between Oak Point lake and Little Sucker lake, T. 64–10, lying next south of the area of granite.

Ref. Annual Report, xxiv, page 52.

Meg. Gray, fine-grained, siliceous, pyritiferous, schistose.

Mic. Evidently a sheared fragmental rock, consisting of fine angular quartz grains, some *old feldspars*, *mica*, *pyrite*, *epidote.* It is evident that a great many old feldspars have been altered into the micro-granulitic mosaic (quartz and feldspar) which is also the product sometimes of recrystallization from a schist of clastic origin to a new rock, approaching granite in proportion as this replacement is coarser and more and more prevalent. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 2162. Quartz Schist. *(Jaspilitic.)*

Little Sucker lake, south shore, near the portage going to Pine lake; sec. 27, T. 64–10.

Ref. Annual Report, xxiv, page 52.

Meg. Very siliceous, weathering nearly as white as a granite, fine grained, gray-green within, fibro-schistose, but not visibly laminated, rising in bold glaciated bosses on the weathered surface pitted from decay of some of the elements of the rock.

Mic. The rock consists essentially of fine interlocking quartz, but with a liberal cement of *calcite,* muscovite and of *chlorite* or chloritized *hornblende.* There are a few *tourmaline* crystals and frequent spicules of *rutile*, and apparently of *actinolite.* The pitted aspect of the weathered surface is due to the weathering out of the chloritic or calcitic areas. One section.

Age. Archean (Keewatin).

Remark. This rock is allied to the greenstones of clastic origin, of which it furnishes a novel phase. It occurs within the general greenstone belt, and it probably fades out into that rock. Compare No. 869. N. H. W.

No. 2164. GREENSTONE.

Northwest corner S. W. ¼ sec. 26, T. 64–10, Pine lake.
Ref. Annual Report, xxiv, page 53.

Meg. Speckled with light and dark, a kind of "pepper-and-salt" rock, apparently a phase of a massive greenstone.

Mic. This rock perhaps had originally an ophitic structure, and some of the feldspars still show a "radial" arrangement, but the pyroxene is altered to *hornblende*, which is probably the "pepper" of the megascopic aspect, while the "salt" is represented by feldspar and *epidote*, and by *calcite*. *Feldspar* is present in ragged remnants, and in altered crystals. The finer epidotes are sometimes idiomorphic within an isotropic *chlorite*. The rock also contains a liberal amount of coarse *leucoxene*. One section.

Age. Archean (Keewatin). N. H. W.

No. 2170. PORPHYREL. *("Porphyritic" conglomerate.)*

N. E. ¼ N. E. ¼ sec. 32, T. 64–9, near Moose lake.
Ref. Annual Report, xxiv, page 55.

Meg. Apparently a porphyry.

Mic. This rock is peculiar in having large feldspars, which speck the surface as in a porphyry, some of them with sharp idiomorphic outlines, and yet in being clastic in all its other characters. There are occasionally quite well rounded feldspars which have the shapes of water-worn pebbles. There are fragments also of all sizes, but in general there is a sharp and remarkable contrast between the *feldspars* and the matrix in which they are embraced. They are completely permeated, uniformly, by the products of alteration, principally by sericite, and their twinning characters are very much obscured, although it is plain that they are twinned quite conspicuously and coarsely. In this character they are like those of Kekequabic lake. *Quartz* in large grains also is seen in this slide, again resembling the conglomerate of Kekequabic lake. The matrix is fine and has much scattered *calcite*. It also contains much fine feldspar. These are interlocked in a characteristic mosaic or micro-granulitic structure with *quartz*. It is also evident that this groundmass consists in part of a finer micro-granulitic structure which comes and goes in a manner indicating that some of the smaller original feldspar grains have given place entirely to the groundmass structure, as in the Ogishke conglomerate, or that there were originally in the rock pebbles of different structure.

Throughout the slide is more or less obscure isotropic chloritic substance, the result of alteration of *hornblende.* This is frequently collected in shreds and patches of larger size, characteristic of fragmental debris. One section.

Age. Archean (probably Upper Keewatin).

Remark. Were it not for the positive field relations it would be difficult to affirm that this is not an eruptive of two dates of consolidation, though much altered.

N. H. W.

No. 2171. PORPHYREL. *(Tuff.)*

Same place as the last, in another little ridge a little further south.
Ref. Annual Report, xxiv, page 55.

Meg. This is "porphyritic" with similar feldspars as No. 2170, also with hornblendes, but at the same time is a pebbly conglomerate.

Mic. The slide consists of fragments of *feldspar* and of *hornblende,* of all sizes, but very few perfect crystals of the former, with much *calcite.* One section.

Age. Archean (Keewatin).

Remark. This is quite similar to several slides already described from the vicinity of Kekequabic lake. The materials show very little effect of abrasion by wave-action, and as there is no other known source for such material, this rock is necessarily classed as of volcanic (tuff) origin. N. H. W.

No. 2175. GREENWACKE. *(Tuffaceous.)*

N. W. ¼ N. W. ¼ sec. 33, T. 64-9, a little north of Flask creek, near Moose lake; near the same place as No. 2171.
Ref. Annual Report, xxiv, page 75.

Meg. Green, massive-looking, apparently a bed in the prevailing conglomerate, but outwardly having the petrographic aspect of a greenstone. Bed is twenty to twenty-five feet thick.

Mic. With less *calcite* than in No. 2171, and with a considerable angular *quartz,* this rock still is of the same category as No. 2171, etc. It shows little or no beach-action, such as rounding of the grains, but it has a large amount of supposed devitrified volcanic *glass,* such glass being now mostly chloritic and isotropic, but showing a few small points in which polarized light passes, as if minute *feldspars* or quartzes were embraced. In the main, it is composed of fragmental *hornblendes, feldspars* and *quartz,* with pebbles which now are composed of micro-granulitic mosaic of feldspar and quartz, but which at first were probably feldspars. Some of the original pebbles were microlitic with feldspar, showing still a fluidal structure in the parallel arrangement of the little feldspars, or a "diabase structure." One section.

Age. Archean (Keewatin).

Remark. The hornblendes were derived from augite in the same manner as those of the Kekequabic Lake region, and they show also the same zoned and parti-coloration between the nicols, the darker, and generally central, areas indicating the forms of the original augite grains—the latest of the hornblende to be formed. Compare Nos. 1051, 1060, 1409–1413. N. H. W.

No. 2176. Andesyte (?)

From a dike cutting the conglomerate; near the same place as No. 2175.
Ref. Annual Report, xxiv, page 56.

Meg. A light-brown rock, fine-grained and compact. One of the specimens is roughly schistose, the other is not. The rock seems to be composed of feldspar, possibly quartz, and dark minerals, probably hornblende and chlorite, in fine grains.

Mic. The section was made from the non-schistose specimen. The rock is porphyritic with small feldspars which, in part at least, appear to be near *andesine-oligoclase.* These phenocrysts are set in a fine-grained groundmass in which feldspar seems to be the only original mineral remaining. It is in part *plagioclase.* Throughout the section and in the porphyritic feldspars much *muscovite* and *calcite* have been developed; also some *chlorite. Magnetite* and a little *pyrite* are seen also. There are some grains of *quartz* which are larger than the grains composing the groundmass, but these quartzes do not appear to be phenocrysts. They sometimes occur in connection with collections of chlorite scales, this mineral and the chlorite apparently occupying the place of an original ferromagnesian mineral. The quartz, in large part at least, thus seems to be secondary. One section.

Age. Dike in Archean (Keewatin). U. S. G.

No. 2177. Greenstone.

Near the "contact" between the foregoing tuff and graywacke and a greenstone, but on the greenstone side. The conglomerate all along dips south about 85°, *i. e.*, toward this greenstone, which is a wide belt extending, in general terms, to the Kawishiwi river.
Ref. Annual Report, xxiv, page 56.

Meg. Apparently massive, at least not showing distinctly any stratification, and thus in marked contrast with the tuff and conglomerate. Weathered surfaces show a protruding siliceous mesh, a character that sometimes distinguishes a clastic greenstone from an igneous one.

Mic. This consists of *hornblende, feldspar, quartz, epidote, sphene, calcite.* The feldspars have been much eaten into by a secondary micro-granulitic generation, which also serves to form a part of the finer matrix or groundmass for the rock in general, constituting the siliceous roughness of the weathered surfaces, but in nearly all cases there is still quite evident a remnant of the original feldspathic constituent. One section.

Age. Archean (Keewatin).

Remark. This rock differs from the foregoing in not showing in the section evident clastic characters, and in possessing some that are of the nature of eruptive rock, viz.: there are no pebbles, nor any variation in the texture or composition comparable with that mentioned in the adjoining strata. The composition includes epidote and sphene, which, while not exclusively characteristic of eruptive rocks, are still wanting in the clastics immediately adjoining. It is, however, to be noted that the original feldspars (as well as the pyroxene) have suffered the same change as seen in the tuffs, etc., viz.: the feldspars are largely micro-granulitized, and the pyroxene is turned to hornblende. In the rock at large are more or less rounded greenstone fragments, indicating a detrital source for the rock. N. H. W.

No. 2178. Kersantyte. *(Dike.)*

Same place as the last.
Ref. Annual Report, xxiv, page 56.

Meg. Acts as an intrusive in No. 2177, forming dikes and bosses, micaceous, the mica appearing in porphyritic crystals. Compare No. 2261. This is a very rare rock petrographically, having been seen in Minnesota only in this region.

Mic. The pyroxene is *augite*, but is almost entirely altered to *hornblende.* The mica is *biotite*, but is also largely changed to chlorite (*clinochlore*), which has n_g perpendicular to the cleavage. *Epidote, sphene, calcite* are also present in notable amounts, while evident feldspar, much corroded and in small interlocking grains (not micro-granulitic) is in subordinate amount, a considerable amount having been lost in alteration to *apophyllite,* which, by its very low double refraction gives a general darkness to the field between cross nicols. One section.

Age. Archean (Keewatin). N. H. W.

No. 2179. Conglomerate. *(Tuff.)*

Same place as No. 2177, but from the conglomerate.
Ref. Annual Report, xxiv, page 56.

Meg. Some of the finer parts of the conglomerate of the region.

Mic. The slide varies from amphibolyte in micro-amphibolyte, and to a porphyritic lava, whose groundmass is finely micro-granulitic and whose crystals are *feldspar* and *hornblende.* The amphibolytes are pebbles of a once diabase rock. One section.

Age. Archean (Keewatin). N. H. W.

No. 2180. Porphyryte. *(Esterellyte.)*

Near the section line between secs. 20 and 21, T. 64-9, near Moose lake.
Ref. Annual Report, xxiv, page 56.

Meg. Pebble in a conglomeratic jaspilyte; weathers red.

Mic. In a finely micro-granulitic groundmass are altered crystals of *feldspar* and of *hornblende.* Much *calcite* is scattered throughout.

This pebble appears to be of the same nature as the granitic and porphyritic intrusive rocks at Kekequabic lake, the feldspars being much twinned, somewhat irregularly. See remark under No. 1065. One section.

Age. Archean (Keewatin). N. H. W.

No. 2181. Conglomerate. *(Greenstone.)*

Near the same place as No. 2180, but further west.
Ref. Annual Report, xxiv, page 57.

Meg. Finely conglomeratic portion of the greenstone lying west from the jaspilyte belt.

Mic. Largely composed of fragmental feldspars with a copious matrix of debris of the same, also of micro-granulitized pebbles in which are visibly embraced small feldspars porphyritically, in the same manner as in No. 2179, with *epidote, calcite* and *chlorite* as usual. One section.

Age. Archean (Keewatin). N. H. W.

No. 2182. Jaspilyte.

Portage from Moose lake to Wood (Wind) lake, near Moose lake; S. E. ¼ S. W. ¼ sec. 20, T. 64-9 W.
Ref. Annual Report, xxiv, page 57.

Meg. The specimens vary from dark-brown jaspilyte to a dark-gray argillyte. Intimately interbanded with the jaspilyte is fine-grained, greenish-yellow material, which is evidently largely epidote. Minute veinlets of quartz cross the specimens and are brought out sharply by weathering. No section.

Age. Archean (Keewatin). U. S. G.

No. 2184. Graywacke. *(Tuff.)*

On the trail from Moose lake to Flask lake, sec. 28, T. 64-9 W. The land rises into a ridge or succession of ridges, consisting mainly of conglomerate and graywacke.
Ref. Annual Report, xxiv, page 57.

Meg. The rock is evidently fragmental and conspicuously stratified, spotted with crystals of feldspar.

Mic. The rock is much decayed. The *feldspars* are of clastic origin, as parts of a coarse graywacke. Since the matrix is largely, or wholly, not recrystallized by regeneration of the original elements, or by the formation of new elements, it was plainly at first a clastic one. The old feldspars are crowded with little crystals of other minerals, such as *mica, calcite* and chloritized *hornblende.* The matrix of these feldspars, which are sometimes perfectly idiomorphic and identical in appearance with those of the graywacke and conglomerate of Zeta lake (Nos. 1062 and 2187), is made up largely of small feldspar fragments, of *hornblende* and *chlorite*, with some *quartz*, and of devitrified glass in small grains, and of *sphene*. One section.

Age. Archean (Upper Keewatin).

Remark. This rock terrane, which is a large and important one in the region, can safely be parallelized with the Ogishke conglomerate, and especially with the conglomerate at Zeta lake. It sometimes takes the character of the Stuntz conglomerate, as seen on the ridge between Moose and Flask lakes. (Compare remark under No. 2189). N. H. W.

No. 2187. CONGLOMERATE. *(Porphyrel.)*

Shore of Snowbank lake, near the centre of sec. 26, T. 64-9.
Ref. Annual Report, xxiv, page 57.

Meg. A condition of the conglomerate of the region, having conspicuous feldspars. Compare No. 1062.

Mic. The large *feldspars* are much twinned, like all those in this curious conglomerate, but are permeated by the same kind of alteration, viz., the production of innumerable scales of *mica*. In this case *epidote*, and occasionally a secondary feldspar with different orientation, are plainly shown. This secondary feldspar is also sparsely distributed in the matrix as an interlocking groundmass and as an interlocking fringe about the crystals. Epidote is quite abundant in the chloritized hornblende areas and *sphene* is in the matrix in sparse grains. One section.

Age. Archean (Keewatin). N. H. W.

No. 2189. GRANITE-PORPHYRY.

At the point, S. W. ¼ N. E. ¼ sec. 26, T. 64-9, Snowbank lake.
Ref. Annual Report, xxiv, page 57.

Meg. This rock acts as dikes cutting mica schist. It contains green pebbles, and is cut by later granite intrusions; *i. e.*, by the prevailing granite of Snowbank lake.

Mic. This is a wholly crystalline rock, but it has two dates of crystallization. The large *feldspars* are "old feldspars" in the sense that they became much altered and were then regenerated. The alteration products are largely *mica*, *calcite*, and *epidote*. Throughout they are renewed by the formation of new feldspars, often globular in form, and still more frequently in the form of an interlocking fringe or exterior zone which surrounds them and unites them with the fine feldspathic matrix in which they lie. They are plainly twinned (albite plan) and their nearly parallel extinction indicates for some of them a composition near *oligoclase*, but they are considerably broken up by the growth of a finer interlocking structure with different orientations. This finer structure is not always of freshly developed material, but is clouded with the same impurities as the unbroken crystal, showing that the old crystal had suffered a partial mechanical as well as chemical disintegration. The surrounding plexus, so far as it is of new development, consists of interlocking small feldspars and *hornblende* in which the hornblendes are earlier, and of *quartz* and *epidote*. Throughout this fine mass are plainly smaller "old feldspar" grains or fragments not entirely replaced by the secondary growth. These contain the same inclusions and are supplied with the same surrounding fringe as the large crystals, and appear to be simply such original grains as have not been entirely lost in the general transformation, but the groundmass in general is wholly new and fresh. The older ingredients, not of feldspar, which are found in this interlocking matrix, are *sphene*, *apatite*, *magnetite* (perhaps of later date), *garnet*. These are in insignificant amounts. The hornblendes are small and are arranged in a gneissic structure. One section.

Age. Archean (earlier granite).

Remark. This rock resembles the so-called porphyry seen at various places, and it is evidently an older intrusive than the granite which cuts it. It has the structure and appearance of the porphyroidal granite of Kekequabic lake, but that does not prove equivalence of age. Given a certain (conglomeratic) formation, such as that about Moose lake or about Kekequabic lake, and it is evident that a metamorphism, and even a plasticity, could be produced at different epochs, and that the resultant rock, under similar or identical agents, would be about the same at different places.

This rock is considered to be essentially the same in original character and genesis as No. 2184, only differing in having more advanced metamorphism. Structurally it is essentially an igneous rock, having been forced, when plastic, amongst the adjoining strata, under great pressure. N. H. W.

No. 2190. Tuff.

S. E. ¼ N. E. ¼ sec. 24, T. 64–9, Snowbank lake, near the head of the little bay, but on the north side of it. *Ref.* Annual Report, xxiv, page 58.

Meg. Schistose, hornblendic, having dim porphyritic feldspars. This is a part of the great conglomerate of the region, but of indefinite outward characters.

Mic. There has evidently been a shearing pressure applied to this rock, as indicated by the elongation. This elongation is expressed chiefly by the streaks and bands of *epidote* and of *hornblende*, and by a uniform direction of the major axes of the feldspars. The old *feldspars* are coarsely and much twinned, and are rather uniformly decayed, *after* the micro-granulitic crystallization. It is also plain in this rock that the hornblende is derived from an alteration from *augite*, for some old augite forms remain. One section.

Age. Archean (Keewatin). N. H. W.

No. 2191. CONGLOMERATE.

Same place as No. 2190, but about 150 feet from the shore.
Ref. Annual Report, xxiv, page 59.

Meg. The matrix of the rock is hard, green and rather fine grained; it contains fragments and crystals of hornblende and of feldspar. There is one large pebble of a very fine-grained, gray, pink-weathering, granitic rock, and also one of a diabase-like rock holding small, little-elongated feldspars in a dark background. No section.

Age. Archean (Keewatin). U. S. G.

No. 2194. GRANITE *(with augite)*.

N. E. ¼ S. W. ¼ sec. 19, T. 64-8, Snowbank lake. Small island.
Ref. Annual Report, xxiv, page 60. (Compare No. 271E.)

Meg. Granite.

Mic. This beautiful rock is porphyritic with an *ægyrine* augite which has its idiomorphic forms. These crystals lie in a coarsely crystalline interlocking granite of *microcline, oligoclase(?)* and *orthoclase,* in which is much *sphene* and also a little *biotite.* The microcline appears to have intergrown *pari passu* in some instances, with another feldspar (oligoclase?), and in other cases to have served simply as a cement to regenerate a decrepit old crystal. Frequently also these two feldspars together form such cement, the only sign remaining of the original crystal being a central area now so crowded with alteration products, chiefly mica, that it cannot be studied. One section.

Age. Archean (granite). N. H. W.

No. 2195. DIORYTE.

Just east of the section line between secs. 19 and 20, T. 64-8, at the shore of Snowbank lake.
Ref. Annual Report, xxiv, page 61. Compare Nos. 271E and 591E, Annual Report, xxii, page 189.

Meg. Granitic.

Mic. The feldspars (triclinic) are very much decayed, and the ferromagnesian minerals are *hornblende* and *biotite,* largely altered to *clinochlore. Epidote* is abundant especially in the clinochlore and also associated closely with *magnetite.* One section.

Age. Archean (intrusive).

Remark. Mr. Elftman obtained rocks near the same place which he found were augite granite. If this rock were ever augite granite, which is possible, it has lost that nature probably by weathering. N. H. W.

No. 2196. SYENYTE. *(Porphyritic.)*

North shore of Snowbank lake, at line between secs. 19 and 20, T. 64-8 W.
Ref. Annual Report, xxiv, page 62.

Meg. A very fine-grained reddish rock, composed largely of feldspar. There are some feldspars which are porphyritic, but the fact that these feldspars on fresh fracture are so closely like the groundmass makes the porphyritic nature of the rock very indistinct.

Mic. The micro-granulitic groundmass is largely of quartz and feldspar. It embraces much-altered crystals of *feldspar*, some *biotite*, *apatite*, *muscovite* in large masses and rarely a roundish quartz. One section.

Age. Archean.

Remark. This rock is allied to the granites and porphyries of Kekequabic lake. Its relation to the granite of the region is not known. N. H. W.

No. 2197. Muscovadyte.

S. W. ¼ N. E. ¼ sec. 4, T. 63-8, Disappointment lake, at Cheadle's cabin, site of an old iron exploration. *Ref.* Annual Report, xxiv, page 62. Compare Nos. 1347, 1781, 1784, 1785; also Annual Report, xxi, pages 149, 150; Final Report, vol. iv, page 303.

Meg. Fine-grained, gray, non-micaceous, mainly massive, but conglomeratic in bands; firm, resembling muscovadyte. Position and dip like that of the conglomerate and tuff of the region.

Mic. The most of this rock is made up of a fine-grained feldspar, which, judged by several determinations on a bisectrix, varies from *labradorite* to *andesine*. These fine feldspars are fresh and interlock in the manner of micro-granulyte. Small *hornblendes* share in this groundmass and embrace the feldspars poikilitically, but the largest poikilitic crystals are *hypersthene*. It is remarkable that a large hypersthene crystal will maintain its orientation over so many of the feldspars, when generally it makes less than one-half of the mass. *Magnetite* is distributed in fine crystals. One section.

Age. Archean (Keewatin modified).

Remark. This rock shows the effect of the gabbro which lies but a short distance further south on the basic Keewatin schist and conglomerate. There could be no more ample and convincing proof of the origin of the rock which has been called muscovadyte. It has been supposed to be a form of the gabbro, as it approximates gabbro in composition and is nearly always near the gabbro margin. In the field work it was very generally denominated muscovado, whether it had any close association with gabbro or not. In the Twenty-first Annual Report a distinction was made, as it was presumed that some muscovado was of irruptive and some of metamorphic origin, and the name was assigned to a supposed phase of the gabbro. It is, however, plain that here it is a product of metamorphism by the gabbro (or cotemporary with it) on the Keewatin. N. H. W.

No. 2198. Muscovadyte.

Same place as No. 2197. Same rock, but plainly conglomeratic.
Ref. Annual Report, xxiv, page 62.

Meg. Fine-grained, pebbly portion of the same rock as No. 2197.

Mic. There is a little *quartz* and many remnants of old *feldspars* that have not been entirely consumed by the micro-granulation which has permeated the rock and which is much finer than in No. 2187. *Hornblende* and *biotite* compose the dark elements with a very little *magnetite* and *sphene*. Two sections.

Age. Archean (Keewatin). N. H. W.

NO. 2199. PERIDOTYTE.

Same place as the last, but further south, at the iron-ore pits.
Ref. Annual Report, xxiv, page 62.

Meg. The rock that embraces the ore, grading into the ore.

Mic. *Olivine*, *diallage* twinned with *enstatite*, *quartz*, *magnetite*, in the order named, compose this rock. The twinned enstatite embraces all the others poikilitically. There is a tendency to roundish outlines, especially for the olivine and the quartz. That this contains enstatite rather than hypersthene is shown by the low double refraction (about the same as quartz), and by a basal section showing with the prismatic cleavages another parallel with the optic plane, and also showing the bisectrix n_g in the acute angle, which latter is quite small.* Probably the more intense contact with the gabbro at this point, or perhaps the presence of a large supply of iron, had something to do with this difference in the ferro-magnesian minerals. The olivine has the small optic angle (containing n_p) characteristic of *fayalite*. One section. N. H. W.

NO. 2201. MAGNETITE IRON ORE.

Same place, Disappointment lake.
Ref. Annual Report, xxiv, page 62.

Meg. Appearing siliceous.

Mic. About one-half this rock is *magnetite*. The larger part of the rest is *quartz*. But there is a noticeable amount of the ferro-magnesian elements seen in Nos. 2198 and 2199, particularly *diallage*. The *magnetite* forms a sort of sponge in which the other minerals are held in roundish kernels. One section.

Age. Archean (Keewatin). N. H. W.

NO. 2202. MUSCOVADYTE. *(Noryte.)*

Thirty feet further south than No. 2201. Disappointment lake.
Ref. Annual Report, xxiv, page 62.

Meg. This cuts the conglomerate which contains the iron ore, and embraces pieces of the conglomerate.

Mic. The pyroxene is *hypersthene*, but it is interleaved parallel to 010 by a monoclinic pyroxene, which has a higher birefringence, probably *diallage*. This

* *Minéraux des Roches*, p. 260.

intergrowth is also parallel with the prismatic cleavage (110) and with the orthopinacoid 100. The *labradorite* is fresh, and twinned on the albite and pericliue plans. *Magnetite* is not abundant. One section.

Age. Cabotian (modified Keewatin).

Remark. This rock, so evidently a phase of Nos. 2198 and 2199, and of the same rock mass, here plays the rôle of an igneous rock intrusive on less modified parts of itself. N. H. W.

No. 2203. Muscovadyte.

Same place as No. 2202, Disappointment lake. At the gabbro contact.
Ref. Annual Report, xxiv, page 62.

Meg. Inclusion of the greenstone conglomerate in the gabbro.

Mic. The structure is granulitic, the *feldspars* averaging larger than any of the other minerals, which they embrace poikilitically. They show the albite and pericline twinning and are fresh and clear. Rarely, however, a *hypersthene* surrounds a few globular feldspars. The hypersthene is fresh and is distinguished from enstatite by having n_p for acute bisectrix perpendicular to 100. Besides the foregoing the rock only embraces a very few grains of *magnetite* and one or two of *biotite*. One section.

Age. Archean (Keewatin).

Remark. It is to be noted that the rocks Nos. 2202 and 2203 mineralogically are very nearly allied, but petrographically and structurally they are contrasted. The The former is a characteristically crystalline gabbro with large plates of hypersthene (interleaved with diallage), showing a partial ophitic structure. The latter is granulitic, the hypersthenes being small and round, and not infrequently wholly surrounded by the feldspar. The species of the feldspar can be safely taken to be labradorite in both cases, but no reliable measurement of extinction is obtainable in No. 2203. Were it not that the rock No. 2203 can be followed continuously from the gabbro border northward to the iron ore pits (but few rods, No. 2201) and thence to the lake shore at Cheadle's cabin (Nos. 2197 and 2198), and that throughout it is uniformly the same rock, often pebbly, distinctly stratified, and is thence demonstrably the same formation as the pebbly greenstone, often called *conglomerate*, it would be hazardous to affirm, in the face of numerous published statements to the contrary, that these are the same rock genetically, structurally and historically. The similarity of the metamorphosed clastic to the contacting gabbro is to be explained by the great *a priori* similarity of the greenstone debris in chemical composition to a basic igneous rock, and leads to the reasonable assumption that the gabbro itself is the end product of such metamorphism. N. H. W.

No. 2207. Granite. *(Esterellyte.)*

Central part of sec. 32, T. 64-8, Disappointment lake.
Ref. Annual Report, xxiv, page 64.

Meg. Dike of red granite cutting the gray pebbly rock.

Mic. In a finely granulitic groundmass are zoned and twinned crystals of *feldspar*, and imperfectly formed crystals and shreds of *hornblende*, with some *biotite*. The appearance is like the esterellyte of Kekequabic lake, with the exception that the ferromagnesian element is less abundant, and does not approach augite. The central portion of the feldspars is frequently converted to an obscure, crowded mass of minute crystals of *mica*, *epidote* and secondary *feldspar*. That the groundmass was at first fragmental, and that the zoning of the feldspars was coincident with the micro-granulitic development by which most of the smaller fragments have lost their identity, is an obvious conclusion which is in keeping not only with the present condition of the feldspar crystals, but also with the heterogeneous aspect of the micro-granulitic groundmass itself. The principal zone of the feldspars has an extinction on n_g of about 3°, indicating *andesine-oligoclase*, but the exterior zone has an extinction angle, in the same crystal, of about 17°, which is near that of *albite*, while the kernel is so obscured by inclusions of mica, etc., that its exact extinction can hardly be determined. Several trials, however, on the kernel, which has not a uniform simultaneous extinction, but a fragmentary or wavy one, give angles varying from 13° to 18°. Not much reliance can be put on this indication, but, if it be supposed that the variation in acidity was in the same direction at the centre as at the periphery (as is usually the case), these figures point toward *labradorite* as the original feldspar. One section.

Age. Archean (dike).

Remark. It is reasonable to infer that this granite is analogous to that cutting the green schists at Kekequabic lake. N. H. W.

NO. 2208. MUSCOVADYTE. (*Micaceous.*)

S. W. ¼ N. E. ¼ sec. 5, T. 63-8, Disappointment lake, at the lake shore.
Ref. Annual Report, xxiv, page 64.

Meg. Apparently a mica schist, but an approach toward muscovadyte. This is also plainly a part of the green, pebbly formation which prevails, irrespective of the intrusives, from Moose lake to Disappointment lake.

Mic. The rock is micro-granulitic, with variations in size, some of it being plainly due to replacement of original clastic feldspars, some of which are still preserved. *Hornblende* in small round and obtuse grains is the most abundant of the dark minerals, but shares with *biotite* and *magnetite*. The old feldspars, so far as they remain, are zoned, and the fringe is interlocked with the surrounding fine groundmass. One section.

Age. Archean (Keewatin).

Remark. This is in the line of strike from Cheadle's cabin, but further removed from the gabbro intrusion. N. H. W.

No. 2209. MUSCOVADYTE.

Still in the line of strike from Cheadle's cabin, but a little further north, at the extremity of the point.
Ref. Annual Report, xxiv, page 64.

Meg. Gray, micaceous.

Mic. With the prevailingly new feldspathic groundmass in this slide are several *quartz* grains. The old feldspars are more numerous and hence more contrasted with the granulitic groundmass. The *hornblendes* are larger than in the last and sometimes surround grains of *quartz, biotite* and *feldspar*. One section.

Age. Archean (Keewatin). N. H. W.

No. 2211. GRANITE.

Head of the rapids at the outlet of Sucker lake, on the Canadian side; Prairie portage. Intrusive on fine schists.
Ref. Annual Report, xxiv, page 66.

Meg. A medium-grained granite.

Mic. The original granite, whatever its nature, shows evidence of having experienced one or more epochs of dynamic stress. The feldspars are much decayed, but rebuilt by small deposits of peripheral, cementing, fresher feldspar, which was perhaps the time of deposition of *microcline*, which occurs in larger crystals. *Quartz* is quite abundant, and was last to take the present posé, but also has a shadowy extinction, indicating a later mountain crushing. *Muscovite* is common. A little *hornblende* and some *chlorite* are the only dark minerals. One section.

Age. Archean. N. H. W.

No. 2215. SYENYTE (?)

N. E. ¼ N. W. ¼ sec. 5, T. 62-10, on the south side of the large triangular island surrounded by the Kawishiwi river.
Ref. Annual Report, xxiv, page 67.

Meg. Rather coarse-grained mass of hornblende and feldspar, making a dark speckled rock.

Mic. The larger *hornblendes* spread rather irregularly so as to embrace poikilitically several other minerals, but they are broken and regenerated by new growths. The minerals thus embraced are usually globular, and consist of *feldspar* (often much altered), *epidote, sphene, apatite* and other hornblendes.

The feldspar is much crushed and kaolinized. It appears to be wholly of *orthoclase*; at least no striated twin-lines are visible. One section.

Age. Archean.

Remark. This rock seems to be of the age of the surrounding granite. It is fresher than the greenstones of the Keewatin, and is probably a variant of the granite of the region. N. H. W.

No. 2216. Dioryte.

Near the same place as the last, but from the north side of the little bay.
Ref. Annual Report, xxiv, page 67.

Meg. A rock of finer grain than the last, of a dark gray color.

Mic. Seems to consist wholly of *hornblende* and a much altered *plagioclase,* the latter being embraced ophitically by the former, and hence was originally a diabase. The plagioclase is so much altered that it has almost entirely lost its striations. One section.

Age. Archean. N. H. W.

No. 2217. Dioryte *(with quartz.)*

From the south side of the same little bay.
Ref. Annual Report, xxiv, page 67.

Meg. Resembles rock No. 2215, but finer grained.

Mic. Considerable areas of *quartz* are found amongst the other minerals so as to embrace them—even the altered *hornblendes.* The feldspar is only partly plagioclase; the rest is more decayed and is taken for *orthoclase.* Biotite and chlorite are quite common. One section.

Age. Archean.

Remark. This rock seems to be only a phase of the granite. N. H. W.

No. 2220. Granite *(with hornblende).*

A short distance further west.
Ref. Annual Report, xxiv, page 67.

Meg. Darker than Nos. 2218 and 2219, but lighter than Nos. 2215 to 2217. Some feldspars are red.

Mic. With much *hornblende* are both *plagioclase* and *orthoclase,* the latter considerably kaolinized; also a little *biotite* and *magnetite.* One section.

Age. Archean. N. H. W.

No. 2221. Granite. *(Hornblendic.)*

Narrows of the Kawishiwi river, N. E. ¼ S. E. ¼ sec. 5, T. 62-10, a little west of the so-called palisades. Forms a small knob on the north shore.
Ref. Annual Report, xxiv, page 68.

Meg. Compact, dark, hornblendic gneiss, with epidote in one of the open seams, cut by veins of red granite.

Mic. The section shows a fresh hornblendic granite, with considerable *quartz.* The more altered *feldspars* may be assumed to be orthoclase, and the rest, which are twinned polysynthetically, are some species of *plagioclase. Epidote* accompanies and surrounds small masses of *magnetite.* It is in multiple granules, and in that form is also scattered through the rock. One section.

Age. Archean.

Remark. The relation of this rock to the adjacent red rock forming the so-called "palisades," could not be exactly determined, but if the red dikes in this are from the red rock, as apophyses, as seems probable, this is the older rock. N. H. W.

No. 2222. Granite. (*Hornblendic.*)

Same place and same rock mass as the last.
Ref. Annual Report, xxiv, page 68.

Meg. Finer grained condition of No. 2221, having a schistose direction in the arrangement of the hornblendes.

Mic. This rock is more abundantly supplied with hornblende, but less with quartz. One section.

Age. Archean. N. H. W.

No. 2225. Gneiss.

N. E. ¼ S. W. ¼ sec. 24, T. 63–10, on the portage from Kawishiwi river to Triangle lake, near the Kawishiwi.
Ref. Annual Report, xxiv, page 68.

Meg. Schistose, fine interlamination of green, apparently chloritic, interrupted sheets with red, fine-grained, broader sheets which appear to be granitic, the whole having the aspect of fluidal structure, or of a transition from the granite to the greenstone, the former existing toward the south and the latter toward the north. As constituents of the red-weathering sheets are a few roundish masses visible on the weathered surface, resembling orthoclase phenocrysts. The fresh fracture of this rock is gray rather than green.

Mic. The rock is in general a granular mass of fine *quartz* and *hornblende*, with feldspar both *orthoclase* and *plagioclase*. There are numerous ragged feldspars of larger size, interlocking with the finer matrix about their margins. The hornblendes are small and ragged, and in places *magnetite* and *biotite* unite with it in composing the darker laminæ. Some fine *apatite* and also *rutile* are scattered irregularly through the slide. One section.

Age. Archean.

Remark. From the microscopical characters it appears that this megascopic laminated structure is probably due to the shearing of an igneous rock (granite).

N. H. W.

No. 2226. Greenstone.

From a large inclusion in granite, near the same place as No. 2225.
Ref. Annual Report, xxiv, page 68.

Meg. Fine grained, dense, hardly showing any structure, yet on the weathered surface the hornblendes and feldspars are seen to have one direction.

Mic. The larger *hornblendes* are ragged and irregularly interlock with and partially enclose some of the *feldspars*. It is apparent that they are secondarily enlarged, and also that numerous hornblendic spicules have been developed, the latter piercing the fresh feldspars which are also secondary. *Quartz,* in fine isolated and sometimes spreading forms, is also secondary. A dark iron mineral which appears to be *magnetite* or *ilmenite,* is in close association with a highly refractive and transparent mineral, which in some of its elongated sections has parallel extinction and is probably *rutile.* This supposed rutile is not in needles, but usually in globular scattered individual grains resembling sphene which are occasionally grouped. Two sections.

Remark. This rock may have been originally a diabase. It is a firm rock and appears fresh, but it is plain that its present condition is wholly due to metasomatic alteration of earlier minerals. N. H. W.

No. 2227. Greenstone.

From the prominent ridge at the corners of secs. 8, 9, 16 and 17, T. 63-9 W., north of the Kawishiwi river. *Ref.* Annual Report, xxiv, page 69.

Meg. Fresh, green, diabase-looking rock. Sample represents the non-agglomeratic portion.

Mic. The trachytic feldspars have a radial manner of piercing the *hornblendes,* suggesting that the hornblende is an alteration product from ophitic augite. Two sections.

Age. Lower Keewatin. N. H. W.

No. 2229. Quartz-Porphyry.

Two hundred paces south of the quarter-post, east side of sec. 8, T. 63-9, southwest of Snowbank lake. *Ref.* Annual Report, xxiv, page 69.

Meg. Light-weathering, massive, porphyroidal rock, containing phenocrysts of *quartz* and *feldspar* in a fine siliceous matrix; also showing a little pyrite.

Mic. The *quartz* is bipyramidal and somewhat resorbed, having embayments filled with the fine matrix. It is not abundant. The *feldspar* is much twinned and somewhat resembles that of the porphyry of Kekequabic lake. They are much altered and in some places wholly disintegrated. The resulting secondary minerals are chiefly *calcite* and *muscovite,* the former sometimes constituting areas of considerable (microscopic) size, but the latter occurring in myriads of isolated minute scales. The same minute muscovite scales are also quite abundant throughout the matrix. *Biotite* in sizable groups is distributed through the rock, but sparsely. Its scales are from twenty-five to fifty times larger than those of the muscovite.

A secondary feldspar, in fine isolated grains, has been generated not only throughout the matrix, but not infrequently in the bodies of the old feldspar phenocrysts. These are glassy and cannot be specifically determined because they are destitute of visible cleavage and other criteria for measurements. While the old feldspars are mainly plagioclase there is occasionally one which has a pronounced *microcline* structure. In such microclines are numerous isolated fresh feldspar grains like the last mentioned, as well as dull areas filled apparently with kaolin, suggesting that the whole microcline grain is due to a regrowth on and in an older feldspar crystal.

Throughout the slide are also shreds of a highly refractive and doubly refractive mineral which resembles *epidote*, but the grains are so small and their color in common light is so white that it is not possible to affirm that these grains are not a light-colored augite. There is also a little *sphene* and a very small amount of green *hornblende*. One section.

Age. Lower Keewatin. N. H. W.

No. 2231. GREENSTONE.

Phase or part of No. 2230; same place as No. 2229. No. 2230 contains rounded and angular pieces of No. 2229 and much finer debris, constituting a conglomerate.

Ref. Annual Report, xxiv, page 69.

Meg. Firm, fresh, uniform, massive aspect in the field, with much hornblende or pyroxene.

Mic. *Hornblende* constitutes the coarsest and most conspicuous part of the slide. It is nearly colorless and almost without pleochroism. Its angle n_g:c=16°. It has positive elongation in a section showing n_p perpendicular, and its acute bisectrix is n_p. If this be an aluminous hornblende it is *edenite**, but optically it is also much like tremolite.

Epidote, which is also almost colorless, is widely disseminated through the section, and frequently is embraced in minute grains in the foregoing amphibole. It constitutes in minute granules the major portion of some areas that were formerly either feldspar or some ferro-magnesian mineral, probably the former, because remnants of an old feldspar are sometimes seen in the midst of such an epidotic mass.

The *feldspar* is so altered that it cannot be specifically determined. It constitutes but a minor portion of the larger grains. It but rarely shows any albite or other twinning. One section.

Age. Upper(?) Keewatin.

Remark. Owing to the great variability in the amount of decay of the feldspars, the manner of connection of the grains into a rocky structure, and the great prevalence of finely granular epidote, it is perhaps reasonable to assign this rock to a clastic origin. Its close connection with rock No. 2230, which in the field was not detected to show an igneous contact, favors that view. N. H. W.

No. 2232. GRAYWACKE.

At a quarter of a mile north of the east quarter-post of sec. 8, T. 63-8.

Ref. Annual Report, xxiv, page 69.

* *Minéralogie de la France*, ii, pp. 634, 661.

Meg. Gray, siliceous, hardly porphyritic, a near approach to graywacke, but apparently, in the field, a variation of the quartz-porphyry No. 2229.

Mic. The rock is largely composed of very fine but irregular matrix of *epidote, feldspar, quartz, calcite, biotite, muscovite,* and a few cubes of *pyrite.* In the midst of this matrix are a few larger, broken plagioclase feldspars, much altered by biotite and epidote growths, and occasionally a large quartz. In the midst of the slide are areas crowded with a very fine, granulated structure consisting of epidote and apparently minute secondary feldspars. These are, in the main, a fine debris more or less regenerated, but some of them are also due to old feldspars that have been lost by micro-granulitization. One section.

Age. Lower Keewatin.

Remark. This rock is believed to have been originally composed of debris of the same elements as the quartz-porphyry. Ordinarily it might be classed as an altered quartz-porphyry, but its essential characters appear in the field to grade into those of the quartz-porphyry—a remark which is equally true of the microscopic characters. N. H. W.

No. 2234. Diabase. *(Uralitized.)*

Fifty-two paces south of the section corner of section 9. Apparently a dike cutting the graywackes and slates which strike northwest and southeast.
Ref. Annual Report, xxiv, page 69.

Meg. This is a dark, heavy rock, and on the weathered surface reveals an original ophitic structure.

Mic. This rock was originally an *olivine*-bearing diabase, but that mineral is altered to a dark, opaque, ferruginous substance which is unidentifiable, while the augite is now in the form of a green pleochroic *hornblende.* It contains also pyrite. One section.

Age. Dike cutting the Keewatin. N. H. W.

No. 2236. Diabase.

From a dike 650 paces west of the corner post, northwest corner of sec. 8, T. 63-9, running north and south, two feet wide, passing through quartz-porphyry No. 2229.
Ref. Annual Report, xxiv, page 70.

Meg. Very fine grained, with specks of pyrite.

Mic. The ferro-magnesian mineral is chiefly *hornblende* in small crystals that interlock with the fine microlitic feldspars. There is a suggestion of an original porphyritic structure, due to the appearance of areas that have become micro-granulitic, which once were apparently of feldspar phenocrysts. The minerals now occupying these areas are granular *epidote,* minute feldspar grains, or remnants of the old crystal, a little hornblende and less of *chlorite.* In the slide is one large porphyritic area occupied almost wholly by many hornblendes that have independent orientations. It has the shape of a feldspar phenocryst.

Throughout the rock is much fine, granular *epidote* and a few grains of *quartz*. One section.

Age. Dike cutting quartz-porphyry of the Lower Keewatin. N. H. W.

No. 2237. Quartz-Porphyry.

At 670 paces west from the same corner post (*i. e.*, northeast corner of sec. 8, T. 63–9), four rods west of the above dike.

Ref. Annual Report, xxiv, page 70.

Meg. The specimen from which the section was made is a gray quartz-porphyry, with the grain of the matrix graduating in size to that of the phenocrysts. The point at which it was collected is in the midst of the general quartz-porphyry mass, and its chief interest consists in its field relations. "At this place the porphyry, so called, presents fragmental characters. It is roughly schistose in a direction E. 25° ± N., and ridged with interrupted finer belts resembling siliceous argillyte. It holds pieces of greenstone and of slaty greenstone, varying in size from ten inches downward (rounded) to half an inch; also pieces of jaspilyte and rounded quartz. The slaty greenstone is like argillyte and runs usually with the structure, standing on edge. The rock contains much quartz in grains less than a pea in size, but also as large as an inch in diameter, the last being very rare, while other quartzes, as of phenocrysts in quartz-porphyry, are abundantly disseminated. Indeed, the bulk of the whole rock consists of more or less rounded fragments of orthoclase and quartz, lying in a pellucid matrix which appears to be quartz, essentially, sufficiently abundant to keep the quartz and orthoclase grains from interlocking, but apparently allowing them to come loosely into contact. * * * In other places near by are other variations in this porphyry. It may hold distinct crystals of orthoclase in abundance, or none at all. It also varies to a fine-grained gray rock with no apparent quartz nor feldspar as crystals, but yet on close examination it is seen that fine quartz grains are still present. In other cases it holds vitreous quartz grains surrounded by a mesh of quartz which is like that of the jaspilyte, *i. e.*, very finely granular and interlocking (rock No. 2238). This serves as a matrix for vitreous quartz grains. Such characters are seen in the porphyry ridge that extends northward along the west side of the dike represented by rock No. 2236.

Mic. The phenocrysts are *orthoclase* and *plagioclase*, with large bipyramidal *quartz*. The feldspars are much eaten into by decay, the resulting micro-granulitic substance being *calcite* (abundant), *muscovite*, secondary *feldspar*, *epidote*, the same feature mentioned already in several instances. Some of the feldspars are wholly obliterated, only their forms remaining, and all of them are more or less changed.

The matrix consists of *calcite*, *muscovite*, *epidote*, little feldspars and quartzes, generally coarser than the structure seen in the micro-granulitized feldspars. Still, these structures grade into each other, and while it is certain that some portions of the slide consist of a fine reconstructed original clastic debris, other portions are simply granulitized feldspars.

A few spicules of bluish-gray *tourmaline* are in the granular matrix. One section.

Age. Quartz-porphyry of the Lower Keewatin.

Remark. It was the examination of this rock, and generally of this belt of quartz-porphyry, with its great alteration and its occasional clastic characters, that suggested the idea that this belt of quartz-porphyry is the result of Archean sedimentation combined and cotemporary with oceanic precipitation of silica and potassa. There must, if such be true, have been a thick akaline mud in the bottom of the ocean, and these crystals must have formed in it as in a saturated solution, many becoming broken by transportation, and all of them much decayed prior to the consolidation of the rock. The reader is referred to Part III. N. H. W.

No. 2238. Quartz-Porphyry.

Near the same place as No. 2237.
Ref. Annual Report, xxiv, page 70.

Meg. A form of the porphyry having a dense, fine, siliceous matrix which surrounds distinct quartzes and indistinct feldspars. The matrix appears like the fine silica of the great jaspilyte lenses.

Mic. Microscopically the matrix of the section examined does not appear so much like the jaspilyte, but is characteristically like that of quartz-porphyry. It is manifestly composed of very fine *quartz* and feldspar, with some *muscovite*, some *epidote* and a little *pyrite*. The phenocrysts, whether of quartz or feldspar, are much broken and disturbed, the latter having given rise to *calcite*, *chlorite* and *muscovite*. Two sections.

Age. Quartz-porphyry of the Lower Keewatin. N. H. W.

No. 2239. Granite. *(Porphyritic.)*

Twenty rods west of the last; in the descent to a swamp.
Ref. Annual Report, xxiv, page 71.

Meg. Reddish gray, rather fine grained, but holding feldspar phenocrysts about a quarter of an inch in diameter.

Mic. The matrix is siliceous with fresh secondary *quartz* and enlargements of *feldspars*. It also contains *calcite*, *hornblende*, *muscovite*, *biotite*, *chlorite*, *sphene* and *epidote*. The feldspar phenocrysts, although for the most part entirely lost as to their optic characters by a kaolinization (accompanied by much epidote) that has permeated them, yet about their borders are fresh and glassy by reason of a recrystallization which has strengthened the whole rock. Throughout the phenocrysts, moreover, there are evidences that this new growth has penetrated and occasionally fresh areas are seen within them, which are like the fresh borders. Two sections.

Age. Archean.

Remark. This rock has the characters of several other granites, and especially that at Kekequabic lake, which indicate a recrystallization of an old debris. N. H. W.

No. 2240. Conglomerate.

Same place as No. 2235, north line of sec. 8, T. 63–9, a quarter of a mile east of the northeast corner of the section, and at the same stratigraphic horizon as No. 2230.
Ref. Annual Report, xxiv, page 72.

Meg. Has a speckled aspect, due to the abundant dissemination of pebbles of quartz-porphyry and of jaspilyte (mostly the former) through a finer matrix of green. Some of the pebbles are also green. Illustrated by figure 1, plate Z, vol. iv. No section.

Age. Perhaps the base of the Upper Keewatin. N. H. W.

No. 2243. Granite. *(Microporphyritic.)*

On the section line between secs. 4 and 5, T. 63–9, northward from the corner of section 8.
Ref. Annual Report, xxiv, page 75.

Meg. Fine grained, gray, subgranitic; except in the absence of porphyritic phenocrysts of feldspar this rock resembles rock No. 2239. A narrow dike running with the structure in slate and graywacke.

Mic. In thin section there appear a few scattered porphyritic phenocrysts, one of which, happening to be cut perpendicular to n_g and showing the basal cleavage (001), affords an angle of extinction of about 13° which, according to the method of Fouqué,* indicates a feldspar between *albite* and *oligoclase-albite*, n_g also being in the acute angle of the optic plane. This particular section shows no albite twinning, but other sections in the same slide show an occasional coarse albite twinning. The rock is considerably altered from its condition at original consolidation. This is evinced not only by the prevalence of various secondary minerals, notably *epidote* and *mica*, but by the microperthitic growth of fresh feldspars in the fissures of the old feldspars. One section.

Age. Archean (perhaps Upper Keewatin). N. H. W.

No. 2244. Porphyry. *(Hornblendic.)*

Near the quarter-section post between secs. 4 and 5, T. 63–9, before crossing the creek at "Nelson's cabins."
Ref. Annual Report, xxiv, page 76.

Meg. Grain and color similar to No. 2243, except that this rock shows a contrast between the fine matrix and the porphyritic crystals. Spreads irregularly as an intrusive in hardened graywackes and slates.

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* Contribution à l' étude des feldspaths des roches volcanic. *Bulletin Société Française de Minéralogie*, vol. 17, p. 283, 1894.

Mic. The feldspar, which appears to have been in part a soda-lime species, is much altered by the development of *mica*, *calcite* and *epidote*, but has also been, in some cases, recrystallized by new growths about the margins, and more or less throughout its entire mass. Rarely a feldspar is embraced wholly within a hornblende, but as a rule these minerals are in independent idiomorphic relations.

The *hornblende* is green, distinctly pleochroic, having the maximum extinction angle, on elongation, about 16°. It is sometimes zoned with different shades of green. It has a negative acute bisectrix (n_p), and n_g nearest the vertical axis, and is hence apparently common hornblende.

The matrix is composed largely of very fine feldspars, micas and *epidote*, with some *calcite* and shreds of hornblende. One section.

Age. Intrusive in the Upper Keewatin.

Remark. This rock, in thin section, has the appearance of having originated from a hardening of a debris of feldspathic character. The alteration of the feldspars took place while they constituted a part of such debris. N. H. W.

No. 2245. Conglomerate. *(Granitized.)*

Part of the same rock as No. 2244.
Ref. Annual Report, xxiv, page 76.

Meg. Shows variations of grain due to a pebbly structure. The pebbles, while mainly of a porphyry, are sometimes of a dark, hornblendic rock, and the face of the rock, where weathered, occasionally shows also a sedimentary structure. The porphyry pebbles differ in the coarseness and in the frequency of their phenocrysts, in a manner like the differences seen in the pebbles of the Stuntz conglomerate. In this case, however, the crystals are of feldspar.

Mic. This rock also presents the appearance of a hardened clastic debris identical in history and origin with No. 2244. The grains of hornblende and feldspar are smaller, and more like fragments and shreds than phenocrysts. This debris contained also a little quartz. They also grade more regularly into the size of the grains of the matrix. One section.

Remark. "On looking about over these knobs it appears that this rock is generally finely porphyritic with feldspar, and had originally pebbles of porphyry and fragments of a dark rock, constituting a conglomerate, showing in spots traces of a sedimentary structure, and really is but a condition of some parts of the fragmental formation. Yet it appears like rock No. 2243, and is massive as granite, having angular cross-jointage. The appearance and action of this intrusion are quite similar to the same in some of the Kekequabic Lake granite. Nos. 2243, 2244 and 2245 constitute a series showing what outwardly indicates intrusive and igneous action of a rock that originally was fragmental, and which still retains (in No. 2245) unquestionable pebbly forms of different kinds of rock. This, however, all appears to belong to the Upper Keewatin, and may be said to repeat the phenomena of Kekequabic lake on a small scale." This structure may be compared with the jointed graywacke seen in figure 2, plate Y in vol. iv, and as a rock it is like the porphyritic conglomerate, or porphyrel, of Zeta lake (vol. iv, page 281), except that the recrystallization has proceeded farther than in the Zeta Lake porphyrel, and the rock has been forced to occupy fissures in the clastics in the manner of an intrusive. N. H. W.

No. 2247. Greenstone. *(Igneous.)*

On the town line, north side of sec. 5, T. 63-9, not far from the lake.
Ref. Annual Report, xxiv, page 77.

Meg. A gabbroid rock in which apparently pyroxene and magnetite exist, the latter being reddish, and perhaps rutile or some other titanium mineral. Has a sharp contact on a schistose and conglomeratic greenstone containing jaspilyte in indigenous masses. It differs from the greenstone containing the jaspilyte in that the hornblendes (or pyroxenes) produce the prominent roughness, the feldspathic ingredient occupying the depressions on the weathered surface, while in the prevalent greenstone, which here embraces the jaspilyte, the surface roughness is produced by a white siliceous net work which permeates the rock and stands out on weathered surfaces.

Mic. The *feldspars,* now much altered, still retain their ophitic relation to the surrounding dark mineral, which, now *uralite,* was originally augite. With considerable *epidote* in small isolated grains is also isotropic *chlorite* and semi-transparent, highly refractive *leucoxene,* which in reflected light coming from the upper surface of the slide appears dull white. Three sections.

Age. Igneous greenstone of the Lower Keewatin. N. H. W.

No. 2248. Granite. *(Sub-porphyritic.)*

On the town line, north side of sec. 5, T. 63-9, not far from the west end of the lake (which is near the section line running north into the next town).
Ref. Annual Report, xxiv, page 77.

Meg. Sub-porphyritic granite. This acts at first like an intrusive, but rapidly widens out in the schistose greenstone. This specimen came from ten feet from either side, weathers nearly white; has pyrite cubes.

Mic. *Quartz* is quite common. It surrounds *muscovite* scales and interlocks with itself and all the other minerals. It was hence the latest of the constituents to take its place. It bears the same relation toward *calcite,* which is abundant. The rock contains a little *sphene, pyrite,* chlorite, and two feldspars, one of which appears to be *orthoclase.* The feldspars which give the rock a sub-porphyritic aspect are occasionally of the soda-lime series and embrace the muscovite scales in the same manner as the quartz. One section.

Age. Intrusive in the Lower Keewatin.

Remark. This rock has the appearance of several others which have been supposed to be derived from the re-crystallization of a fine acid, feldspathic debris. It is allied to the quartz-porphyry of the Lower Keewatin, from which it is perhaps an apophysis. N. H. W.

No. 2250. Granite. *(Fine.)*

Same rock as Nos. 2248 and 2249, at its northern contact on the greenstone. Finer grained. No section.

Remark. This rock has much pyrite in scattered cubes, and is scatteringly "porphyritic" with a feldspar. Its southern line of contact on the greenstone is curious, for it is mixed with the greenstone very confusedly. There are many angular pieces of the porphyry in the schistose greenstone through an interval of six or eight feet, and in many places these two rocks both appear to share in that confusion, there being many pieces of greenstone mingled with the porphyry. It is difficult or impossible to decide whether the porphyry, as an intrusive, has spread itself amongst the greenstone, involving and surrounding many pieces, and itself losing many, or the greenstone as a fragmental has formed a basal sedimentary contact on the porphyry—or whether, again, this confusion is due to friction along a plane of contact between the two rocks. Whatever the cause, it is apparently at the same horizon as seen near the section line between sections 5 and 8, three-fourths of a mile further south. This is probably the rock which forms fine-grained, red-weathering dikes in the upper greenstone that holds the jaspilyte along the south side of this lake, and which appears amongst the graywackes near Nelson's cabins, as described under Nos. 2244, 2245 and 2246. These are, hence, probably all later than the great quartz-porphyry, but belong above the agglomeratic greenstone. As granites or porphyries they may appear as apophyses in later formations if by metamorphism that great quartz-porphyry should become plastic. N. H. W.

No. 2251. Felsyte.

Near the same place as No. 2250, but a little to the west.
Ref. Annual Report, xxiv, page 78.

Meg. Nearly as fine and siliceous as flint, the only mineral visible, besides the fine-grained quartz, or mesh of quartz, which can be identified, being pyrite, which is sprinkled sparsely through the rock. From a narrow red dike, three inches wide, cutting the greenstone No. 2252 in a winding zigzag course along the side of a vertical cliff which looks northeast. No section.

Remark. It is reasonable to infer that this little dike is an offshoot from the mass represented by Nos. 2248–2250. Its densely fine grain is somewhat like that at the contact on the greenstone (No. 2250) and proves that it entered the greenstone when the latter was much cooler than it was. N. H. W.

No. 2252. DIORYTE. *(Uralitic.)*

Near the lake mentioned, and on the knob presenting a northeastward vertical cliff mentioned under No. 2251. S. W. ¼ sec. 33, T. 64-9.
Ref. Annual Report, xxiv, page 78.

Meg. Has the aspect of an igneous greenstone of medium grain; occurs as an irregular intrusive in the midst of the general greenstone.

Mic. The relation subsisting between the hornblende and the altered feldspars is imperfectly that of an ophitic rock, showing that this rock was one that congealed from fusion, and is of later date than the greenstone which it cuts irregularly. One section.

Age. An ancient greenstone cutting Lower Keewatin greenstone. N. H. W.

No. 2253. GABBRO *(with quartz).*

Same place as No. 2252.
Ref. Annual Report, xxiv, page 78.

Meg. Sprawling, dike-like areas, nearly white, in rock No. 2252.

Mic. *Quartz* is quite abundant in this rock, but it plainly was last to take its place amongst the other minerals. The feldspar is *labradorite,* as shown by its acute bisectrix n_g, and its extinction angle at about 20° on a section cut perpendicular to n_g. The *augite* is scarce and is broken and uralitized, but not wholly lost. One grain shows an angle n_g:c of 54°, which indicates an *ægyrine-augite.* These augites are idiomorphic toward the labradorite, as well as toward the quartz. One section.

Age. Gabbro cutting Lower Keewatin greenstone.

Remark. Owing to its light color, and the evident quartz, this rock was taken in the field to be granitic. The augite is inconspicuous and on alteration has lost its usual dark color, becoming light yellowish green, and the resultant uralitic mineral is scarcely pleochroic. A little original magnetite was apparently titaniferous, as it appears now as a dark *leucoxene* with a white reflecting surface. N. H. W.

No. 2254. DIABASE. *(Uralitized.)*

At the west end of another small lake, a little further north, yet in S. W. ¼ sec. 33, T. 64-9.
Ref. Annual Report, xxiv, page 78.

Meg. A greenstone, cutting a coarse Keewatin conglomerate; fine grained at the conglomerate contact.

Mic. This rock was originally ophitic. It now has no augite, but *uralite*; also *leucoxene, calcite* and *epidote.* Two sections.

Age. Dike in Upper Keewatin. N. H. W.

No. 2255. DIABASE. *(Uralitized.)*

North side of the west end of the same lake; top of the southward facing cliff.
Ref. Annual Report, xxiv, page 79.

Meg. Same rock as No. 2254, but showing roundish, light-colored mineral aggregations that give it the appearance of being amygdaloidal.

Mic. The ophitic structure is preserved although the augite is wholly altered to *uralite.* Considerable masses of coarsely cleaved *calcite* are conspicuous in this rock. The feldspar is so altered that its space is occupied by granular secondary minerals, and these are so abundant that it is wholly impossible to determine even the direction of extinction of the original feldspar. Amongst these secondary minerals, probably *epidote, chlorite, calcite* and *leucoxene* are the most abundant. Spicules of hornblende also sometimes pass through these areas. In the slide there is no evidence of amygdaloidal structure. One section.

Age. Igneous, cutting Upper Keewatin conglomerate. N. H. W.

NO. 2256. DIABASE. *(Uralitized.)*

Same rock, same place.
Ref. Annual Report, xxiv, page 79.

Meg. Same rock, showing the white fillings.

Mic. The section cuts one of the white fillings. The structure of the mineral composing this substance is nearly parallel, fibrous or lamellar, but divergent and blending and confused, having a predominant positive elongation, but with some fibres of a negative elongation. It has a very low double refraction, and an extinction angle of about 10° on the elongation of the fibres. About the periphery of this mass is much granular *epidote.* From the single section at hand it is not possible to name this species with certainty by the foregoing optical characters alone; but, except for the small angle of extinction, it agrees well with *apophyllite.* If the interferences and anomalies which are known to appear in that mineral be allowed for in this section perhaps there is no obstacle to that identification. While some of the fibres have a small angle of extinction others have parallel extinction, and in others it is shifting and imperfect, which can be attributed to overlapping twins, or combinations which are somewhat oblique or distorted. Compare No. 2258. One section.

Age. Greenstone (igneous) cutting the Upper Keewatin.

Remark. Later this zeolitic mineral was repeatedly subjected to the Boricky test with hydrofluosilicic acid. No distinct crystalline forms were produced, but the field was covered with minute irregular rods and globules, the former branching and crooked. Through these forms feeble double refraction could be perceived by reason of extinction recurring at certain points on rotation, but for the most part the crystals were confused and imperfect. These forms were evidently fluosilicate of lime. There was no appearance of cubic forms, and hence the mineral may be free from potassium. N. H. W.

No. 2257. Diabase. *(Uralitized.)*

Same place as No. 2256.
Ref. Annual Report, xxiv, page 79.

Meg. Same rock, but having small masses more hornblendic and green in which are small aggregations of hornblende arranged radiatingly and ophitically. No section.

Age. Igneous greenstone cutting the Upper Keewatin. N. H. W.

No. 2258. Diabase. *(Uralitized.)*

Thirty paces north of the quarter-post, west side of sec. 33, T. 64–9.
Ref. Annual Report, xxiv, page 79.

Meg. Coarser condition of the rock last mentioned, forming a rough country, the ridges running a little north of east. The coarse hornblendes stand above the weathered surface.

Mic. The secondary *hornblendes* embrace the altered feldspars in the ophitic manner, and are sometimes interpenetrated and embraced in the same manner by *leucoxene*. The products of alteration of the feldspars are *epidote*, an isotropic, chloritic substance, and *apophyllite*. The epidote is abundant in granular aggregates so fine and so highly refractive that they show no polarization colors, but, between the nicols, present a nearly isotropic field. It also rises into grains of considerable size. The mineral here identified as apophyllite is scattered quite commonly throughout the slide, having low single and double refraction, appearing much like a secondary feldspar. It is sometimes in large plages which embrace much epidote. It has a parallel extinction, some of the crystals being much elongated and usually negative, having n_p parallel with their length, but not invariably. In numerous instances these elongated crystals are nearly isotropic except along a narrow margin, and sometimes different orientations appear in the same mass. The accompanying diagram represents an oblique basal section. The central area is biaxial and has n_g as acute bisectrix, extinguishing at about 45° from the point at which the peripheral portion extinguishes. This mineral was later in origin than the hornblende and epidote, enclosing both, epidote also being enclosed by the hornblende. It serves, apparently, as a background in much of the rock. One section.

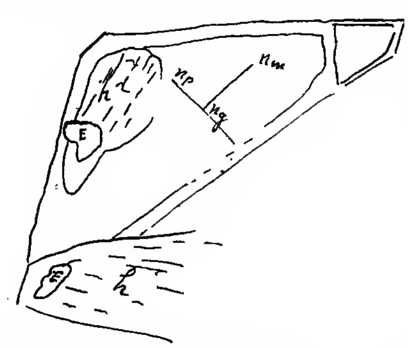

FIG. 50. BASAL SECTION OF APOPHYLLITE IN No. 2258.

Age. Igneous greenstone cutting Upper Keewatin. N. H. W.

No. 2259. Graywacke.

From a conglomeratic ridge running northeastwardly, lying some distance north of the west quarter-post of sec. 33, T. 64–9.
Ref. Annual Report, xxiv, page 79.

Meg. Gray or greenish-gray, granular, clastic; the matrix of a coarse conglomerate.

Mic. For such a rock this contains comparatively little *quartz*, many of the few translucent grains being biaxial and hence probably *feldspar*. None of the grains are friction-rounded. Other feldspars, which are now micro-granulitized, must have been much longer subjected to disintegration, and are rounded, but these are few. Some are plainly striated in the manner of the soda-lime feldspars. The most of the rock is of the darker minerals, *hornblende* and *leucoxene* predominating, while chloritic substance gives darkness to the slide between crossed nicols. One section.

Age. Upper Keewatin (Ogishke conglomerate).

Remark. The fragmental fresh feldspars are apparently only a finer dissemination of the clastic ("porphyritic") feldspars seen in No. 2260. N. H. W.

No. 2260. Porphyrel.

From the same rock as No. 2259, but from the northern part of the ridge.
Ref. Annual Report, xxiv, page 79. Compare the porphyrel of Zeta lake.

Meg. The specimen collected has a porphyritic aspect, due to the dissemination of white feldspars, the matrix being grayish green.

Mic. This rock, in its general composition and structure, is quite similar to No. 2259, but it contains larger feldspars. These are conspicuously banded on the pericline and albite plans of twinning, resembling those of the porphyry of Kekequabic lake, and of the porphyrel of Zeta lake. This rock also embraces notable amounts of calcite. One section.

Age. Upper Keewatin (Ogishke conglomerate). N. H. W.

No. 2261. Kersantyte. *(Dyke.)*

Intrusive in No. 2260.
Ref. Annual Report, xxiv, page 80. (Compare No. 2178.)

Meg. Greenstone, porphyritic with mica, the groundmass having a flesh-color tint.

Mic. The porphyritic scales are *biotite*. About one-half of the area of the section is occupied by a very low refractive mineral which is probably *apophyllite*, but that determination is not certain. It but rarely transmits sufficient light, between crossed nicols, to become visible. The rock contains much *calcite*, as well as innumerable small flakes of mica. One section.

Age. Dike cutting No. 2260.

Remark. This rock is unquestionably identical with rock No. 2178, which shows evident apophyllite. Compare, also, No. 2258. N. H. W.

No. 2262. Chlorite Schist.

A part of rock No. 2260, on its more northern extension.
Ref. Annual Report, xxiv, page 80.

Meg. A rather fine-grained, greenish-gray schist, with a few larger feldspars disseminated.

Mic. The section shows a much decayed clastic debris, which originally was constituted of the same materials as No. 2260, but now is darkened by the prevalence of *chlorite, leucoxene* and some iron oxide. But it is also lightened by *calcite* and a little *quartz*. The "porphyritic" feldspars were chiefly, if not wholly, of plagioclase, but are altered beyond specific determination. The quartz is in fine grains, sharply angular. In places it can be seen that the coarser feldspars have undergone an incipient loose micro-granulitization, with a scant development of fine epidote, but for the most part the feldspars and the finer parts seem to be darkened and disintegrated with development of a fine, highly refractive substance which is granular or irregularly spreading. This is in part chlorite, which embraces calcite. *Apatite* as clastic grains also exists in the rock in small amount, also an isotropic but perfectly transparent mineral, not determined. One section.

Age. Upper Keewatin. N. H. W.

No. 2263. Granite.

Near Moose lake, north from the last, on the section line.
Ref. Annual Report, xxiv, page 80.

Meg. Rather fine-grained for granite, gray.

Mic. The scant coloring elements are *chlorite*, mingled with some *hornblende*. There is, besides, a nearly colorless *amphibole* disseminated in minute fibres throughout the rock. There is a feldspathic and quartzitic background which is closely interlocked, embracing the few dark minerals and a notable quantity of *calcite* and numerous fine scales of *muscovite*. A considerable number of the feldspars are microlitic plagioclase, with nearly parallel extinction and negative elongation as cut, consisting of two to four albite macles; but both these and the larger feldspars, which may be orthoclase, are so related to the muscovite and the calcite that they surround them and appear to be of later date. One section.

Age. Intrusive in the Upper Keewatin.

Remark. This fine-grained, holocrystalline rock, with its curious petrology, is believed to be due to a recrystallization of a fine and clastic debris, a transformation which must have taken place simultaneously with the dynamic action which thrust it in the manner of an intrusive amongst its neighboring fragmentals where they were broken or bent so as to give it entrance. N. H. W.

No. 2264. Granite. *(Incipient.)*

Near the same place as the last, but a little further south.
Ref. Annual Report, xxiv, page 80.

Meg. A gray, felsitic-looking rock, without apparent phenocrysts, except pyrite, which is plainly visible in cubic forms; has a similar dike-like action, cutting a greenstone conglomerate.

Mic. The size of the grains in the composition of this rock is about the same as that of No. 2263, and the materials are about the same. The *hornblendes,* however, are more conspicuous, and in some cases they show their derivation from augite by the peripheral growths beyond the augitic nucleus, the whole being now converted to hornblende, but having a central area of greater absorptive power. For the most part, however, the hornblendes seem to be independent of any augitic nuclei, and especially the smaller ones. These degenerate in size to mere club-shaped spicules in which form they are very abundant in some places, and these spicules still further degenerate in size, becoming only minute globules, illustrating the infantile growths which have been noted in the case of quartz, feldspar, siderite and pyroxene and other minerals.

The principal ingredient of the rock is *feldspar*, but it is so far obscured by decay that it cannot be specifically identified, except that, in some cases, it can be seen to be of a striated species. The grains are, it is true, held together by a background of similar materials, through which has run a secondary feldspathic crystallization, and this has also permeated the old feldspars, but the secondary growths are very inconspicuous, and do not generally appear about the margins of the old feldspars. Occasionally, however, an old feldspar can be seen to be wholly rewrought by a more or less distinct granulitization, and the hornblende spicules run into such grains. Amongst the original clastic debris was an occasional distinct *quartz* grain. Such grains are somewhat enlarged by secondary growths, and finer secondary quartz appears also where there is no evidence of any original quartz. Scattered throughout the slide, and especially in the old feldspars, is a finely granular and highly refractive mineral which cannot be certainly determined, but may be *epidote*. With a little *leucoxene* and some *muscovite* this list completes the mineral composition.

Age. Intrusive in the Upper Keewatin.

Remark. This rock is intermediate, in crystalline state, between the last (No. 2263) and a compacted graywacke. The decay of the feldspars is exactly like that of the graywackes, and is here supposed to have taken place prior to consolidation into a rock, at least before the metamorphism. The mass, when still in its clastic condition, was under such pressure that it was forced as an intrusive amongst the adjoining rocks, and this generated an incipient recrystallization which was arrested before it completely permeated and altered the clastic grains, hornblende and muscovite being the first and most obtrusive forms in this regeneration. N. H. W.

No. 2265. Granite.

On the portage from Moose lake to Flask lake, sec. 28, T. 64–9 W. At several places a rock of this kind appears in lenticular bosses and dike-like intrusions in the coarse fragmentals.
Ref. Annual Report, xxiv, page 81.

Meg. Except for a tendency to a reddish color this rock is quite similar to the last two mentioned, but approaches nearer to No. 2263.

Mic. The old *feldspars* are crowded with *muscovite* flakes, and these are sometimes interleaved with *chlorite.* Calcite is not so abundant as in No. 2263, nor pyrite so abundant as in No. 2264. One section.

Age. Intrusive in the Upper Keewatin.

Remark. This rock is holocrystalline. The present feldspars, a regeneration from the old clastic feldspars, like those of Nos. 2263 and 2264, while generally fine, and for that reason hardly susceptible of specific determination, are occasionally larger, presenting a vanishing, irregular and interlocking periphery, set in close order with the finer feldspar grains that surround them. The present feldspar is probably more basic than the original, some of the potassa having gone into the production of the muscovite scales. The rock contains very little quartz. N. H. W.

No. 2266. Granite. (*Porphyritic.*)

On the same portage trail as the last, near the same place.
Ref. Annual Report, xxiv, page 81.

Meg. A reddish rock, porphyritic with feldspar, sprinkled with pyrite, and with an abundant finely disseminated, ferruginous oxide that appears to be the result of alteration of a carbonate. Considerably coarser grained than Nos. 2263–2265, containing pebbly forms, especially of greenstone.

Mic. The ferruginous oxide surrounds more or less completely cores of a gray or reddish-gray, highly doubly refracting, negative, uniaxial mineral, evidently that from which the oxide is derived, and it is necessary to infer that the rock originally contained a notable amount of *siderite.* It also contains now a large amount of *pyrite,* which sometimes is also peripherally oxidized in the same way. The feldspars are like those of the last described rocks (Nos. 2263–2265), except that some are larger and present a distinctly porphyritic appearance. They are also accompanied by original *quartzes* which are in part evidently bipyramidal. Some of the angular fragmental quartzes are enlarged by secondary rims which extend into and embrace the surrounding matrix, causing a narrow simultaneous darkening with the regular extinctions of the quartz. The feldspars are conspicuously twinned like those of the porphyrel of Zeta lake, and like those of the porphyry and granite of Kekequabic lake.

The matrix is non-homogeneous, but varies in spots in a manner suggestive of the assimilation and reconstruction of pebbles under the action of profound metamorphism. For instance: (1) Siderite is very abundant or is wanting; (2) There are patches where chlorite and secondary quartz prevail almost to the exclusion of everything else, and others that consist almost exclusively of chlorite and muscovite; (3) There are isolated, sometimes roundish, spots in which there is a coarser granulitic recrystallization consisting apparently of new feldspar. These fine, new feldspars embrace no siderite nor muscovite, but the old feldspars are sprinkled with muscovite and sometimes with siderite. Muscovite and siderite seem to have been about cotemporary with the new feldspars. One section.

Age. Intrusive in Upper Keewatin.

Remark. It is probable that the mineral identified as calcite in No. 2263 and others may be in part siderite, but no oxidation is apparent in those rocks. This rock is comparable with the porphyrel of Zeta lake and with the porphyry of Kekequabic lake, standing between them in degree of regeneration. N. H. W.

No. 2267. Dioryte.

On the portage from Moose lake to Flask lake, sec. 28, T. 64–9 W., a little further east than the last. *Ref.* Annual Report, xxiv, page 81.

Meg. A rather fine-grained, hornblendic rock, "which also has the jointage and aspect of an igneous rock. It is firm, fine grained, weathers coarsely very schistose, and is full of pebbles, rounded and angular, mostly and most evidently those of greenstone. These seem to be of the nature of inclusions in a basic intrusive, owing to the nature of this rock."

Mic. The rock consists essentially of *plagioclase* and *hornblende*, the latter, in its crystal faces, being independent of the former, but never having its faces 110 filled out. On the other hand those faces, as shown in section, are seen to be terminated by vanishing and irregular, ragged ends composed of sharp-pointed fibres that penetrate unequally into the surrounding rock, a feature quite common in regenerated rocks. Most of these hornblendes have borders surrounding darker cores, indicating an original augite, or some earlier condition of the hornblende itself. Besides the larger hornblendes there are a great many isolated spicules of the same mineral *(actinolite?)*. These in the same manner pierce the plagioclases in all directions.

The plagioclases are small, and of interlocking, irregular outlines. Some, which appear to be older than others, are pierced by mica scales.

Accessories are *epidote* and *iron ore*. One section.

Age. Upper Keewatin.

Remark. This is a reconstructed rock, whatever its original condition. It is very difficult to form an opinion as to its origin. Its outward megascopic characters, as above enumerated, appear to indicate a fragmental source, and there is nothing in its microscopic composition, so far as seen in the section examined, that precludes that origin. It would be ordinarily classed, however, as a basic intrusive of the diabase type, uralitized. N. H. W.

NO. 2268. PORPHYRY *(or porphyrel).*

On the same portage, near the same place as the last.
Ref. Annual Report, xxiv, page 81.

Meg. A gray rock with coarse, porphyritic white feldspars.

Mic. This is a compacted debris, partially regenerated by new minerals, but showing still plainly the decayed original stuff. There is a little fine quartz, but the rock is almost wholly feldspathic. *Epidote* and a little *hornblende* (often chloritized) give it a darker color. The twinned and striated porphyritic feldspars contain *epidote*, *muscovite*, *calcite* as products of alteration, also occasionally a hornblende spicule. These secondary minerals are distributed evenly throughout the feldspar "phenocrysts," *i. e.*, they do not affect the central areas. In that respect they differ from the secondary products of old feldspars that have been regenerated, as in granites. The only rule that can be observed is that epidote is apt to be more abundant in the peripheral parts. Most of the feldspar grains are so fine that they have been destroyed and blended in the general matrix by a micro-granulitization, and they can then be detected only by the contrast of their fineness with the coarser grain of the surrounding parts. The abundant calcite visible in some parts of the slide does not probably arise wholly from alteration of the phenocrysts, since sometimes such phenocrysts cut off the calcites sharply, with a distinct margin which encloses none of them. They seem to be due to some calcareous clastic ingredient which has been lost by alteration.

In the slide is one small crystal of *sphene*, also several irregular *pyrites*. One section.

Age. Intrusive in Upper Keewatin.

Remark. This rock stands intermediate, in point of recrystallization, between the porphyry of Kekequabic lake and the porphyrel of Zeta lake. N. H. W.

NO. 2269. GRAYWACKE. *(Hardened, feldspathic.)*

On the same portage, near the same place as the last.
Ref. Annual Report, xxiv, page 81.

Meg. A fine-grained, light-green-gray rock, having the appearance of an igneous intrusion, sharply much jointed.

Mic. In the field it was suggested that this rock might be due to the hardening of a siliceous mud, but it was, instead, a fine feldspathic mud with very little *quartz*. The section presents distinctly a field that is made up largely of small, angular fragments of *plagioclase*, very much altered with development of *muscovite*, *epidote* and *calcite*, being a rock essentially the same as the last, and differing in the absence of phenocrysts. One section.

Age. Upper Keewatin. N. H. W.

NO. 2270. GREEN SCHIST. *(Ferruginous.)*

At the summit of the large island in Moose lake crossed by the section line between secs. 28 and 29, T. 64–9.
Ref. Annual Report, xxiv, page 81.

Meg. Has a bright-green, weathered surface, rough with siliceous projections from between which some softer mineral has been weathered out. It is charged, within, with carbonate of iron which on oxidizing does not stay so as to stain the weathered surface. The superficial green color fades out in other places, and the surface is more or less rusty, the interior being gray. It is cut by a rather fresh diabase dike four feet wide and by a narrow, vein-like quartzose dike of fine red granite. No section.

Age. Lower Keewatin(?) N. H. W.

NO. 2271. GRAYWACKE. *(Siliceous, ferruginous.)*

Part of the same mass as No. 2270.
Ref. Annual Report, xxiv, page 81.

Meg. This compact, fine-grained graywacke is quite siliceous, almost deserving the name quartzyte. It has *pyrite*, and is apparently cemented throughout by carbonate of iron, which, on oxidizing, gives the surface of the rock a rusty color. No section.

Age. Lower Keewatin(?) N. H. W.

NO. 2272. GRAYWACKE. *(Schistose, with chalcopyrite.)*

Part of the same rock mass as No. 2271, further east.
Ref. Annual Report, xxiv, page 81.

Meg. The rock is more schistose, sericitic, and, while rusty by oxidized pyrite, is also specked with a malachite green color, indicating that the pyrite was copper-bearing. No section.

Age. Lower Keewatin(?)

Remark. The copper in this rock may be compared with the metallic copper found in the Lower Keewatin at Tower, No. 2278. N. H. W.

NO. 2273. ARGILLYTE. *(Breccia.)*

On the trail from Moose lake to Wood lake, about the centre of sec. 20, T. 64–9 W., westward from the exposure of conglomeratic jaspilyte. The last and highest ridge before reaching Wood lake.
Ref. Annual Report, xxiv, page 82; Final Report, vol. iv, pages 557–562.

Meg. The ridge is composed of a fine, compressed reibungs breccia of fine graywacke and argillyte, the two rocks being closely folded and broken uniformly into a series of alternating short parts. "On the upper weathered surface where glaciation has evenly planed the rock off, the two parts recur with an irregular regularity, causing the rock to present an aspect of a squeezed conglomerate. But on the face of the vertical surface the different pieces can be seen to extend downward for a foot or more in the general mass. The rock must have been at first a banded argillyte." No section.

Age. Lower Keewatin(?)

Remark. This structure is illustrated and discussed in volume iv, of the Final Report, pages 558–562. N. H. W.

No. 2274. Jaspilyte and Argillyte. *(Interbanded.)*

At the southerly slope of the hill containing conglomeratic argillyte near Moose lake, on the trail to Wood lake.

Ref. Annual Report, xxiv, page 82.

Meg. The weather-banding is very evident. The jaspilitic bands are about a third of an inch in thickness and of a light-grayish color, appearing like flint and nearly black within. The argillitic laminæ are about one-sixteenth of an inch in thickness and they weather out more rapidly, producing little grooves that run parallel. No section.

Age. Upper Keewatin(?) N. H. W.

No. 2275. Quartz-Porphyry.

"Burnt forties," near Soudan, at the corner of secs. 13, 14, 23 and 24, T. 62–15.

Ref. Annual Report, xxiv, page 84; vol. iv, pages 528-538.

Meg. Gray, with some feldspar, the probable source of the pebbles of the Stuntz conglomerate.

Mic. This rock is like numerous others that have been described as quartz-porphyry, or porphyrel. There are numerous old *feldspar* pieces and crystals nearly perfect, which are uniformly permeated by decay, with development of *muscovite* and *calcite,* and occasionally a distinct bipyramidal quartz. Some of the feldspars are so far decayed that they can with difficulty be distinguished from the matrix. This decay has been interrupted by an opposite process, which has thoroughly permeated the matrix, where it was originally fine grained, and has partly regenerated the feldspars. This regeneration is marked by fresh feldspathic substance which is clear and glassy, seen throughout the matrix and sparsely in the peripheries of the old feldspars. (Figure 4, plate V.) The quartz, where originally fine, has also been recrystallized and is clear and glassy; such quartz also forms a narrow rim about the old original quartzes, which penetrates the matrix and darkens in unison with the crystal to which it is an appendage. It is most marked about the distinctly bipyramidal grains. One section.

Age. Lower Keewatin(?)

Remark. This rock differs petrographically in no way from those porphyries and porphyrels which have been described between Moose and Flask lakes, which cut the Upper Keewatin conglomerate of that region. N. H. W.

No. 2276. Quartz-Porphyry. *(Granitic.)*

Part of the same rock as No. 2275, but further west.
Ref. Annual Report, xxiv, page 84.

Meg. Weathering pinkish, approximately a granitic structure, with a few coarse, roundish quartz grains or pebbles.

Mic. In the main this is a coarser rock than the last, and is more recrystallized. It also contains a larger percentage of free silica. This is in the form of original rounded grains and of minute, interlocking and micro-granulitic secondary *quartz*, fresh and glassy, some of it being arranged in a vein-like band in which the individual grains are coarser than throughout the rock generally. There are in the slide none of the original bipyramidal quartzes. The *feldspars* are in the form of fragments of uniform size. They never interlock, and rarely come into contact. Many of them are plainly triclinic, but quite a number appear to be of *orthoclase*—perhaps one-half of them. The arrangement of a few linear shreds of *hornblende* and of *biotite* is so generally roughly parallel with itself that there seems to be a trace of an old structure, which, if the hornblende were more abundant, would perhaps develop into a coarse schistosity. The secondary quartz surrounds the fine biotites. While most of the old feldspars are still perfectly evident, there are some that are nearly lost in a fine granulation, caused by decay and subsequent regeneration. Such feldspathic grains can be distinguished from the recrystallized matrix by the greater fineness of the structure in the areas occupied by their sections, their greater obscurity or their greater brightness and sometimes by the greater abundance of fine mica scales, or by an identifiable remnant of the original feldspar itself. In the last case there are apt to be a few peripheral secondary fine feldspar grains attached to the old feldspar.

The isolation of the old feldspar fragments in the regenerated fine matrix is illustrated by figure 5, plate V. That these are fragments and not phenocrysts developed in a magma is evident from the following considerations:

1. They never show crystal outlines, although they are perfectly unimpeded by the surrounding rock substance.

2. In size they graduate from the coarsest to the finest, passing into the general matrix.

3. Their forms are usually subrounded.

4. This rounding cannot be due to resorption, for the surrounding matrix never enters into them in embayments such as often seen in the quartzes of a magmatic quartz-porphyry.

5. The only manner in which they are linked with the matrix is by a later regeneration of the rock, by which the matrix has been reformed and the peripheral portion of the old feldspars has been simultaneously developed by secondary growths that interlock in the regenerated matrix.

6. The finer the grains the more they were decayed, and the less evident they have become after the regeneration.

7. They are both orthoclastic and plagioclastic, a fact which can be explained by reference to an original clastic accumulation, but hardly by simultaneous crystallization from a homogeneous molten magma. One section.

Age. Lower Keewatin(?)

Remark. It should not escape notice that this rock, here supposed to belong in the Lower Keewatin and to have contributed to the formation of the Stuntz conglomerate of the Upper Keewatin, is petrographically identical with much of the quartz-porphyry and granitic intrusive rocks, already described, occurring between Moose and Flask lakes, supposed to be intrusive in the Upper Keewatin, viz.: Nos. 2263, 2264, 2265, 2266, and is also structurally and genetically the same apparently as the quartz-porphyry of Kekequabic lake, which is also supposed to be intrusive in the Upper Keewatin. Therefore, the assignment of this to the Lower Keewatin must be with some uncertainty. N. H. W.

No. 2277. Chlorite. *(Massive, ripidolite.)*

In vug-like angular spaces of No. 2276, as exposed on the weathered surface.
Ref. Annual Report, xxiv, page 84.

Meg. Very fine grained, green; hardness about that of chlorite; massive.

Mic. The mass of this substance, when viewed with high power objective, is resolved into little groups of very low doubly refracting scales or fibres, which are placed divergently and irregularly together. They extinguish parallel and have a negative elongation. Their effect is to make the field of the microscope rather dark.

A micro-chemical preparation with hydro-fluosilicic acid affords numerous microscopic rhombohedrons of more or less irregular development, but with perfect edges and faces. These may be, and probably are, silicic fluorides of magnesium and of iron.* The species is probably *ripidolite*, owing to the position of the axis (n_g) with relation to the lamellæ, and the tendency of the clusters to assume vermicular forms. One section.

Age. In vugs in No. 2276.

Remark. In this chloritic mass are a very few *muscovite* scales, which are as fine as those of the ripidolite, and are arranged parallel with them. N. H. W.

No. 2278. Copper. *(Metallic.)*

Montana shaft of the Minnesota Iron company, Soudan.
Ref. Annual Report, xxiv, page 84: Proceedings of the Lake Superior Mining Institute, iv, 70, 1896. Compare No. 2272.

Meg. Occurs in a vein-like sheet, which crosses the ore deposit diagonally, and dips eleven or twelve degrees toward the south, encountered in mining iron at the

*The elements of a new method of chemico-microscopic analysis of rocks and minerals. Emanuel Boricky. Translated in *Nineteenth Minnesota Report* (for 1890).

depth of 265 feet below the surface of the ground, from one-fourth to one-half inch thick. The principal vein of copper was accompanied by several thinner ones which extended in crevices in the ore and also in the enclosing rock. Malachite, azurite and cuprite also existed in small quantities, thought to be secondary results by alteration of the pure copper, indicated by the discovery of an octahedron, which consisted at the centre of copper, surrounded first by cuprite and outwardly by malachite. According to Mr. Eby some copper specimens were as large as six by ten inches, and some were remarkably well crystallized and free from alteration products. Alteration products from the metallic copper extend downward into the ore for several feet, but above it the ore is free from such products. Dr. C. P. Berkey has discussed these minerals and their paragenetic relations in the paper above referred to.

Remark. This occurrence of metallic copper is in the upper part of the Lower Keewatin and is hence in the oldest rocks known to contain that substance. Its full extent is unknown. It may develop into a much larger body as the iron mining proceeds. The position of the metallic mass transverse to the ore body and to the main structures of the country rock indicates that its origin is not coeval with the ore nor with the country rock. In that respect it differs remarkably from the iron ore. Its manner of occurrence is very similar to that of the copper sheets in a heavy diabase layer of the Keweenawan at Fall river near Grand Marais already described (No. 200). Whether its date of origin is as late as that of the Keweenawan copper deposits is an interesting question which there is at present no means of answering satisfactorily. It can only be said that so far as its alliances and structures can be interpreted, they favor the idea of its dating from the same great convulsive epoch. If that be admitted there result some interesting corollaries.

1. The metallic copper of the Keweenawan was not the result of fusion or reduction of previously existing post-Archean ores.

2. It did not come to the surface of the earth by reason of igneous eruption.

3. The causes that gave it origin and location were not primarily seated in the Keweenawan, unless, as suggested by Dr. Berkey, the Keweenawan formerly existed in the region of Tower. There are some extensive diabase dikes in the region of Vermilion lake supposed to have the Keweenawan age, and these may ultimately be thought to prove the former existence of the Keweenawan overlying the Archean in an extensive deposit in that region. Aside from that consideration this metallic copper is far isolated geographically and structurally from the Keweenawan as now known.

4. If dating from the Keweenawan, but not of the Keweenawan, this occurrence still points to some relation or alliance of the rock (greenstone) in which the copper occurs, with the diabase of the Keweenawan.

If on the other hand this copper existed in the Archean prior to the Keweenawan other important corollaries are evident.

1. The conditions precedent for the development of metallic copper in connection with basic eruption existed in the Archean before they existed in the Taconic.

2. Metallic copper in the Archean may be the direct source of that of the Taconic, through the fusion and complicated chemical reactions attending the transformation of the basal (Keewatin) greenstones into gabbro and diabase of the Keweenawan. Archean metallic copper or copper ores, and the Keewatin iron ore may have locally gone together into the composition of the gabbro and diabase of the Keweenawan.

3. If that be the source of the metallic copper of the Keweenawan, it implies the probable present existence of large bodies of copper in the Keewatin, but probably at great depths within the Lower Keewatin. N. H. W.

NO. 2279. JASPER. *(Red.)*

From the dump of the Lee mine, near Tower.
Ref. Annual Report, xxiv, page 84. Compare No. 140.

Meg. Brick red, dense, but on a freshly fractured surface presenting an internal structure that shows numerous small and irregular conchoidal vitreous surfaces which resemble irregular cleavages. There are in the mass a few small, scattered, massive hematite grains of considerable size, also smaller ones of quartz, which latter also forms a few thin veins, and still fewer specks of a yellow sulphide, which resembles chalcopyrite. The entire mass seems not only to be finely crystalline, but to belong to the hexagonal system, resembling quartz. On the fresh surfaces mentioned are seen numerous dull faces which were produced by the separation of a crystal from its neighbors. These are sometimes grouped so as to suggest the hexagonal system with terminal pyramidal or other faces.

Mic. The coloring material is *hematite.* This is mainly as a pigment, but occasionally takes the form of minute, cherry-red, sub-translucent scales and crystals. The whole section breaks up, between crossed nicols, into angular, "patchy" areas of poikilitic quartz which have varying orientation. The rock might be called a vitreous quartzyte except for its fiery red color.

Age. Lower Keewatin(?)

Remark. It is unfortunate that the structural relations of this rock with the greenstone and the ore are unknown. N. H. W.

NO. 2280. QUARTZ AND RED JASPER. *(Spongy.)*

Same place as No. 2279; a portion of the same rock.
Ref. Annual Report, xxiv, page 84.

Meg. A harsh, siliceous, spongy mass, the cavities evidently due to the oxidation and removal of pyrite. The siliceous remnant consists in part of red jasper, the same as rock No. 2279, and in part of white quartz. The latter is plainly of the same date as the quartz described as permeating the red jasper of No. 2279. The whole rock is evidently a secondary result of chemical infiltration in cavities within the iron ore or its surroundings. These elements, especially the sulphur of the pyrite, may be referred to the clastic (largely volcanic) greenstone in which the ore bodies are embraced. No section.

Age. It is unknown whether this jasper and pyrite are in the original rock containing the ore of the Lee mine, or in the conglomeratic base of the Upper Keewatin. Petrographically Nos. 2279 and 2280 much resemble the silicified "patchy" aporhyolytes of the Keweenawan, suggesting the same petrology; while they have an alliance with the jaspilyte of the Vermilion Iron range, in that they consist solely of quartz and hematite, the former embracing the latter in a poikilitic manner. N. H. W.

SPECIMENS COLLECTED BY U. S. GRANT.

No. 61G. Camptonyte (?)

From a dike in the granite at the falls of Gunflint river in N. E. ¼ N. E. ¼ sec. 13, T. 65–4 W. The dike is on the Canadian side of the falls.

Ref. Annual Report, xvii, pages 160, 161, 199, 204.

Meg. This rock is the same as No. 1318.

Age. Archean. U. S. G.

No. 86G. Esterellyte.

From the point on which is the northwest corner of sec. 32, T. 65–6 W.; north shore of Kekequabic lake.

Ref. Annual Report, xvii, pages 197, 205; Annual Report, xxi, pages 39–50. (This rock is the type of the porphyritic facies of the granite here described.)

Meg. This rock is the same as No. 1094, of which a complete description is given elsewhere. Three sections.

Age. Archean (Keewatin). U. S. G.

No. 344G. Syenyte (*in contact with amphibolyte*).

Shore of Clearwater lake, E. ½ N. E. ¼ sec. 32, T. 63–10 W. Here is an amphibolyte cut by stringers of syenyte.

Ref. Annual Report, xx, pages 41, 97.

Meg. The specimen shows both rocks. The syenyte is of medium grain and reddish in color, and the amphibolyte is of about the same grain and contains a little feldspar. In the syenyte near the contact of the two rocks the hornblende is quite abundant.

Mic. The section shows both rocks. The syenyte is composed essentially of (1) An almost opaque feldspar, which, nothwithstanding its alteration, shows traces of polysynthetic twinning; (2) A fresh feldspar with abundant twinning lamellæ; and (3) A few pieces of green hornblende. The small part of the amphibolyte in the section is seen to be made up almost entirely of green, highly pleochroic hornblende; a small amount of altered feldspar is also present. One section.

Age. Archean. U. S. G.

No. 368G. Granite.

Kawishiwi river (west shore) in S. W. ¼ sec. 34, T. 63–10 W.
Ref. Annual Report, xx, pages 43, 98.

Meg. A medium-grained, brownish granite forming the shore of the river.

Mic. The entire section shows essentially a granitic aggregate of orthoclase, hornblende and quartz. The orthoclase is gray and usually shows a cloudiness due to alteration; a few of the grains show a polysynthetic twinning lamellæ. The hornblende is the ordinary green, highly pleochroic variety, and is completely allotriomorphic; it has altered in some places to chlorite, but elsewhere appears to be quite fresh. Quartz is scattered through the whole section, but is not noticeable macroscopically; it presents the characters of ordinary granitic quartz. It occurs oftentimes in polysomatic areas, and a large number of the grains show decided undulatory extinction. The quartz makes up less than ten per cent of the whole rock. Apatite, sphene and magnetite are the accessory minerals; they all occur in only small amount. The apatite is in both short, stout and long, slender prisms. The sphene and magnetite show no characteristic crystal outlines. One section.

Age. Archean. U. S. G.

No. 383G. Graywacke. *(Fine.)*

North branch of the Kawishiwi river, N. E. ¼ N. E. ¼ sec. 28, T. 63–10.
Ref. Annual Report, xx, pages 46, 99.

Meg. Fine graywacke, evidently somewhat hardened by metamorphism. In the field shows distinct stratification.

Mic. The rock shows a slight schistosity, the graining being elongated prevailingly in one direction, and the darker elements arranged in broken lines or shreds in the same direction.

The most noticeable feature is the decayed condition of the feldspathic grains. They are permeated with *muscovite, chlorite* and *epidote*, which, in finer grains, render the original feldspar so vague and invisible that generally no part of it is sufficiently intact to afford any characteristic tests for species. Some of them can be seen to have been twinned formerly on the albite plan. These decayed grains do not show any conspicuous, and but rarely a narrow, indistinct, broken, reconstructed margin.

Yet it is evident that they are not now in a process of decay, but have been reconstructed and hardened by metamorphism. The matrix in which these old feldspars lie seems to consist of newly crystalline materials, viz., a new feldspar and quartz, with scattered scales of muscovite, a little hematite, chlorite. The little fresh quartzes interlock as in a granitic rock, being interlobed in and around each other.

In a second slide the whole grain is coarser. A well-preserved feldspar, showing n_g perpendicular, has extinction on cleavage at 12°, but a refractive index greater than the quartz adjacent, indicating a species lying between *andesine* and *labradorite.* All the quartz is so completely remodeled in both slides that there is nothing remaining to show its original clastic nature. Indeed, the only remaining clastic feature, so far as can be determined by the slides, is the decayed and then regenerated condition of the feldspars. Two sections.

Age. Keewatin.

Remark. In the field appearance this rock, which alternates with some that are coarser, is in places distinctly micaceous, being near a granitic area. N. H. W.

No. 384G. Graywacke.

Same locality as No. 383G.
Ref. Annual Report, xx, pages 46, 99.

Meg. Similar to the last, but coarser.

Mic. This rock is not distinctly schistose. It contains a conspicuous amount of *calcite, chlorite* and *muscovite.* The feldspars, some of which are large, while showing the same kind of alteration, are occasionally bordered by fresh interlocking growths, and this new growth penetrates and permeates, apparently, the whole feldspar grain and is not observable or is less distinguishable in the body of the grain because of the many muscovite scales and other inclusions which have been developed. The acid feldspars seem to be but little more prone to this alteration than the basic. One section.

Age. Keewatin. N. H. W.

No. 385G. Graywacke. *(Subcrystalline.)*

North shore of the Kawishiwi river, N. E. ¼ N. E. ¼ sec. 28, T. 63–10, near the same place as the last.
Ref. Annual Report, xx, pages 46, 99.

Meg. Gray, firm, when fractured, glistening with scattered cleavage surfaces.

Mic. This rock is quite similar in all respects to the last two. It is noticeable, however, that it contains much *epidote.* It is also observable that some of the larger *feldspars,* which were plainly triclinic at first and must have extinguished alternatingly in the albite twinning bands, in the regular manner of such twinning, now do not extinguish alternatingly. They are instead, simply banded, coincident with the albite macles, with lighter and darker lines and bands, but these bands extinguish simultaneously. At the extinction point certain bands are faintly darker than the others, and at full illumination certain ones are somewhat brighter than the others. Others preserve the albite twinning distinctly. It is observable also that throughout the finer matrix the secondary feldspar is more freely developed, interlocking with the secondary quartz, some of the fine older grains being surrounded by a new rim, while the large feldspars exhibit usually no rim of new growth, although they are probably largely regenerated throughout, and it appears reasonable to attribute to such regeneration the impairment of the albite alternate maclation. The quartz is wholly remodeled, thus making a firm interlocked granitic structure. One section.

Age. Keewatin.

Remark. The modifications of this rock, due to metamorphism (Twentieth Annual Report, page 46), are in nature and structure like those seen in various crystalline rocks which, called granite or dioryte, are intrusive on the adjacent clastics. N. H. W.

No. 386G. Graywacke. *(Metamorphosed.)*

Same place as the last.
Ref. Annual Report, xx, pages 46, 99.

Meg. Weathers nearly white, apparently consisting of quartz and feldspar, fine grained.

Mic. The renewed mineral condition of the whole rock is the same as in the last four described rocks, but this rock contains almost nothing but quartz and the white silicates, with epidote which also is itself nearly white. In some instances (noted also in No. 385G), isolated small globular quartz granules are in the feldspars. This seems to imply that the feldspar has undergone a general molecular rearrangement. One section.

Age. Keewatin. N. H. W.

No. 403G. Quartz-Porphyry.

From a dike in the greenstone north of the Kawishiwi river; N. ½ N. W. ¼ sec. 28, T. 63–10 W.
Ref. Annual Report, xx, pages 48, 99.

Meg. This rock has a grayish groundmass in which are embedded a few quartz grains and numerous flesh-colored and blood-red feldspars. The quartz is more plentiful near the edge of the dike (No. 402G). In places the rock contains minute cavities, apparently formed by the weathering out of certain constituents of the rock.

Mic. Under the microscope the rock is seen to have a microgranitic groundmass of rather variable grain. In this are feldspars of all sizes up to pieces over a quarter of an inch in length. The crystal outlines of the feldspars are not usually distinct and most of them show no planes at all, being pieces with irregular outlines. Many of the feldspars show polysynthetic twinning lamellæ, and a large number do not. Alteration to sericite is quite common, and in some cracks and areas of considerable size in the groundmass sericite has been developed in large amount. Secondary calcite is also present. No distinction between the flesh-colored and the blood-red feldspars can be made in ordinary section,—they both appear colorless; and as yet no oriented sections of the two kinds have been studied; they appear very distinct in the hand specimen. Scattered through the rock are colorless to greenish secondary needles of chlorite or hornblende. A few areas of green hornblende, more or less altered, also occur, but it is not possible to say whether this hornblende was the form of the original ferro-magnesian constituent of the rock. Sphene and apatite are present in small amount. Large quartz grains are not present in the sections examined, although macroscopic grains are often seen in the hand specimens collected. One section.

Age. Archean. U. S. G.

No. 407G. Gneiss. *(Biotitic.)*

S. E. ¼ N. W. ¼ sec. 28, T. 63–10 W. South of the Kawishiwi river.
Ref. Annual Report, xx, pages 49, 99.

Meg. Medium grained, gray, showing biotite.

Mic. This is like a regenerated graywacke. It contains many old, centrally-clouded *feldspars*, most of which have not been much extended, or not at all, beyond their original limits, by new growths, but some of which have been thus enlarged, and they have probably all been more or less reformed by the metamorphosing action which the rock has suffered. This metamorphosing action has wholly reformed the *quartz*, some small granules of which are embraced within the regenerated feldspars, but the most of which forms the interlocking plexus in which the feldspars lie. Besides *biotite*, the rock contains *epidote*, *brown hornblende(?)* and *chlorite*, these forming part of the groundmass; also muscovite (generally within the feldspars) and a little *apatite* and *sphene*. One section.

Age. Archean (modified Keewatin).

Remark. Neither by its mineral composition nor by its internal structure can this rock be distinguished from many granites, nor from the modified graywackes, such as Nos. 385G and 386G. N. H. W.

No. 408G. Gneiss.

Same place as No. 407G.
Ref. Annual Report, xx, pages 49, 98.

Meg. Gray, medium-grained, typical gneiss.

Mic. The same barred structure of some of the large feldspars mentioned in the description of No. 385G, is conspicuous in this rock, and the bars sometimes have two directions, in the same crystal, crossing each other at an angle of about 30°. Other feldspars are distinctly twinned on the albite plan. Otherwise this rock is much like No. 407G. One section.

Age. Archean. N. H. W.

No. 416G. Quartz-Porphyry.

South shore of small lake, W. ½ N. E. ¼ sec. 21, T. 63–10 W. From a dike, within two inches of its edge, in greenstone.
Ref. Annual Report, xx, pages 56, 57, 100.

Meg. A very fine-grained, pinkish rock, with porphyritic quartzes and abundant pinkish porphyritic feldspars.

Mic. Similar to No. 417G, except that the groundmass is some finer grained and the feldspars are not usually in well defined crystals. One section.

Age. Archean. U. S. G.

No. 417G. Quartz-Porphyry.

From the centre of the same dike (see under No. 416G).
Ref. Annual Report, xx, pages 56, 57, 100; Annual Report, xxi, page 43.

Meg. Similar to No. 416G, but more granite-like in appearance.

Mic. Microscopically the rock shows a decided microgranitic groundmass of rather small but irregular grain. Embedded in this are numerous feldspar phenocrysts of all sizes up to those nearly half an inch in length. Most of these feldspars show their crystallographic outlines on all sides, but some few appear as fragments partially bounded by crystal planes. Zonal structure is quite common, and about half of the individuals show polysynthetic twinning lamellæ. Quartz individuals of good size are also present, but are not nearly as abundant as the feldspars. The quartzes are all corroded and show no crystal faces, and they frequently have large embayments filled in with the groundmass. Some of the quartz shows undulatory extinction, but otherwise the rock gives no evidence of having been subject to pressure. Scattered through the groundmass are irregularly outlined green areas composed of chlorite and epidote. What the original ferromagnesian constituent of the rock was is now impossible to determine. A few small acute rhombs of sphene are also present. Two sections.

Chemical analysis. An analysis of this rock, made by Mr. A. D. Meeds, is as follows:

SiO_2	69.70
Al_2O_3	18.72
Fe_2O_3	.65
FeO	.79
CaO	2.25
MgO	.45
K_2O	1.68
Na_2O	5.01
H_2O	.71
Total	99.96

Age. Archean. U. S. G.

No. 490G. Porphyry. *(Syenitic.)*

West shore of a narrow bay of Snowbank lake, S. E. ¼ S. E. ¼ sec. 27, T. 64-9 W. From a dike cutting diabase.
Ref. Annual Report, xx, pages 61, 102.

Meg. This porphyry has a reddish to purplish aphanitic groundmass, in which are porphyritic crystals of red feldspar and small areas of chlorite.

Mic. Under the microscope the groundmass is seen to be microgranitic in structure and apparently composed of *quartz* and *feldspar*. The feldspar phenocrysts are more or less altered and the majority of them show polysynthetic twinning. Irregular areas of chlorite occur in the groundmass, but nothing is left to show what was the mineral that originally occupied these areas. A few small apatite prisms are present, and scattered through the whole rock are minute green flakes of chlorite. Two sections.

Age. Archean. U. S. G.

No. 491G. Granite.

West shore of Snowbank lake, at the line between secs. 26 and 35, T. 64-9 W.
Ref. Annual Report, xx, pages 62, 102.

Meg. It is a granite of medium grain, reddish color and compact texture; the feldspar varies from reddish to white, and the hornblende is in small grains and does not make up more than one-fifth of the whole rock. Quartz is present in small amount.

Mic. Under the microscope this rock is seen to be a distinct hornblende granite. *Quartz* is present in larger quantity than is noticed in the hand specimen. The *feldspar* is more or less cloudy and many of the grains show a microcline structure and have a wavy extinction, as have also some of the quartz grains. The *hornblende* is quite fresh and of the ordinary green variety. A few scales of brown *biotite* are present, and also some green *chlorite*, which appears as an alteration product from the biotite. Bright brownish *sphene* is seen in considerable amount. *Ilmenite,* or *magnetite*, and *apatite* prisms are also present. One section.

Age. Archean. U. S. G.

No. 499G. Gneiss.

South shore of small bay on the west side of Snowbank lake, S. E. ¼ S. W. ¼ sec. 26, T. 64-9 W.
Ref. Annual Report, xx, pages 63, 64, 102.

Meg. A fine-grained, granular, biotitic gneiss.

Mic. In section this gneiss is seen to be a holocrystalline aggregate of interlocking grains of *quartz*, *feldspar*, *biotite* and *hornblende.* Many of the grains are elongated somewhat in one direction; this is especially true of the biotite, and there seems to be a tendency for grains of the same size and of the same minerals to be collected somewhat in irregular parallel lines. This causes a decidedly schistose structure to pervade the rock. None of the mineral grains show any evidence of a clastic origin. The quartz is clear and limpid and is in larger grains than the other minerals; it makes up about half of the rock. The feldspar, while cloudy in small areas, is usually clear; most of it is orthoclase, but some good-sized plagioclases are present. The biotite is brown and fresh; it, more than any of the other minerals, is chiefly confined to certain irregular lines. The biotite is in small scales, most all of which are arranged with their long axes in the direction of the schistosity of the rock. Hornblende of the ordinary green variety is present in a few irregular areas; it appears very fresh. All the minerals of the rock present a decidedly fresh and unaltered appearance. One section.

Age. Archean (Keewatin). U. S. G.

No. 521G. Granite.

North shore of Snowbank lake where the east line of sec. 24, T. 64–9 W., cuts the shore.
Ref. Annual Report, xx, pages 66, 103: Annual Report, xxii, page 156.

Meg. A very fine-grained, dark-gray granite.

Mic. Dr. A. H. Elftman's description of this section is as follows (Twenty-second Annual Report, page 156): "Specimen No. 521G, from the S. E. ¼ of N. E. ¼ sec. 24, T. 64–9, is a fine dark hornblende granite. Under the microscope this shows the *feldspars*, *hornblende*, *sphene* and *magnetite*. The hornblende has altered to chlorite and shows no traces of augite." One section.

Age. Archean. U. S. G.

No. 522G. Granite. *(Augitic.)*

Small island in Snowbank lake, N. E. ¼ S. W. ¼ sec. 19, T. 64–8 W.
Ref. Annual Report, xx, pages 66, 103; Annual Report, xxii, page 156.

Meg. A medium-grained, pinkish-gray granite.

Mic. Dr. A. H. Elftman's description of this rock is as follows (Twenty-second Annual Report, page 156): "No. 522G, from the island in the N. E. ¼ S. W. ¼ sec. 19, T. 64–8, is an augite granite. The mineral constituents are the same as in No. 271E.* *Augite* and *hornblende* are present in separate plates. There is no direct alteration of the former into the latter, but the hornblende possesses the fibrous cleavage of uralite and is a paramorph after the augite. *Biotite* is secondary from the hornblende. In this section we have a change of augite to hornblende, which in turn is altering to biotite and chlorite." Two sections.

Age. Archean. U. S. G.

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*The description of No. 271E is as follows (*Twenty-second Annual Report*, p. 155): "On the west side of the narrow bay in the W. ½ of sec. 20, T. 64–8, is a large outcrop of a light-gray granite (No. 271E). The rock is medium grained, and the ferro-magnesian minerals constitute about one-half of the rock mass. Under the microscope this rock is shown to be an augite granite. *Orthoclase*, *microcline* and *oligoclase* occur in equal proportions. All of the feldspars have a well-defined, clear zone around a kaolinized centre and are in some cases porphyritically developed. Quartz is not very abundant and occurs in small grains. The augite and hornblende are closely associated. The *augite* is of a light-green color, has no pleochroism and extinguishes from 45° to 50°. It forms the cores of the hornblende, which has a darker color, is pleochroic in brown and dark green, and extinguishes at less than 22°. The cleavage of the hornblende is a continuation of that in the augite core. The line of division between the two minerals is distinct, and the extinction angle of both minerals is readily measured along the same cleavage. One pyroxene plate is unaltered, and its extinction and striations bring it near to diallage. Hornblende occurs in several places in bent bundles of slender rods. *Sphene* occurs in double wedges and rounded grains. *Magnetite* and *biotite* are secondary and are not abundant."

No. 523G. Granite.

North shore of Snowbank lake, N. W. ¼ S. W. ¼ sec. 29, T. 64–8 W.
Ref. Annual Report, xx, pages 66, 103; Annual Report, xxii, page 156.

Meg. A medium-grained gray granite, with small yellow stains.

Mic. Dr. A. H. Elftman's description of this rock is as follows (Twenty-second Annual Report, page 156): "No. 523G from the N. W. ¼ of S. W. ¼ sec. 29, T. 64–8, is a medium-grained hornblende granite of a light-gray color. Examined in thin section, this rock shows the usual composition of the hornblende granite in this locality. The *feldspars* are considerably altered, *quartz* occurs only in small grains, and the *hornblende* is highly pleochroic in green and brown. *Sphene* is the oldest mineral. *Magnetite* is largely secondary. *Limonite*, an alteration product, stains the rock yellow. Combined with the kaolin of the feldspar this produces a yellow powder which is easily removed from the rock and leaves cavities. In the hand specimen this peculiar yellow stain is very noticeable." Two sections.

Age. Archean. U. S. G.

No. 524G. Granite. *(Augitic.)*

East shore of Boot island, Snowbank lake. This island is the one crossed by the line between ranges 8 and 9 west.
Ref. Annual Report, xx, pages 67, 103; Annual Report, xxii, page 157.

Meg. A medium-grained, dark-gray granite, in which the ferromagnesian minerals are abundant.

Mic. Dr. A. H. Elftman's description of this rock is as follows (Twenty-second Annual Report, page 157): "No. 524G, from the east shore of the large island (Boot island) on the range line between T. 64–8 and T. 64–9, is a coarse augite granite. In general the rock is the same as No. 271E,* differing only in the character of the augite, which in this section is fresh, shows no signs of alteration, is not pleochroic, extinguishes at 45° and has a deep green color." Biotite is common. Three sections.

Age. Archean. U. S. G.

No. 551G. Granite. *(Augitic.)*

From a little promontory on the south shore of Kekequabic lake, S. W. ¼ S. W. ¼ sec. 3, T. 64–7 W.
Ref. Annual Report, xx, pages 71, 104; Annual Report, xxi, pages 39–50. (This rock is a good representative of the normal phase of the granite here described.)

Meg. A fine-grained, pinkish-gray granite composed of pinkish feldspar, quartz and small grains of augite. Sub-porphyritic feldspars are common.

Mic. Under the microscope the sub-porphyritic feldspars are not so noticeable, except for their size, as in the hand specimen. All the feldspar has a tendency to an idiomorphic form, and all is somewhat clouded by alteration. It is frequently polysynthetically twinned and sometimes, especially in the larger crystals, is zoned. On separating the powder of this rock by means of Thoulet's solution, the larger

*For the description of No. 271E see foot-note under No. 522G.

proportion of the feldspar fell between a specific gravity of 2.58 and 2.62, which would indicate that the mineral was a mixture of the orthoclase and albite molecules; and the analysis, as here given, shows that it belongs to the *anorthoclase* series. It is

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	H_2O	Total
67.99	19.27	.82	.75	.02	3.05	6.23	.90	99.03

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

Quartz is present only in small amount. Green augite is common. A description and analysis of this green augite is given under No. 1094. One section.

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

SiO_2	P_2O_5	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	H_2O	Total
66.84	trace	18.22	2.27	.20	3.31	.81	2.80	5.14	.46	100.05

Age. Archean.

Remark. This rock is a typical specimen of the augite soda granite of Kekequabic lake. U. S. G.

No. 593G. Conglomerate. *(Granitized.)*

S. W. ¼ N. W. ¼ sec. 31, T. 65-6, south shore of the east end of Kekequabic lake.

Ref. Annual Report, xx, page 76. "On the northeast corner of this point is a low outcrop of a fine-grained, gray, apparently holocrystalline rock. The groundmass is grayish, and in it are small, black needles, probably of hornblende, and a few scattered, rather irregularly outlined feldspar individuals. There are also a few rounded pebbles up to those two inches in diameter, scattered through the rock. The specimens collected (No. 593G) show some of the pebble forms. Some of these pebbles are seen to be subangular, but most of them are rounded. They seem to be scattered irregularly through the rock, and lie in no definite planes or layers. There is nothing in the rock to show any sedimentary lamination or bedding; it appears perfectly massive. This rock is seen in several outcrops in the N. E. ¼ S. W. ¼ sec. 31, T. 65-6, and the shore is here usually lined with fragments of it. In the eastern part of this one-sixteenth section is quite an extensive exposure a short distance back from the shore. Here the pebbles, which have been steadily increasing in abundance eastward from the first-mentioned outcrop, are very numerous. It would be almost impossible to find any surface a foot square in the rock at this place which would not contain one or more pebbles, and many areas of this size would include as many as twenty. The rock is here represented by No. 594G, and pebbles from it by No. 594aG. This rock extends along the shore in a few outcrops nearly to the east line of section 31. The pebbles grow less abundant in going east from No. 594G. No. 595G shows a more highly crystalline condition of this rock from the S. E. ¼ N. E. ¼ sec. 31. The noticeable features of this rock are its sharply outlined, rounded and subangular pebbles, and a few scattering, apparently porphyritic, feldspar crystals, sometimes a quarter of an inch in length. No bedding, lamination or definite arrangement of the pebbles could be seen in the rock. It seems that this rock is a metamorphosed conglomerate, and it strongly reminds one of certain facies of the Ogishke conglomerate." *U. S. Grant.*

Meg. The rock is gray, of medium but not uniform grain, and specked with white feldspars that are usually mere fragments of crystals and with pebbles. Its feel is sharp and rough. While evidently a fragmental rock originally it is now compact, sub-crystalline and massive.

Mic. The bulk of the rock is composed of feldspar, the most of which appears to be of *orthoclase*, some of it originally zoned, but there is occasionally an instance of albite twinning. The grains are fresh and even glassy in their translucency about their margins, and by these fresh margins they interlock with each other. Their central portions are invariably clouded by decay.

Quartz unites with feldspar to form the interlocking bond which gives firmness to the rock. There is nothing that can be identified as original clastic quartz. If it ever existed in this rock—and it probably did—it has been reformed so that now it is in sharply interlocking grains. This alteration of the quartz appears to have been simultaneous with the new growths of the feldspars. The feldspars did not lose their original forms and identity, but the quartz is wholly transformed. Occasionally the quartz is so shaped in contact with a border of a feldspar that it shows it was either later or was not able to resist the recrystallizing force in the feldspar.

A few rather fresh, long *hornblendes* are conspicuous for their independent manner of thrusting themselves among the other minerals. There are also many small and irregular ones. The whole of the hornblende is probably of secondary growth, especially the straight and independent crystals; but there is besides a a considerable hornblende which seems to occupy the places of some other original mineral, and some of this is chloritic. They are irregular and imperfect both in form and in cleavages. Indeed, sometimes two dark minerals are curiously and quite irregularly intergrown, having different extinction points. This is caused by partial uralitization of *augites* which in part retain still their crystalline integrity. Such augite, however, is quite light colored.

With some *chlorite* and accessory amounts of *biotite*, *pyrite* and *sphene*, the foregoing constitutes the mineral contents of this rock. Two sections.

Age. Upper Keewatin.

Remark. This rock perfectly exemplifies the manner of conversion of an evidently clastic rock into a crystalline one, and is comparable to several others described from the same region. Its granitization is not so nearly perfect as in some that belong to this belt taken at points further west, but it is more nearly perfect than some which came from the same mass a few miles further east, *i. e.*, from the porphyrel at Zeta lake.

It is evident that it is difficult to decide, in some such cases, whether the rock should be called granite or graywacke, for it has characters of both.

N. H. W.

No. 594G. Conglomerate. *(Granitized.)*

N. E. ¼ S. W. ¼ sec. 31, T. 65-6, south shore of Kekequabic lake.
Ref. Annual Report, xx, page 66.

Meg. Like the last, but more completely conglomeratic, and in general perhaps a little coarser in the general matrix.

Mic. This rock is like the last in all respects, but contains more *sphene.* These grains are usually nearly perfect crystals, though very small, and occasionally one is wholly within a hornblende. One section.

Age. Upper Keewatin. N. H. W.

No. 594aG. Dioryte.

Pebbles from No. 594G; same locality.
Ref. Annual Report, xx, page 76.

Meg. Fine-grained, dark, greenish-gray rock appearing like a fine diabase, of granular texture.

Mic. The slide varies, having on one side apparently a portion of the matrix of the conglomerate. This portion is composed of small *feldspars* compactly crowded together, more or less decayed, but subsequently regenerated, with occasionally a small *hornblende* and a small *sphene.* The rest of the slide consists of the same minerals, but hornblende greatly preponderates. It is also here apparent that the hornblendes are poikilitically embraced in the secondary feldspars. One section.

Age. Pebble in Upper Keewatin conglomerate. N. H. W.

No. 601G. Slate. *(Metamorphosed.)*

S. W. ¼ N. W. ¼ sec. 3, T. 64-7, west shore of Kekequabic lake.
Ref. Annual Report, xx, page 72; Annual Report, xxi, pages 37, 51.

Meg. Aphanitic, almost flinty, greenish gray.

Mic. A fine, pulpy mass of feldspathic debris, with a few quartzes. There were a few grains of *feldspar* that were larger than the average, but they were decayed and macerated before consolidation. Their disintegrated remnants are dislodged and slightly out of place with each other, the interstices having been filled with the finer matrix; yet these remnants have been recrystallized and appear now quite fresh. Their borders throw angular and hooking projections into the surrounding matrix. The whole matrix is also in a completely recrystalline condition, and is composed of finer feldspars and *quartz,* with a sparse network or sprinkling of a light-green, non-pleochroic, highly refractive mineral or minerals, which, in high power, seems to be resolved into granular *epidote,* spicules of *hornblende* and grains of *calcite.*

The rock shows indistinct variations in size of grain as well as in composition, the same that are more conspicuous in the coarser clastic rocks of the region, viz.: Small, angular and roundish areas occur in the midst of coarser grains which are either (1) More abundantly supplied with the darker elements, and between the nicols are so much darker constantly as to suggest the existence of chlorite, or (2) Are almost wholly occupied by finely interlocking granular quartz. These seem to have been originally small clastic masses which differed from the prevailingly feldspathic material, and which, on recrystallization, have been reformed but have not been so completely transformed, molecularly, as to have lost their original shapes. Another variation consists in the occurrence of occasional irregular bands of much finer materials. One is quite marked. It transmits but little light between the nicols owing to the overlapping refraction, but is no less transparent than the adjacent rock. It evidently consists of the same minerals in finer comminution, quartz being evident. One section.

Age. Upper Keewatin.

Remark. This rock was collected as a possible gray slate, with a view to representing the clastic end of a gradation to the granite of the region. It is very evident that it is now in the form of a regenerated fine debris such as could be produced at first in rather quiet water. It seems to have been affected by the same process as that which has passed over the coarser debris, giving it a secondary crystalline bond.

Dr. Grant's note is as follows: "Here there is a gradual change from a gray aphanitic rock much resembling some of the gray slate of the vicinity to the pyroxene granite as represented by Nos. 556G and 557G. The gray rock, however, shows no evidence of lamination or any definite slaty cleavage; it may be a very fine-grained facies of the granite in which the porphyritic feldspars are lacking. As yet these specimens have not been studied microscopically. Nos. 601G to 615G represent this gradation. No. 601G is the gray rock. The specimens up to No. 612G were taken within distances of one to four feet, going eastward from No. 601G. Nos. 613G, 614G and 615G occurred thirty or forty feet further east, and there pass into the facies of the granite represented by Nos. 556G and 557G." N. H. W.

NO. 602G. SLATE. *(Metamorphosed.)*

Same place as No. 601G, but further east.
Ref. Annual Report, xx, page 72; Annual Report, xxi, pages 37, 51.

Meg. Quite similar to the last, but with greenish shadings in which evidently epidote is more abundant.

Mic. Same as the last, but with fewer of the coarser feldspars. There is also occasionally a fine alternation of *epidote* with the rest of the rock, producing a microscopic, banding-like schistosity. One section.

Age. Upper Keewatin. N. H. W.

NO. 603G. GRAYWACKE. *(Fine, metamorphosed.)*

Same place as the last; a little further to the east.
Ref. Annual Report, xx, page 72; Annual Report, xxi, pages, 37, 51.

Meg. Appearing much like the last two, but evidently of coarser grain, showing an occasional cleavage reflection of feldspar.

Mic. *Hornblende* appears more evident as a constituent of the dark (and greenish) element of the rock. The coarser feldspars are fragmentary, and some of them are striated. The coarser grains are rather evenly distributed in the midst of the fine, but in size they grade downward to the fineness of the matrix. Indeed, there is no way of separating the grains distinctly into coarse and fine, except arbitrarily, as the coarse grade into the fine. Still the coarser are sometimes prevailingly in one part of the slide and wanting in another, the texture varying in its average coarseness. *Quartz* is more common than in the last. One section.

Age. Upper Keewatin. N. H. W.

NO. 604G. GRAYWACKE. *(Granitized.)*

Same place as the last.
Ref. Annual Report, xx, page 72; Annual Report, xxi, pages 37, 51.

Meg. Undistinguishable from the last. Some close, irregular joints, opened by the fracture, show epidotic lining.

Mic. This averages somewhat coarser, but is still a fine-grained rock. Some of the feldspars, in the regrowth, show a clear peripheral portion which surrounds the more clouded central area. *Hornblende* is more plentiful. It is granular and ragged, and but faintly pleochroic. Some of the feldspars are distinctly plagioclastic, with extinction angle between the optic plane and the basal cleavage in a section perpendicular to n_g 18°, indicating *oligoclase-albite*, near albite. The latest to take its present place was *quartz.*

This rock has a finely-granitic, interlocking structure, and being wholly crystalline, might be classed amongst the crystalline rocks approaching granite. One section.

Age. Upper Keewatin. N. H. W.

NO. 605G. GRAYWACKE. *(Granitized.)*

Same place as No. 601G to 604G.
Ref. Annual Report, xx, page 72; Annual Report, xxi, pages 27, 51.

Meg. Fine grained, gray, similar to the last, but rather coarser.

Mic. In this it is apparent that the *hornblendic* masses are finely granular, the short individual hornblendes lying at sixes and sevens with each other. This probably accounts for the absence of evident pleochroism in the hornblendic masses, since the general effect would be monochromatic and greenish in such a composite.

In this slide are larger examples of a mineral that exists also in the foregoing (from No. 601G), but in so fine a state that its name could not be ascertained. It is apparently *garnet.* It is highly refractive, but usually dark or faintly light at four points on rotation between crossed nicols. It is water-clear, but has a wide refractive margin on lowering the lower nicol. It is most frequent in the vicinity of the composite hornblendic masses, and is even included within them. It is in irregular, and sometimes sprawling, shapes, without cleavage.

This rock might be called a fine-grained granite. One section.

Age. Upper Keewatin. N. H. W.

NO. 630G. CONGLOMERATE. *(Metamorphosed.)*

N. W. ¼ S. E. ¼ sec. 31, T. 65–6, south of Kekequabic lake.
Ref. Annual Report, xx, pages 79, 107.

Meg. Rather fine, conglomeratic, with much feldspar, making a speckled-gray rock, with no evidence of sedimentary bedding in the field.

Mic. The original *quartz* is entirely reformed, and no trace of the clastic shapes remains. The forms of the *feldspars* are preserved, especially of the larger ones, but frequently the finer feldspars are much changed by regeneration, having a narrow rim of new growth. The larger feldspars are zoned, but not by new increments. The impurities are, for the greater part, arranged in belts that run parallel with the margin. The marginal or first belt is most conspicuous, and gives outline to the grain. Occasionally a second belt is formed parallel with the first, but usually the whole of the interior is irregularly crowded, though less thickly than in the margin, with the same fine inclusions as seen in the marginal belts. These consist of *muscovite, epidote, chlorite* and apparently of *zoisite.* There are in the matrix of these feldspars abundant epidote, some *calcite, hornblende, sphene, chlorite* as well as quartz. One section.

Age. Upper Keewatin. N. H. W.

NO. 638G. CONGLOMERATE. *(Crystalline.)*

S. E. ¼ S. W. ¼ sec. 7, T. 64–6, south of Kekequabic lake.
Ref. Annual Report, xx, pages 80, 107.

Meg. A gray, plainly fragmental rock, holding pebbles. Some red granitic pebbles seem to have been fused or plastic, and are distorted and diffused more or less amongst the surrounding matrix; but the dark pebbles, whether coarse or fine grained, maintain their round outlines.

Mic. This rock has very noticeably the muscovadyte structure, *i. e.*, the minerals have globular shapes, and when large they act poikilitically toward each other. *Hornblende* and *hypersthene* are the coarsest and most conspicuous of these poikilitic minerals, but there is a feldspar (or cordierite?) which also plays the same rôle toward the finer grains. *Quartz* in small quantity mingles in the interlocking mosaic. One section.

Age. Keewatin.

Remark. Gabbro exists on the south half of the southeast quarter of the same section (No. 639G) on the east shore of a small lake, but is rather fine grained.

N. H. W.

NO. 686G. GRANITE. *(Hornblendic.)*

Saganaga lake, S. W. ¼ N. E. ¼ sec. 22, T. 66–5 W.
Ref. Annual Report, xx, pages 88, 109; Annual Report, xxi, page 43.

Meg. A rather coarse-grained, pinkish-gray granite composed essentially of quartz, feldspar and hornblende. Epidote is present, and sometimes small crystals of sphene. This rock is a typical specimen of the Saganaga granite.

Mic. The section shows a granite composed mainly of quartz and feldspar. The latter is commonly clouded and in part altered to fine flakes of a micaceous mineral. The feldspars appear to be in part orthoclase and in part plagioclase near oligoclase. Hornblende is present and has largely altered to a mixture of chlorite and epidote. Sphene is present in small amount, as are also calcite, magnetite and apatite. Two sections.

Chemical analysis. An analysis of this rock by Mr. A. D. Meeds gave the following result:

SiO_2	Al_2O_3	Fe_2O_3 and FeO	CaO	MgO	K_2O	Na_2O	H_2O	Total
69.34	17.25	2.46	3.43	1.18	.71	4.33	1.17	99.87

Age. Archean. U. S. G.

No. 739G. Graywacke. *(Matrix of altered conglomerate.)*

S. W. ¼ S. E. ¼ sec. 1, T. 64–7, south of Kekequabic lake.
Ref. Annual Report, xxi, page 59; Annual Report, xxiv, page 88.

Meg. Gray, fine, firm.

Mic. The rock contains quite a number of angular clastic *quartzes*, also areas, sub-rounded or angular, of a mosaic of quartz grains that closely interlock in the manner of the quartzes of jaspilyte; in these the size of the quartz grains, while about uniform in any individual area, varies from fine to coarse. Other areas seem to have been occupied by different rock pebbles, amongst which some were apparently fine diabase or basaltic (glassy) rock which now is thickly sprinkled with *actinolite*, or with fine scales of yellowish-green *biotite*, but these can with difficulty be distinguished from the general matrix. *Magnetite* and *sphene* (the latter scantily) are scattered through the slide. *Feldspars* in conspicuous grains are as abundant as the quartzes. They are much altered and are sometimes pierced by actinolite and biotite. They show no marginal enlargements. Their edges are ragged and the fine matrix fills in the angles between the ragged projections, and also enters fissures.

The rock is simply a densely compacted, fine debris, the alteration of whose individual grains was accomplished mainly prior to their incorporation in this rock. It is probable that the actinolite is of secondary origin. It is impossible to say whether quartz has been transformed. The only indication of such change that is apparent is the fact that sometimes the actinolites penetrate it for short distances, and that different quartzes are sometimes interlocked in a secondary manner. One section.

Age. Archean (Upper Keewatin). N. H. W.

NO. 740G. MUSCOVADYTE. *(Matrix of altered conglomerate.)*

N. W. ¼ N. E. ¼ sec. 12, T. 64–7, south of Kekequabic lake, in the vicinity of the gabbro border, No. 741G.
Ref. Annual Report, xxi, page 59; Annual Report, xxiv, page 88.

Meg. Gray, firm, showing in the field a few pebbly forms.

Mic. This is a rather uniform muscovadyte. The minerals tend to have a roundish form, and embrace, poikilitically, many small, round grains, each of the others. *Feldspar*, occasionally albite-twinned, is the most abundant. *Augite* and *biotite* come next in amount, the former sometimes surrounding small globular feldspars and sometimes piercing them, and frequently containing small granules of augite, and most frequently having the form of isolated roundish grains scattered promiscuously and apparently of about the same date of generation as the feldspars. Biotite acts poikilitically toward the other minerals. A little pleochroic *hornblende* serves the same purpose, but is usually in larger crystals. *Quartz* is not abundant, but some large secondary grains are distinctly composed of quartz. A little fine magnetite is scattered in the feldspars, in the hornblende, the augite and the biotite. One section.

Age. Upper Keewatin. N. H. W.

NO. 766G. PORPHYRY.

Kekequabic lake, E. ½ S. W. ¼ sec. 34, T. 65–7, point on the north side of the lake.
Ref. Annual Report, xxi, page 60.

Meg. Conspicuously porphyritic with a white feldspar in a fine matrix; contains considerable pyrite. The specimen shows the intrusive contact of the porphyry on a black slate, the former not showing, however, a finer grain at the exact contact, some of the large feldspars being in absolute contact on the slate.

Mic. The feldspars, which are twinned, both by pericline and by albite, the former sometimes coarsely, are much altered by the usual microscopic growths, such as *sericite*, *calcite* and perhaps *epidote*, and sometimes appear to be distorted or crushed, evinced by the interruption of the albite twins. There are several conspicuous original *quartzes* and much quartz that is finer and evidently of later origin. The later quartz forms a coarsely micro-granulitic interlocking matrix, and is mingled with some feldspar grains of about the same size, and also with much *calcite*. The earlier quartzes are somewhat fissured or granulated, and occasionally give an undulatory extinction. The *hornblendes*, which are not common nor conspicuous, are fragmentary and feebly pleochroic, usually much chloritized—indeed, it cannot be affirmed safely that a trace of hornblende remains in the slide examined. One section.

Age. Intrusive in the Upper Keewatin.

Remark. It is evident that since the formation of this rock it has undergone a rough and precarious history. It is also evident that the phenocrysts did not form from a molten magma in the places in which they now lie in proximity to the slate with which the intrusive is now in contact. In other words the porphyry was not a molten mass when intruded into the slate, but simply a plastic mass, moved by pressure, suffering internal fracture and subsequent recrystallization. It might be called a secondary intrusion, but hardly an igneous rock. What may have been the age and origin of this rock at first, it is impossible to state from any evidence in the rock itself, but from general considerations and from alliances which it shows with other Keewatin "porphyries," it is reasonable to assume that it dates from some earlier portion of the Archean. It may have been at first a *porphyrel* like that of Zeta lake. N. H. W.

No. 798G. Diabase. *(Coarse grained.)*

From the centre of a dike at least 150 yards wide and running nearly north and south, near the south line of sec. 20, T. 65-6 W., between Knife and Epsilon lakes.

Ref. Annual Report, xxi, page 62.

Meg. A coarse-grained, somewhat uralitized, greenish diabase. The feldspars are also somewhat greenish in color.

Mic. The section shows a coarse-grained diabase, the essential minerals of which are plagioclase, augite and iron ore. The plagioclase (species not carefully determined, but apparently near labradorite) is much clouded by kaolinic alteration. The augite is reddish in color and very slightly pleochroic. It occurs in large ophitic grains and there is more fresh augite than would be supposed when one considers the altered nature of the feldspar. The augite has, however, altered in many places to a more or less confused, fibrous, greenish and yellowish aggregate, in which can be recognized some green hornblende, some chlorite and a little biotite. The iron ore is accompanied by opaque gray alteration products (leucoxene) and is thus shown to be ilmenite. A little secondary quartz is present. One section.

Age. Cabotian(?)

Remark. This rock (also No. 799G) is somewhat similar to and comes from the same general locality (Knife lake) as Nos. 1742 to 1751. U. S. G.

No. 799G. Diabase. *(Olivinitic.)*

Near the centre of the east side of N. W. ¼ sec. 7, T. 65-6 W., Amœba lake, at the portage to Knife lake.

Ref. Annual Report, xxi, page 62.

Meg. A coarse-grained diabase, with gray to greenish feldspar.

Mic. The section is quite similar to that of No. 798G. No. 799G, however, has a little olivine. One section.

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

No. 847G. Muscovadyte. *(Fragment in gabbro.)*

S. W. ¼ N. W. ¼ sec. 6, T. 64-5. Island in Gabemichigama lake.

Ref. Annual Report, xxi, page page 65; Annual Report, xxiv, page 127; Annual Report, xv, pages 171, 172; Final Report, vol. iv, figure 43.

Meg. A characteristic, gray muscovadyte.

Mic. While the general grain is fine, the structure is decidedly ophitic. The *augite* has a violet tint. Besides the feldspars the rock contains some *quartz* and *biotite.* One (thick) section.

Age. Cabotian. N. H. W.

Remark. Owing to the importance of the ophitic structure in this rock, another slide was prepared. In this the characteristic granular structure is well displayed, differing from the foregoing. The augite has the lamellation of diallage, and, while it occasionally surrounds roundish feldspars, the augite thus surrounding the feldspars is not of the same orientation, but is divided between two or four or more orientations. It is but rare that a single grain of augite, having a single orientation, wholly surrounds a single roundish feldspar, yet there are a few such instances. This slide does not show the normal ophitic structure of the foregoing, since the feldspars thus included do not possess their crystal forms. It is possible, therefore, that the former slide, by some mistake in handling, was not made from the rock No. 847G. One section. N. H. W.

No. 854G. Gabbro? *(with quartz).*

S. E. ¼ S. W. ¼ sec. 12, T. 64-6, southwest shore of a small lake west of Little Saganaga lake.
Ref. Annual Report, xxi, page 65.

Meg. A pinkish-gray syenitic rock.

Mic. The feldspars appear to be both *orthoclase* and *plagioclase*, but they are crowded with *muscovite, calcite,* iron ores, and perhaps other products of alteration, and are closely associated with *quartz.* Within the quartz, and elsewhere, is *pennine.* Quartz embraces the altered feldspars in an ophitic manner, yet in the slide it is also in isolated patches that extinguish in common. There is no olivine nor augite. If these ever existed in this rock, which is doubtful, they are now represented by the pennine and iron ores. One section.

Age. Cabotian.

Remark. It may be considered very questionable whether this rock ever was a gabbro. It is now more nearly a granite, and seems to have resulted from the transformation of an "intermediate" clastic rock. N. H. W.

No. 854aG. Gabbro *(with quartz).*

Same place as the last.
Ref. Annual Report, xxi, page 66.

Meg. A coarse gabbroid rock, with some pinkish feldspar and some quartz.

Mic. Essentially like No. 854G, but having more of the structure of gabbro while lacking its minerals. There are areas that are now occupied by *biotite* (or biotite and *chlorite*) which appear to have been once occupied by *augite,* inasmuch as they sometimes embrace the much altered feldspars in an ophitic manner. This rock has less quartz than the last, but what it has is secondary to the other minerals as in that. It contains also much *calcite.* Biotite and chlorite are interleaved. Two sections.

Age. Cabotian.

Remark. This rock is in a secondary state. The most of its minerals are such as are known to be the products of alteration. The introduction of the quartz, biotite and calcite seems to have been simultaneous with the alteration of the plagioclase.

There may have been a primordial basic magma of the ordinary diabase type, which rose near the surface of the earth at the time of the Cabotian disturbance, but coming into contact with the clastic crust, which was necessarily more acid than itself, was modified by it during the process of cooling. This modification, so far as evinced by the composition of rocks Nos. 854G and 854aG, and the altered condition of the primordial minerals, consisted in the total loss of the ferromagnesian minerals (augite and olivine) and of any magnetite or apatite that may have been in the primordial magma, and the introduction of acid elements, viz., quartz, orthoclastic feldspar and muscovite. Calcite may have been derived from the simultaneous alteration of the original labradorite. These changes were a "secondary" process so far as concerns the original basic rock, but the minerals that resulted are as old as the rock itself, considered as a solid body, and in that sense they are original to the rock. These alterations therefore are believed to be not due to weathering nor to dynamic action, nor to contact metamorphism of any igneous rock of later date than that of the rock itself. These "secondary" minerals are more stable, as a group, than the minerals which they have replaced. They are quartz, biotite, calcite, muscovite; and such minerals as a group endure weathering and all dynamic action, as is well known, more successfully than olivine and augite. Throughout the body of the diabase and gabbro mass in Minnesota, wherever olivine and augite are found at all and have not been subjected to abnormal contacts or dynamic action, they are apparently as fresh and clear as when they were first formed. They have not suffered any deep-seated, metasomatic alteration. That fact not only shows that they have endured intact since Taconic time, but also that it is only in abnormal conditions resulting from igneous contact and its heated solutions under dynamic stress that they are lost to the rock. N. H. W.

No. 857G. Gabbro. *(Olivinitic.)*

Northeast shore of bay at north side of Bashitanaqueb lake, near the north line of sec. 2, T. 64-5 W.
Ref. Annual Report, xxi, pages 66, 150, 151.

Meg. A fine-grained, dark-gray, granular rock composed of feldspar and dark minerals.

Mic. The section shows a granular aggregate of feldspar, pinkish diallage and olivine. The latter is altering to a fibrous green material, and throughout the section is much of a very fine-grained, secondary mineral, which appears to be calcite. The feldspar is frequently, though not always, polysynthetically twinned; equal extinction angles in sections cut normal to 010 run up to 20°, indicating a plagioclase as basic as andesine. A little biotite is present, as is also a small amount of magnetite. Three sections.

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

SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	MnO	Na_2O	K_2O	CO_2	H_2O	Total
49.07	17.21	.46	12.18	9.66	3.60	trace	2.96	trace	2.70	1.55	99.39

Age. Cabotian.

Remark. This is one of the rocks to which the name "muscovadyte" has been applied. U. S. G.

No. 879G. Taconyte (?)

E. ½ S. W. ¼ sec. 21, T. 65-4 W., north of the works of the Gunflint Lake Iron company.
Ref. Annual Report, xxi, page 67. (Compare No. 1896.)

Meg. A fine-grained, heavy, banded rock, the bands being composed of (1) Magnetite, and (2) Very fine-grained, gray, siliceous material.

Mic. With a scattered taconitic structure, evinced both by the prevalence of an interlocking quartz background and by globular aggregations of siliceous iron ore, this rock shows much *pyroxene*, which serves to include poikilitically many fine granules of *magnetite*, of *quartz* and of globular pyroxene. There are also a few needles of *actinolite* that radiate into the quartz from some of the small augite grains, and a small amount of *cummingtonite*. Two sections.

Age. Animikie(?)

Remark. The irony, taconitic globules of this rock are like those of the Mesabi iron ore; but here they are mingled with much pyroxene, some of which is in imperfect crystals as large as the taconitic globules. The usual quartz mosaic serves as background for both these substances. This pyroxene is an anomaly for taconyte. The taconitic nature of this rock is determined by the patchy and globular grouping of the magnetite grains, these grains being sometimes quite coarse, but also sometimes finer, and more scarce or wanting in some portions of the slide. N. H. W.

No. 989G. Gabbro *(with diallage)*.

S. W. ¼ N. W. ¼ sec. 11, T. 64-3. At the south end of the portage from Tucker lake to the long lake next south.
Ref. Annual Report, xxii, page 84; Final Report, vol. iv, page 489.

Meg. Granulitic gabbro, heavy with magnetite.

Mic. The minerals are fresh and all have rounded outlines, as if they were formed simultaneously. The *augite* is uniformly diallagic, and, while it spreads irregularly amongst the feldspars, it does not surround them ophitically. The slide contains very little *olivine.* There is a small amount that surrounds in a narrow rim some of the magnetites, but it is so small that it is only accessory, the rock being composed essentially of *diallage, feldspar* and *magnetite*, one-half being diallage. One section.

Age. Cabotian. N. H. W.

No. 989aG. Gabbro. *(Almost anorthosyte.)*

Same place as No. 989G, and interbanded with it.
Ref. Annual Report, xxii, page 84; Final Report, vol. iv, page 489.

Meg. Coarsely crystalline, and consisting largely of gray feldspar.

Mic. The minerals show a succession in the date of formation. The *magnetite* and coarse *feldspars* were the first to crystallize. Next came the *diallage* which is not abundant, or rather small in amount, occupying the open angular spaces left between the feldspars. If it had been in sufficient amount the diallage would have embraced the feldspars ophitically. The slide contains no olivine. The diallage is largely altered to *hornblende.* One section.

Age. Cabotian.

Remark. With some qualification this rock might be styled a diabase, since its structure is essentially ophitic. N. H. W.

ROCKS COLLECTED BY A. WINCHELL.

No. 24W. Quartz-Porphyry.

S. W. ¼ N. W. ¼ sec. 3, T. 62–14; eastern extremity of Little Mud lake.
Ref. Annual Report, xvi, page 27. (Compare No. 376.)

Meg. Light gray, massive or coarsely schistose.

Mic. In a very fine, interlocking and rather uniform groundmass of *feldspar, quartz, muscovite, chlorite* and *calcite* are large feldspars of idiomorphic form, which are themselves so crowded with the same minerals in fine granules that they can hardly be distinguished from the rest of the section. It is only by rotation of the stage between the nicols that it can be seen, at the points of greatest light, that feldspar forms are concealed in the section. There are also a few irregular patches, of considerable size, of *chlorite* which has doubtless resulted from an alteration of hornblende. *Apatite* in a few small crystals, and *sphene* smaller and fewer, can be noted. Besides the large feldspars there is also one large bipyramidal *quartz* crystal. One section.

Age. Keewatin (Lower).

Remark. The appearance of this section indicates a clastic rock rather than an igneous one. There is no apparent schistosity in the slide. The rock is of a common kind. N. H. W.

No. 25W (bis). Quartz-Porphyry.

S. E. ¼ N. W. ¼ sec. 3, T. 62–14, south side of Mud lake.
Ref. Annual Report, xv, page 27.

Meg. Light gray, nearly massive.

Mic. Like No. 24W, except that the feldspars are not so far decayed. One feldspar shows a large embayment, as if produced in the magmatic state. This rock, like the preceding, is slightly reconstructed after long decay, by the formation of new feldspar and quartz which interlock throughout the fine matrix, while a new feldspar substance has generally not replaced the original species, at the same time that most of the fine inclusions have had birth. These inclusions are evenly distributed or are most abundant about the ragged edges of the feldspar sections. The old feldspars are best preserved at their centres, and they have no marginal new growths. One section.

Age. Lower Keewatin. N. H. W.

No. 26W. Schist. *(Flinty.)*

S. E. ¼ N. W. ¼ sec. 3, T. 62–14, south side of Mud lake.
Ref. Annual Report, xv, page 27.

Meg. Bluish, fine, compact, jointed like the quartz-porphyry.

Mic. Exceedingly fine, without large feldspar forms, yet this slide shows a few apparently fragmental pieces of feldspar. The rest of the rock is much darker between the nicols than the foregoing, and this darkness is seen to be due (on lowering the lower nicol) to the presence of much finely divided *chlorite* and highly refractive *epidote* with a little *sphene.* One section.

Age. Lower Keewatin.

Remark. This is not known to be separable either structurally or petrographically from No. 25W. N. H. W.

No. 27W. Schist. *(Flinty.)*

S. E. ¼ N. W. ¼ sec. 3, T. 62–14, south side of Mud lake.
Ref. Annual Report, xv, page 27.

Meg. Gray, fine, hard, but internally somewhat conchoidally brecciated.

Mic. Like No. 26W, but having somewhat larger and more numerous feldspar grains, but not approaching the porphyritic aspect of No. 24W. One section.

Age. Lower Keewatin. N. H. W.

No. 33W. Greenstone. (*Graywackenitic.*)

N. E. ¼ S. W. ¼ sec. 14, T. 62–14, northwest part of Sand lake.
Ref. Annual Report, xv, page 29.

Meg. Compact, but finely jointed, tough, weathering like a greenstone.

Mic. *Hornblende, chlorite, epidote,* with more or less indistinct *feldspar,* compose this rock, giving it a green color. The first is in more or less large crystals and parts of crystals, as well as in fragmentary and interlocking shreds which are spread throughout. One section.

Age. Lower Keewatin. N. H. W.

No. 82W. Amphibolyte.

S. W. ¼ N. W. ¼ sec. 29, T. 63–12, Long lake. Island north of point.
Ref. Annual Report, xv, page 53; Annual Report, xxiv, page 42.

Meg. Fine, compact, with weathered aspect of a schist. Compare No. 2104.

Mic. *Hornblende* and an altered *feldspar,* with a little *quartz,* compose essentially this rock. The feldspars are nearly dark between crossed nicols, due to a saussuritization (largely of granular and scaly chlorite) which they have suffered, except in an occasional very narrow thread-like border or zone about their peripheries, which is quite bright and evidently of some other but indeterminable mineral. One section.

Age. Keewatin. N. H. W.

No. 83W. Amphibolyte.

N. W. ¼ S. W. ¼ sec. 29, T. 63–12, Long lake. Island close to point.
Ref. Annual Report, xv, page 53.

Meg. Green, feebly schistose.

Mic. This slide is like No. 82W, but in addition shows considerable *leucoxene.* One section.

Age. Keewatin. N. H. W.

No. 84W. Tuff(?)

N. W. ¼ S. W. ¼ sec. 29, T. 63–12, Long lake. Little island near the shore.
Ref. Annual Report, xv, page 54. (Compare rock No. 2099.)

Meg. Fine sericitic schist, holding hornblendes porphyritically.

Mic. This rock has a strong schistosity. The porphyritic *hornblendes* are surrounded by a fine saussuritized feldspathic mass, which is nearly dark between the nicols, like the feldspars in No. 82W. These hornblendes are bordered and patched by a second development, *i. e.,* the forms of the original augites are shown by the different coloration of the central portions, these central portions being the latest to acquire the hornblendic composition and cleavage.

Age. Keewatin. N. H. W.

No. 89W. Schist. *(Sericitic.)*

S. E. ¼ S. E. ¼ sec. 29, T. 63-12, main land, shore of Long lake.
Ref. Annual Report, xv, page 55.

Meg. Coarse, gray, schistose.

Mic. The same fine interlocking groundmass of fresh quartz and feldspar embraces *feldspar* and *augite* forms, but in place of feldspar and augite are now other minerals, viz., in place of feldspar *muscovite and calcite*, with considerable *chlorite*, the two former in unusually large grains, and in place of augite is chlorite. There is also in general much *epidote*, sometimes in grains of size sufficient to give colored polarization. One section.

Age. Archean (Keewatin). N. H. W.

No. 91W. Greenwacke.

Centre of N. E. ¼ sec. 28, T. 63-12, Long lake.
Ref. Annual Report, xv, page 55.

Meg. Chloritic graywacke.

Mic. A confused mingling of fine *feldspars* and *quartz*, with abundant *hornblende*, *calcite* and *leucoxene*, and with *epidote*. In the slide are inequalities of grain and in the distribution of the hornblendes, denoting the former existence of other minerals, probably of feldspars, which have been absorbed and replaced by a fine micro-granulitic growth, such as is common in old greenstones. In other places remnants of such old feldspars are still visible. The rock was probably at first a debris of basic composition, perhaps tuffaceous. One section.

Age. Archean (Keewatin). N. H. W.

No. 92W. Graywacke.

S. W. ¼ S. W. ¼ sec. 23, T. 63-12.
Ref. Annual Report, xv, page 55.

Meg. Graywacke.

Mic. Similar to 91W, but much lighter colored, having no hornblende, little chlorite, and much better preserved feldspars, but the rest of the slide is largely composed of a fine quartz-feldspar secondary replacement, which is irregular in fineness, indicating that the rock was originally fragmental.

Age. Archean (Keewatin). N. H. W.

No. 94W. Greenstone. *(Altered diabase.)*

S. E. ¼ S. W. ¼ sec. 20, T. 63-11, Garden lake.
Ref. Annual Report, xv, page 68.

Mic. The *feldspar* is almost wholly destroyed, its place being occupied by saussuritic products, largely *epidote*. *Hornblende* is abundant, but is frequently replaced by a later isotropic chloritic substance. There are large angular masses of *leucoxene* and others of *pyrite*, and groups and scattered grains of *epidote;* but the general aspect is that of a much altered diabase rock of originally massive nature, there being a structure which is like the ophitic structure of diabase. One section.

Age. Archean (Keewatin). N. H. W.

No. 139W. Camptonyte (?)

N. W. ¼ S. W. ¼ sec. 18, T. 63–11, Fall lake.
Ref. Annual Report, xv, page 66.

Meg. Coarse, green, schistose, with distinct hornblende crystals.

Mic. In a fine groundmass of indistinct *feldspar* and fibres of *hornblende* are numerous idiomorphic crystals of *hornblende* usually twinned on 100, and frequently showing a narrow peripheral zone which extinguishes with the central area, but exhibits slightly different polarization tints, and in some instances the original augitic form is well preserved by this difference of polarization. The rock is not much decayed. One section.

Age. Archean (Lower Keewatin). N. H. W.

No. 177W. Diabase. *(Altered.)*

N. E. ¼ N. E. ¼ sec. 30, T. 64–10, Urn lake.
Ref. Annual Report, xv, page 95.

Meg. Doleritic.

Mic. With much *calcite* and *magnetite* and some *chlorite*, a little *hornblende* and *leucoxene* this rock still shows, in the position of the feldspars, that it was originally a diabase with ophitic structure. One section.

Age. Archean (?) N. H. W.

No. 770W. Gabbro.

T. 64–5 E. (unsurveyed), Pigeon river.
Ref. Annual Report, xvi, page 289.

Meg. Compact, hard, gabbroid.

Mic. This rock seems to have been an olivine gabbro, but nothing now remains to attest the former presence of olivine except a yellowish, serpentinous substance in which apparently *antigorite* takes part. The *augite* was nearly cotemporary with the feldspar and is in small grains. The feldspar is evidently *labradorite.*

Age. Cabotian. N. H. W.

ROCKS COLLECTED BY H. V. WINCHELL.

NO. 2H. GRAYWACKE. *(Sheared, or sericitic schist; fine.)*

Stuntz island, sec. 21, T. 62-15.
Ref. Annual Report, xv, pages 276, 280, 283, 304, 310, 312, 314, 413.

Meg. Schistose indistinctly, also presenting a basaltic appearance.

Mic. The rock is mostly a sericitic schist. The very fine micro-granulitic groundmass having *mica* and much *calcite,* contains numerous forms of old *feldspars* that are much altered by the generation of secondary minerals, such as mica and calcite. The points of darkening, on rotation between the nicols, are distinct, but the twinning bands are lost. In some places also no trace of the original feldspar is left, except its shape and size outlined in an area that has a general uniform fineness contrasted with the surrounding variations. A little *epidote* and *leucoxene* appear, the former in the areas of the altered feldspars. The feldspars show no new growths of feldspar. One section.

Age. Archean (Keewatin). N. H. W.

NO. 2aH. SERICITE SCHIST.

Pebbles contained in No. 2H.
Ref. Annual Report, xxv, page 276.

Meg. Soft and greenish, schistose.

Mic. The rock consists entirely of very fine sericitic scales, and debris of feldspathic character, having a marked schistose structure. N. H. W.

NO. 4H. GRAYWACKE.

From the island crossed by the line between secs. 15 and 16, T. 62-16, Vermilion lake.
Ref. Annual Report, xv, pages 281, 413.

Meg. Gray, sericitic, hard, tough, compact, with pyrite.

Mic. *Quartz* and old *feldspars* lie loosely in a micro-granulitic groundmass. The latter are plainly striated, but still are very much replaced by secondary *sericite* and *calcite.* They, as well as the quartz, are interlocked at their margins, with the fine groundmass. One section.

Age. Archean (Keewatin). N. H. W.

NO. 6H. GRANITE. *(Hornblendic.)*

North side of the bay in S. E. ¼ sec. 7, T. 62-16, Vermilion lake.
Ref. Annual Report, xv, pages 282, 414.

Meg. Reddish gray, somewhat gneissic.

Mic. The *quartz* in this slide appears as a pneumatolitic product, and not as original grains; along with *feldspar* in form of old (even porphyritic) crystals, is also a considerable amount of *hornblende*, and, later, a large amount of *epidote*. The groundmass in general is coarser, and more varied, and the hornblendes are evidently the result of uralitization, the old form of the augite scarcely remaining in the dark central areas. One section.

Age. Archean (Keewatin).

Remark. This rock shows well the partial formation of granite from a clastic rock, affording some of the same phenomena as described at Kekequabic lake.

N. H. W.

No. 7H. Graywacke.

From the point, S. E. ¼ sec. 8, T. 62–16, Vermilion lake.
Ref. Annual Report, xv, pages 282, 414.

Meg. Gray, fine, slaty or coarsely schistose.

Mic. A fine debris of feldspar and quartz, with a little *hornblende; mica*, *epidote*, *calcite*, *chlorite*, as later products, having a schistose structure. One section.

Age. Archean (Keewatin). N. H. W.

No. 8H. Graywacke (?) (*Sericitic.*)

Same locality as the last.
Ref. Annual Report, xv, page 414.

Meg. Finely conglomeratic; color varies from reddish to greenish; essentially an acid rock, now sericitic.

Mic. Coarse *feldspars*, large *quartz* grains and probably some augite composed this rock originally. It is now so changed that the finer grains and much of the feldspar have been recrystallized, forming an interlocking, fine groundmass; the feldspars are affected by the generation of multitudes of *sericite* scales and *calcite*, and furnished with a new interlocking border, and the rare hypothetical augite is now in the form of *hornblende* and *chlorite*. Cotemporary with this transformation has been produced a considerable amount of *epidote*. A small *sphene* is preserved in one of the old feldspars. One section.

Age. Archean (Keewatin). N. H. W.

No. 9H. Greenstone

N. E. ¼ sec. 9, T. 62-16, Black Duck point, Vermilion lake.
Ref. Annual Report, xv, pages 282, 283, 299, 414.

Meg. Acts somewhat like a dike, but has an indistinct sedimentary structure; gray, schistose.

Mic. This rock is similar to the last, except that it contains more *chlorite* and *hornblende*, and the *feldspars* are almost entirely lost in the granulitization of the rock. In this slide also is a larger amount of *calcite.* *Sphene* also exists in grains in the groundmass. One section.

Age. Archean (Keewatin).

Remark. According to the field description this was an igneous rock. N. H. W.

No. 10H. Quartz-Porphyry.

West side of point in sec. 5, T. 62–16, Vermilion lake.
Ref. Annual Report, xv, pages 283, 414.

Meg. Homogeneous dike-rock cutting graywacke.

Mic. Coarse, idiomorphic, but somewhat altered, *feldspars*, with some large *quartzes*, are in a uniform, fine mosaic of feldspar and quartz. In this fine matrix are many *sericites*, which frequently pierce the little quartzes. There are also areas of *calcite.* One section.

Age. Archean (Keewatin).

Remark. The date of the matrix of the large crystals is later than the sericites. The sericites have resulted from an alteration of feldspathic material. They are also distributed through the feldspar crystals, but not so abundantly. The rock shows traces of hornblendic material; therefore, notwithstanding the striking contrast between the crystals (phenocrysts they might be called in an igneous rock), and the fine, uniform grain of the interlocking matrix, it is possible, if not probable, that this rock has resulted from a debris of acid porphyritic rock. Further, the fact that the large feldspars are striated and much twinned, evidently like those of the *esterellyte* of Kekequabic lake, shows that, if from a granite as a debris, the granite was not of the normal type, and that it supplied large, perfect crystals at the same time with a very fine debris, with no grains (or fragments) of intermediate sizes. For these reasons it is quite reasonable to consider this rock as an intrusive, in the manner of the esterellyte of Kekequabic lake, and originating in the same way from some of the neighboring clastics of the Keewatin. N. H. W.

No. 11H. Greenstone. *(Altered.)*

S. E. ¼ sec. 5, T. 62–16, Vermilion lake.
Ref. Annual Report, xv, pages 283, 414.

Meg. From a dike running through graywacke; tough, grayish green, hornblendic.

Mic. Roundish, interlocking grains of *quartz* and of a glassy *feldspar* (oligoclase or oligoclase-albite) are visible throughout this slide, but they are liberally mingled with *hornblende, sericite, calcite* and *epidote.* The minerals are largely or wholly secondary, the hornblendes being the largest. There is no radial or other structure indicating an original igneous origin. The feldspars and quartzes are later in origin than the hornblendes and sericites. One section.

Age. Archean (Keewatin).

Remark. The field relations show that this rock was intrusive in the graywacke of the region. Its great alteration shows to what extent original diabases or dolerytes are transformed; *i. e.*, unless the rock be a regenerated basic debris compelled to act as an intrusive by dynamic folding and fracture. N. H. W.

No. 12H. Greenwacke.

South side of the island in S. W. ¼ sec. 32, T. 63–16, Vermilion lake.
Ref. Annual Report, xv, pages 299, 414.

Meg. Cut by dikes of greenstone; a green, coarse rock.

Mic. Uralitized and chloritized *augites*, lie in a debris of the same material. In the finest material is apparently a little *feldspar* and a noticeable amount of *epidote*. One section.

Age. Archean (Keewatin). N. H. W.

No. 15H. Dioryte.

Near the township line, in N. W. ¼ sec. 7, T. 62–16, Vermilion lake.
Ref. Annual Report, xv, pages 284, 285, 415.

Meg. Heavy, massive, greenish black, probably a dike.

Mic. Principally composed of coarse *hornblende* and of *feldspar* interlocked in a somewhat igneous fashion. The feldspar is considerably broken and reconstructed by new growths, but shows still, in the main, the sizes and forms of the original crystals. The hornblendes are secondary after pyroxene, and in numerous instances they show the usual differences of polarization which indicate approximately the forms of the original pyroxene grains. *Calcite, epidote, magnetite, biotite* and *muscovite* appear in accessory amounts. One section.

Age. Archean (Keewatin). N. H. W.

No. 17H. Greenwacke.

S. W. ¼ S. E. ¼ sec. 1, T. 62–17, from the point, Vermilion lake.
Ref. Annual Report, xv, pages 285, 415.

Meg. Greenish, siliceous schist.

Mic. Schistose. The rock is quite fine grained, but long-drawn bands of *hornblendic* debris give it a strong parallelism of schistosity, while *epidote* in fine, granular, mostly isolated individuals, is very numerously distributed, but somewhat in lines parallel with the schistosity. The finely granulitic matrix is of *quartz* and *feldspar* of later date than the hornblendes, but the epidote is earlier than the hornblende. There are but very few, if any, sericite scales. One section.

Age. Archean (Keewatin). N. H. W.

No. 19H. Dioryte (*with sphene*).

Sec. 3, T. 62–17, Vermilion lake.
Ref. Annual Report, xv, pages 286, 287, 415.

Meg. In hills and ridges that alternate with hills of mica schist along the shore.

Mic. Similar to No. 15H but less altered, the *pyroxene* being still somewhat preserved. Large *sphenes*, with crystal outlines, are frequent. These crystals, as well as all the smaller grains which do not show definite crystal form, are secondary to the hornblende. Not only is the sphene indented by hornblende about its margin, but it surrounds completely several globular grains of hornblende, as shown in the accompanying figure. It also encloses two other grains that are apparently calcite and feldspar. One section.

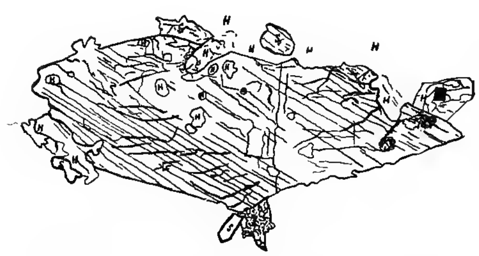

FIG. 51. SECONDARY SPHENE IN NO. 19H.
H-Hornblende; S-Sphene.

Age. Archean (Keewatin). N. H. W.

No. 22H. Chlorite Schist. (*Greenstone.*)

From the top of Sunset peak, north of the east end of Long lake, sec. 22, T. 63-12.
Ref. Annual Report, xv, pages 404, 416.

Meg. Greenish, schistose.

Mic. In the midst of the *chlorite*, which is in fine, radiating or fan-shaped forms, are a few spicules of hornblende, and a finer, granular feldspar fills some of the interspaces. The most of the rock consists of chlorite. A few minute *sphenes*, some *pyrite* and *leucoxene* are also visible. Two sections.

Age. Archean (Keewatin).

Remark. Another section bearing the same number is from what was probably originally an igneous rock, but which now has no feldspar, there having been substituted for it a very fine granular mass of secondary products which, owing to the thickness of the section, cannot be minutely studied, but in which *calcite* seems to enter largely, probably consisting of *feldspar* and *quartz*. In this fine substance lie numerous *hornblendes*, much chloritized, whose size is in strong contrast with the very fine matrix in which they lie. N. H. W.

No. 26H. Amphibolyte.

Sec. 15, T. 63-12, ridge north of Long lake.
Ref. Annual Report, xv, pages 404, 416.

Meg. The crystals of hornblende stand out on the weathered surface, giving a darker and rougher appearance.

Mic. The rock consists almost entirely of *hornblende*, but also contains *muscovite*, which is also intimately associated with *chlorite*, with a little *epidote*. Between the hornblendes, which in one section lie uniformly in one direction, is a fine granular matrix of muscovite and feldspar, the contrast with the nearly idiomorphic hornblendes being quite remarkable. Two (thick) sections.

Age. Archean. N. H. W.

NO. 256H. QUARTZYTE.

Pokegama falls.
Ref. Annual Report, xvi, pages 438, 473.

Meg. Gray quartzyte, weathering red.

Mic. *Quartz* only composes this rock. The original clastic round grains are grown out to fill the angular interstices, making a dense quartz rock. Nearly all the original grains are unique, *i. e.*, simple, having one orientation, but two or three in the slide are compound, the parts being interlocked in the fashion of secondary quartz. They all have lines of inclusions. One section.

Age. Pokegama (at the base of the Animikie). N. H. W.

NO. 257H. QUARTZYTE.

Pokegama falls.
Ref. Annual Report, xvi, pages 438, 473.

Meg. Rusty quartzyte.

Mic. Same kind of rock as No. 256H, but having some rustiness in the planes separating the individual grains. One section.

Age. Animikie, basal member. N. H. W.

NO. 261H. QUARTZYTE.

Foot of the lower falls of Prairie river.
Ref. Annual Report, xvi, page 473.

Meg. Quartzyte.

Mic. Same as No. 257H, but shows also a few grains of triclinic *feldspar*, and one of *hornblende*. One section.

Age. Animikie, basal member. N. H. W.

NO. 265H. QUARTZYTE.

Upper end of the lower falls of Prairie river.
Ref. Annual Report, xvi, pages 441, 473.

Meg. Quartzyte.

Mic. Quite like No. 257H, but finer, less cemented by secondary quartz, and more coated by an opaque oxide; also, apparently, has some garnet(?) One section.

Age. Animikie, the basal member. N. H. W.

NO. 364H. CONGLOMERATE.

From a boulder seen east of Iron lake, N. W. ¼ sec. 24, T. 60–13.
Ref. Annual Report, xvii, pages 83, 136.

Meg. Rounded quartz pebbles, three to ten times as large as mustard seeds, are the most conspicuous element. They lie in a matrix of ferro-magnesian debris, and are associated with some feldspathic detritus.

Mic. *Quartz* and *labradorite(?)*, (extinction 58° on n_p in the obtuse angle), are the most conspicuous and coarsest parts of this rock. Some of the quartz is in individual grains, but some was originally an interlocking multiple quartz with rounded outlines. *Actinolite* forms the chief coloring element, being in confused, fibrous, matted and fine mass which surrounds the quartz and which in form of rosettes penetrates the quartz about its borders, and which is in general much chloritized, or at least is associated with chlorite. Besides these are pebbles that appear to have been feldspars of detrital origin, but now consist wholly of micro-granulitic replacement, the grain (or pebble) maintaining its size and form in the midst of the green matrix. In other parts the matrix does not consist of this green substance, but of a mixture of all the other elements in fine granules, including also some *mica* and *epidote*, and in others it is of the same fine interlocking quartz-feldspar mosaic as has replaced the feldspars. *Sphene* is scattered in the section. One section.

Age. Pokegama.

Remark. It is remarkable that in this rock, while all the fine clastic feldspars of the matrix, and also several large ones which now are still evident in their outlines, have been replaced, as above stated, by a quartz-feldspar mosaic of fine grain, there remains one large labradorite which has not been affected in that way. Compare No. 366H, where it is shown that pebbles of originally micro-granulitic quartzyte(?) are embraced in a conglomerate similar to this. It is hence probable that this supposed replacement of old feldspars is not tenable, but that these were also original pebbles of micro-granulitic quartz, perhaps from jaspilyte of the Lower Keewatin.

No. 366H. Conglomerate.

S. W. ¼ sec. 13, T. 60-13, north end of Iron lake.
Ref. Annual Report, xvii, pages 84, 136. (Compare Nos. 364H, 370H.)

Meg. Conglomerate, rather coarse.

Mic. Six sections made from this rock are calculated to show its composition: 1. A piece of granite, consists largely of *quartz* and *microcline*, the latter being intergrown with another feldspar in manner of a *microperthite*, and also containing numerous isolated small crystals of some triclinic feldspar, the microcline having embraced them pokilitically, and being much more preserved than the inclusions. The same crystal of microcline also embraces a crystal of *sphene*. Besides microcline the slide contains several large but considerably decayed feldspars, which have a close albite twinning and are probably *oligoclase*. *Chlorite*, some of which is *pennine*, *muscovite*, *epidote* and more or less iron oxide *(limonite?)* also appear as alteration products. 2. At first this slide appears much like No. 1, but it differs in having a matrix matter of green, fine, granular *hornblende* (with some chlorite) which in some places is abundant and forms a large proportion of the slide, and in others is only a narrow band between the large grains, and yet in others is absent, allowing the feldspars and quartzes to come exactly into contact. In that case these minerals also appear to be interlocked as if they had been connected originally in a common foreign source. In short, the fine green debris seems to embrace a quartzose coarser debris derived from granite. 3. With a few large grains of quartz and of a microperthited feldspar *(orthoclase?)* is much of the same green fine substance, which shows not only hornblende in its composition, but also much of an amorphous green chlorite. In this green hornblendic mass are also included as foreign grains a few crystals of *apatite*, one of which is abnormally slightly biaxial. 4. Same as No. 3, even to the occurrence of *apatites* in the green matrix. 5. With a diminution of detrital *quartz* and *feldspar* there is an appearance of granulitic and micro-granulitic quartz, which is distinctly separable from the detrital quartz, both in its boundaries and in its microscopic aspect. The detrital quartz extinguishes in a shadowy manner, and is in large grains, but the granulitic quartz is fresh and fine, and each grain is throughout simultaneous in its extinction, while sometimes the hornblendic fibrous development encroaches on it, sending sharp needles into it, yet there are *pebbles* of granulitic quartz, as of the shadowy quartz, some of them being much coarser and some much finer than the general matrix of granulitic quartz. One large round pebble of granulitic quartz is coarse, and lies in a matrix of very fine granulitic quartz, the separating boundary of the pebble being distinct through its whole circumference. Other similar pebbles are much finer than the granulitic quartz matrix in which they lie. Other pebbles are partly of granulitic quartz and partly of the green matrix, while in still other places the green matrix itself is gathered in spots resembling pebbles. The green substance is almost entirely of *hornblende*. 6. In the midst of a general groundmass of micro-granulitic quartz, varying in fineness, are roundish spots or pebbles of the green hornblendic "matrix," but here the hornblende is so stained by iron oxide that it appears red, and instead of acting as matrix, it is surrounded by the granulitic quartz in the manner of a matrix. Six sections.

Age. Animikie(?)

Remark. When collected, this conglomerate was supposed to be a part of the Animikie, but both the field and microscopic characters indicate that some parts are in the Keewatin. The entire series of interesting facts can apparently only be explained by supposing that here the Pokegama conglomerate, the base of the Animikie, lies non-conformably on the conglomeratic base of the Upper Keewatin, and that the latter exhibits, as it does at Saganaga lake, a gradual and almost imperceptible transition to the underlying Archean, the difference of dip of the two formations not being evident. N. H. W.

No. 370H. Mica Schist *(with cordierite)*.

Ref. Annual Report, xvii, pages 85, 136.

Meg. Tough, black, heavy, but not magnetic.

Mic. The rock is thickly set, as it were porphyritically, with idiomorphic small

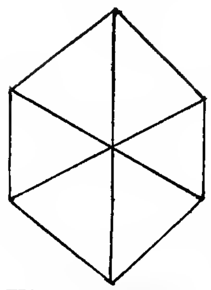

FIG. 52. CORDIERITE IN NO. 370H.

crystals of *cordierite*, which are uniformly twinned so as to show six individuals whenever they are cut perpendicular to the bisectrix, as shown by the sketch here given. These extinguish in pairs, composed of opposite sectors, when well exhibited, but there are numerous instances in which the grouping seems to be irregular or defective. Such sections have approximately a hexagonal outline, although the crystal is orthorhombic.* Most of the sections of this mineral are elongated parallel with n_p, and contain many fine inclusions, such as *biotite*, but the most of these inclusions are undeterminable. The rock at large containing these cordierites is crowded with biotite. One section.

Age. Animikie. N. H. W.

No. 372H. Conglomerate.

S. W. ¼ N. W. ¼ sec. 32, T. 60–13, south of Birch lake.
Ref. Annual Report, xvii, pages 86, 136. (Compare No. 366H.)

Meg. Conglomerate.

Mic. The slide shows principally *quartz*, of interlocking structure, varying in fineness, some of it having the original detrital form of pebbles, and some of it having originated since the pebbles were deposited in this position. It is also evident that the rock contains pebbles of quartz of detrital origin, which were not of interlocking structure, but which since have been built into the general rock by the secondary deposition of interlocking quartz. Throughout the interlocking finer portion of the slide are *calcite* and *mica*, *hornblende*, *epidote* and small triclinic *feldspars*. One section.

Age. Upper Keewatin(?)

Remark. This occurrence of fragmental grains or pebbles of interlocked *quartzyte* in this conglomerate indicates a break of structure between the base of the conglomerate and that on which it lies. If the conglomerate be the bottom of the Animikie, then these curious composite pebbles of quartzyte were before the Animikie. Still, they resemble very closely the fine interlocking quartzyte associated with and forming a large constituent in the iron ore rocks of the Mesabi range. They are probably to be referred to an underlying older quartzyte, or jaspilyte, belonging in the Keewatin.

Since such pebbles are also common in the basal conglomerate of the Upper Keewatin, they do not here demonstrate whether this conglomerate is of the base of the Animikie or older. The features described by the field notes rather indicate the Keewatin age of the most of this conglomerate, at least at the point where the most of the specimens bearing this number were collected. N. H. W.

**Minéralogie de France*, vol. i, p. 515.

No. 378H. Graywacke. *(Conglomerate.)*

Southeast "forty" of sec. 11, T. 59–14, Mesabi range.
Ref. Annual Report, xvii, pages 87, 137.

Meg. Gray, coarsely slaty graywacke.

Mic. Rather fine *quartz* and *feldspar*, with a finer intermixture of chlorite. The feldspars are old and altered. These elements vary in grain, especially the interlocking quartz, showing pebble forms, as in No. 372H. Two sections.

Age. Keewatin. N. H. W.

No. 379H. Grünerite (?) and Magnetite. *(Rock.)*

N. W. ¼ sec. 14, T. 59–14, from a shaft northeast of Mesabi station.
Ref. Annual Report, xvii, pages 88, 137. (Compare No. 437.)

Meg. Apparently a breccia of black slaty rock with an actinolitic cement.

Mic. The slide contains two quite different rocks. 1. *Calcite,* embracing crystals of grünerite(?), through which are also distributed some coarse magnetite groups. 2. Taconyte in which the rounded pebbles of interlocking quartz are very numerous and essentially compose the rock. The matrix of these pebbles is also a coarser interlocking quartz, the pebbles being outlined by the characteristic distribution of *magnetite* about their borders. There is also in this part a much coarser magnetite in spreading sponge-like mesh, and in some of the angles between the groups or within a circular band formed by the magnetite, is *calcite,* while small spangles or stellar rosettes of *actinolite* (or grünerite) pierce the quartz in places. With the exception that the taconitic structure is not visible in the calcite side of the slide, the two parts are quite alike in their essential characters, differing only in the relative proportions of the minerals. One section.

Age. Animikie. N. H. W.

No. 385H. Granite. *(Decayed.)*

Three miles north of the Giant's range, on the Duluth and Iron Range railroad.
Ref. Annual Report, xvii, pages 89, 137.

Meg. Coarse, hornblendic, with red orthoclase.

Mic. There is a noticeable contrast in the apparent freshness and integrity of the different minerals of this slide. There seems to have been a granitic rock or a granitic debris consisting of *feldspar, quartz, sphene, apatite,* more or less decayed, having *epidote, chlorite,* etc., already generated, which was microperthited and surrounded by fresh *microcline,* cementing the whole into a firm rock, so that now it has again the aspect of granite. One section.

Age. Archean. N. H. W.

No. 387H. Mica Schist *(with biotite)*.

Partridge river, N. E. ¼ S. W. ¼ sec. 9, T. 58–14.
Ref. Annual Report, xvii, pages 90, 137. (Compare No. 1708.)

Meg. Dark, silico-argillaceous and micaceous.

Mic. There is an interlocking fine *quartz* as a basis of this schist, which was later in its granular deposition than the *mica* which cuts the quartz and maintains its form in the granular structure. But there are larger, later micas, which give way to the quartz. These are colorless, and appear to be of *muscovite*. One section.

Age. Animikie. N. H. W.

No. 389H. Graywacke (?) *(Subcrystalline.)*

Near the centre of S. E. ¼ sec. 8, T. 59–14.
Ref. Annual Report, xvii, pages 91, 137.

Meg. Gray, gneissoid, having the aspect of an igneous rock.

Mic. A fine-grained rock, consisting largely of old *feldspars*, has been permeated by secondary fresh *quartz* and fresh *feldspar* (near oligoclase). Some shreds of hornblende are changed to chlorite, while fine *muscovite* scales permeate thickly the original feldspars. There are also several grains of *sphene* and of *biotite*. One section.

Age. Keewatin (regenerated). N. H. W.

No. 390H. Graywacke. *(Fine.)*

S. E. ¼ sec. 11, T. 59–14, Mesabi range.
Ref. Annual Report, xvii, pages 91, 137.

Meg. Fine, gray, micaceous.

Mic. This rock is finer, but is essentially the same as No. 389H; it shows also *hornblende*; and *muscovite* and *biotite* are intimately associated. The feldspars have the form and size of clastic debris. Some of the larger muscovites enclose poikilitically several of the small old feldspars. One section.

Age. Keewatin. N. H. W.

No. 397(a)H. Amphibolyte.

S. E. ¼ N. E. ¼ sec. 26, T. 61–12, near Birch lake.
Ref. Annual Report, xvii, pages 93, 137.

Meg. Hornblendic quartzyte.

Mic. The slide consists almost entirely of *hypersthene*, in which are embraced, however, poikilitically, a number of round, small grains of *quartz*, and others of about the same size and shape of a highly refractive mineral resembling *olivine*, and a few of *magnetite*. This gives place to a fibrous divergent network of some amphibole, which in turn passes into a distinct *cummingtonite* (often known as grünerite), having multiple twinning. At the extreme other end of the slide is another crystal of orthorhombic pyroxene showing the twinning of 104. It is here plain that the orthorhombic pyroxene was of later origin than the monoclinic. One section.

Age. Keewatin (condition of the jaspilyte). N. H. W.

No. 399H. Quartzyte *(with magnetite, hypersthene, etc.)*

E. ½ N. E. ¼ sec. 35, T. 61-12, near Birch lake.
Ref. Annual Report, xvii, pages 95, 138.

Meg. Nearly all quartz, but with varying amounts of magnetite and hypersthene.

Mic. *Quartz, magnetite, hypersthene, cummingtonite, diallage(?)* constitute this rock about in the order named. It is a phase of the ferriferous beds which are common near the gabbro, and as a rock is difficult to name. It is always accompanied by some form of the well-known muscovadyte.

Age. Pewabic quartzyte, a phase of the jaspilyte of the Keewatin, under the action of the gabbro revolution. N. H. W.

No. 402H. Pyroxenyte.

N. E. ¼ S. W. ¼ sec. 35, T. 61-12, near Birch lake.
Ref. Annual Report, xvii, pages 95, 138.

Meg. Hornblendic and magnetitic.

Mic. *Hypersthene* and *augite* are closely associated in the composition of this rock, the former being the later to be formed. With these, especially in the hypersthene, are also a little *quartz* and *magnetite.* One section.

Age. Same age and genesis as No. 399H. N. H. W.

No. 405H. Pyroxenyte. *(Ferriferous.)*

N. ½ S. E. ¼ sec. 24, T. 61-12, near Birch lake.
Ref. Annual Report, xvii, pages 95, 138.

Meg. Quartz and iron ore in bands, alternating with bands of pyroxene.

Mic. *Magnetite, augite* and a little *quartz.* This is so heavily magnetited that it might be taken for a lean iron ore. One section.

Age. Pewabic quartzyte, same as No. 399H. N. H. W.

No. 406H. Pyroxenyte. *(Ferriferous.)*

S. E. ¼ N. E. ¼ sec. 35, T. 61-12, near Birch lake.
Ref. Annual Report, xvii, pages 94, 138.

Meg. Hornblendic.

Mic. *Augite, hornblende, biotite, magnetite, apatite, quartz.* The apatite is sometimes within magnetite and sometimes within feldspars, of which a few are seen in the slide, though they are considerably altered. Two sections.

Age. Same age and genesis as 399H, but more allied to muscovadyte.

Remark. For some years these olivinitic and pyroxenic rocks were considered a part of the Animikie, especially when they were found to be iron bearing, under the name Pewabic quartzyte, while the muscovadyte, which always accompanies them, and which has strong affinities with the gabbro, was assigned to the gabbro, or post-Animikie. The various chapters descriptive of the geological plates were all written from this point of view (vol. iv).

It became evident, however, that this olivinitic iron ore belonged with the Keewatin, and that the muscovadyte is only a regenerated basic debris of the Keewatin. It remained to complete the genetic round of transformation by recognizing the bond which attaches the gabbro to the muscovadyte, and to reach the hypothesis that the gabbro itself is the last result of the metamorphism of the the Keewatin greenstones. This point has since been critically examined at Disappointment lake and everything seen there tends to show such a relationship. The term Pewabic quartzyte is retained for this modified jaspilyte, and the term Pokegama has been applied to the basal member of the Animikie. Consult the Lake county chapter in volume iv. N. H. W.

No. 505H. Noryte *(with olivine)*.

A short distance north of the quarter-post between secs. 14 and 15, T. 63-9 W., south of Snowbank lake. *Ref.* Annual Report, xvii, pages 120, 142; Annual Report, xxi, pages 151, 152.

Meg. A rather fine-grained rock of a gray to brownish-gray color. Not gneissic. Composed of grains of a glassy mineral and smaller ones, which are yellowish to black in color.

Mic. A granular aggregate of *feldspar*, *pyroxene*, *olivine*, *magnetite* and a little *biotite*. The feldspar is largely, perhaps entirely, plagioclase. Some grains do not show twinning striæ, and in some the cleavage is not well marked. Such grains might be quartz; however, a dozen such grains which, if quartz, would be approximately basal sections, were examined for interference figures and every one showed a distinct biaxial figure. I think there is no quartz in the section. The pyroxene is distinctly pleochroic, and is hypersthene. The minerals of this rock, except the olivine, are unaltered and fresh. A little monoclinic pyroxene is also probably present.

Age. Cabotian.

Remark. This rock is one to which the name muscovado (or muscovadyte) has been applied. U. S. G.

ROCKS COLLECTED BY J. E. SPURR.

No. 37S. Flint.

S. E. ¼ sec. 4, T. 58–16, Chicago property, Mesabi range.
Ref. Annual Report, xxii, page 127; Bulletin x, page 53.

Meg. Gray, fine, with calcite.

Mic. Very fine mosaic of *quartz* (and feldspar?) interlocking, interspersed sparingly with *calcite*, which also crosses it in veins, accompanied by a little *hematite*. One section.

Age. Animikie (iron-bearing member). N. H. W.

No. 39S. Taconyte.

Same place as No. 37S.
Ref. Annual Report, xxii, page 127; Bulletin x, page 53.

Meg. Light-green, spotted, granular taconyte.

Mic. In a framework of interlocking *quartz* of the typical character are many roundish, greenish-yellow areas, which are not in crystalline condition (at first), but simply amorphous, isotropic aggregates. These are crossed by numerous irregular cracks, and along these cracks, in other grains, it is seen that a kind of change is set up. This change progresses irregularly, frequently appearing in isolated points in the yellow mass (figure 53) and forming more transparent, finely crystalline nests. These nests multiply and also enlarge, such enlargements taking on a radial, or

FIG. 53. GREENSAND IN NO. 39S.

spherulitic structure, thus converting the whole original grain into a finely reticulated and radial network of fine, fibrous, crystalline matter. Many such spots are wholly changed to this network, others are in process of change, and others show the change only about their margins. As to the nature of these radiating fibres, they are plainly *actinolite*, or an amphibole allied. At the present stage of change shown by this rock, about five-sixths of the whole area are of this fibrous network and the yellow substance that gives place to it, the rest being of the interlocking quartz, which forms the general matrix. One section.

Age. Animikie (iron-bearing member).

Remark. This slide shows that the green substance, supposed by Mr. Spurr to be glauconite, is of such a nature that it almost spontaneously gives place to an amphibole and that it thus has an alliance with the darker debris of the tuffaceous greenstones.

The figure above is designed to illustrate some of the changes that take place in this primordial greensand. Within the area of the field is one grain of that substance so magnified as to occupy nearly all the space, that is, about one hundred diameters. Some grains in the rock are larger, and their size also runs down to mere specks. There are to be noted various things of interest and importance in connection with this greensand:

1. In its earliest state, so far as can be affirmed by the evidence of the section illustrated, it is feebly translucent, greenish, or olive green, and is broken into many irregular areas by cracks that cross it in the manner of shrinkage cracks.

2. It becomes transparent when it begins to crystallize by the chemical separation of its ingredients into definite compounds. Several such more transparent roundish spots are seen in the figure. These are, for the most part, filled with quartz in imperfect or globular fine grains, but are also somewhat occupied by actinolite. The size of the quartz grains in these confined areas is smaller than that of the quartz which is outside of the glauconite, and which forms the groundmass of the rock.

3. Radiating, fibrous actinolite (or perhaps cummingtonite) pierces the quartz, being apparently cotemporary with or a little earlier than the quartz. This amphibole surrounds the greensand grain and its fibres run independently into the margin of the grain in such a manner as to show that it, as well as the quartz, originated wholly from the greensand. Such actinolite spicules are sometimes seen (in other greensand grains) wholly within the body of the greensand.

4. The greensand begins to crystallize and is wholly transformed about its margin and at points within the grain, giving rise to quartz and actinolite (or cummingtonite).

5. In the case of the grain illustrated there is no apparent segregation of iron ore, but in other slides cut from this rock sample iron ore is manifested as one of the secretions from the greensand. These are its appearance within certain grains, rendering them wholly opaque, and in the same way as with the quartz and cum-

mingtonite it begins at points in the main greensand grain, involving certain of the polygonal areas into which it is cut by the general cracking.

6. It is apparent that the greensand is the source of the quartz, the cummingtonite and the iron ore, and that the quartz, gathering in the interspaces about the greensand grains, is coarser than that in the areas of the grains themselves, because of greater freedom of chemical transference in those open spaces.

It seems to the writer that these features, and other facts mentioned in the description of other rocks derived from the Mesabi Iron range, whether at Gunflint lake or at Prairie River falls, indicate that the greensand was of the nature of a ferruginous volcanic sand. This result is further discussed in Part III. N. H. W.

No. 43S. QUARTZYTE.

S. E. ¼ S. W. ¼ sec. 4, T. 58-16, Mesabi Iron range, near Biwabik.
Ref. Annual Report, xxii, page 127.

Meg. Loose conglomeratic quartzyte with kaolin.

Mic. Round grains of uniform size of clastic *quartz* are surrounded by a debris which is probably of kaolinic nature which has been incorporated in the secondary rim of quartz by which the rock is cemented and made firm. One section.

Age. Pokegama quartzyte(?) (base of the Animikie). This rock may belong to the Cretaceous instead of the Animikie.

No. 47S. GRANITE AND AMPHIBOLYTE.

S. W. ¼ N. W. ¼ sec. 35, T. 59-17, Mesabi Iron range.
Ref. Annual Report, xxii, page 127.

Meg. Contact of granite on the Keewatin.

Mic. The slide differs. One side consists almost wholly of green *hornblende* in large crystals, but having a general parallelism of direction. With these are mingled a little *quartz* (within the hornblendes), *epidote* and *pyrite.* The other part of the slide, while containing also hornblende in form of elongated schistic fibres, consists chiefly of much altered *feldspars* and interlocking *quartz,* with *biotite.* These feldspars (oligoclase, apparently), evidently of some anterior state, are now charged with *muscovite,* some *calcite,* and occasionally contain *quartz* as secondary products, while epidote also is in scattered grains. One section.

Age. Archean. N. H. W.

No. 53S. TACONYTE. *(Greensand.)*

S. E. ¼ sec. 4, T. 58-16, Mesabi Iron range.
Ref. Annual Report, xxii, page 127; Bulletin x, page 68.

Meg. Dark green, spotted-granular.

Mic. The green primordial element is in one slide entirely broken up, and a crystalline network is formed, consisting of the same actinolitic(?) ingredient as noted in No. 39S, but the stellate structure is wanting. Further, in the midst of this actinolitic product are areas of loose *magnetite* and occasionally of irregular *siderite* with a few small grains of *quartz*. Indeed, it appears that quartz and siderite alternate in areas, forming the supporting background for this yellowish actinolitic product. In a second slide the forms of the primordial pellets are distinctly preserved, but they are replaced by the products of alteration, sometimes by siderite, which frequently is of a single crystal orientation occupying nearly the whole area of the original pellet, sometimes by a biotitic and ferruginous substance, and sometimes by a globular or an interlocking quartz finer than the rest of the rock, but usually they are in some part still preserved as greensand, often with shrinkage cracks. These pellets are surrounded by an interlocking quartz. In still another section the same characters are seen as in the last. Three sections.

Age. Animikie. N. H. W.

No. 55S. Greenstone. (*"Mottled."*)

N. W. ¼ S. W. ¼ sec. 34, T. 59-16, Mesabi Iron range.
Ref. Annual Report, xxii, page 128.

Meg. Greenstone.

Mic. *Feldspar* of a triclinic species composes this rock essentially, but there was originally a ferro-magnesian mineral in small amount which is now turned to *chlorite*. Some opaque *leucoxene*, some *sphene*, *calcite* and *epidote* are subsidiary in amount. The structure seems to indicate that this rock has suffered pressure amounting almost to crushing, but the feldspars are not lost as to crystalline form, showing occasionally an interlocked growth. They have been subsequently recemented and regenerated by a microperthitic deposition of a fresh feldspar. The rock may have been a hornblende granite or a diabase with little augite. One section.

Age. Keewatin. N. H. W.

No. 58S. Hornblende Schist.

About 200 paces north of No. 57S.
Ref. Annual Report, xxii, page 128.

Meg. Hornblendic.

Mic. *Hornblende* and secondary interlocking glassy *feldspars* with a little *biotite* compose this rock. One section.

Age. Keewatin, recrystallized. N. H. W.

No. 59S. Hornblende Schist.

Same locality as No. 58S.
Ref. Annual Report, xxii, page 128.

Meg. Hornblendic.

Mic. Same kind of rock as No. 58S, but containing evidently also a considerable quartz in the interlocking groundmass. One section.

Age. Keewatin, recrystallized. N. H. W.

No. 60S. Mica Schist.

Interbanded in No. 59S.
Ref. Annual Report, xxii, page 128.

Meg. Micaceous.

Mic. *Quartz*, *muscovite*, interlocked in cotemporary development, compose this rock. One section.

Age. Keewatin, recrystallized. N. H. W.

No. 61S. Taconyte. *(Pebble from conglomerate.)*

S. E. ¼ N. E. ¼ sec. 6, T. 58-17, Mesabi range.
Ref. Annual Report, xxii, pages 122, 128.

Meg. Green conglomerate, with rusty specks; accompanied by green shale.

Mic. A green mass from the rock, consisting of chlorite, *stained* with *hematite.* Round the green mass are taconitic pellets of the characteristic form and size, some of which are replaced by *siderite* and *siderite* enters considerably, in places, into the green mass. This is preferably siderite, since it is numerously and regularly cleaved and is iron stained by oxidation. One section.

Age. Cretaceous.

Remark. Rock No. 62S is from the same conglomerate, but is wholly hematited.

N. H. W.

No. 77S. Graywacke. *(Very fine.)*

N. W. ¼ N. E. ¼ sec. 7, T. 58-17, Mesabi range.
Ref. Annual Report, xxii, page 128.

Meg. Dark, slaty, banded with stratification.

Mic. This rock is made up of a fine debris of *quartz*, *feldspar*, *sphene*, and some dark mineral which is now altered to *chlorite*, and of *muscovite.* It is darkened also by *pyrite*, *hematite* and apparently by a dark *leucoxene*, with a scant cement of *calcite* One section.

Age. Animikie. N. H. W.

No. 94S. Amphibolyte.

S. W. ¼ N. E. ¼ sec. 17, T. 59-17, Mesabi range.
Ref. Annual Report, xxii, page 129.

Meg. Massive hornblende rock.

Mic. *Hornblende* in coarse (microscopic) crystals, and a little *feldspar* and *apatite* are the only minerals perceptible in this rock. One section.

Age. Keewatin (metamorphosed). N. H. W.

No. 125S. Taconyte.

N. E. ¼ S. E. ¼ sec. 17, T. 58-19, Mesabi range.
Ref. Annual Report, xxii, page 130.

Meg. Glauconitic taconyte.

Mic. Green pellets are breaking up into interlocking *quartz*, *siderite* and *actinolite*, the last being sometimes stained by *hematite*. These pellets, still preserving their forms, lie in a groundwork of coarser interlocking quartz. One section.

Age. Animikie. N. H. W.

No. 127S. GRAYWACKE. *(Fine, sideritic.)*

S. E. ¼ N. E. ¼ sec. 17, T. 58–19, Mesabi range.
Ref. Annual Report, xxii, page 130; Bulletin x, page 129.

Meg. Banded taconyte slate.

Mic. A very fine grouping of *quartz* (and feldspar?) similar to No. 77S, but stained by oxidized *siderite*, which still retains its crystalline outlines, though converted to oxide. Much of it, however, is not oxidized. One section.

Age. Animikie. N. H. W.

No. 133S. TACONYTE.

S. E. ¼ S. E. ¼ sec. 18, T. 58–19.
Ref. Annual Report, xxii, page 130.

Meg. Taconyte grit rock, with seams of iron.

Mic. This rock represents various stages in the transition from greensand to iron ore as described by Mr. Spurr in Bulletin x, viz.: (1) "Glauconite" without alteration; (2) With the formation of *actinolite;* (3) Formation of *siderite;* (4) Formation of fine interlocking *quartz;* (5) Formation of crystalline iron ore, apparently *magnetite*. These products, with occasional exception of the last, are generated within the pellets, which, surrounded by a coarser interlocking quartz, retain their original round outlines distinctly until the process is completed in the production of a promiscuous mass of iron ore; and, even after the ore is complete, the pisolitic structure prevails in thousands of tons which are shipped from the state. One section.

Age. Animikie. N. H. W.

No. 158S. SIDERYTE *(and hematite).*

N. E. ¼ S. E. ¼ sec. 33, T. 58–17, Mesabi range.
Ref. Annual Report, xxii, page 131; Bulletin x, page 53.

Meg. Banded taconyte slate.

Mic. The slide consists of two parts: one is largely made up of closely set, narrow bands of *hematite* which are irregular, wavy and interrupted, and which contain, between the bands, a few grains of *quartz* and areas of *siderite*. Between the bands are other equally narrow and interrupted bands which are translucent, though specked finely with hematite, and between the nicols are almost dark. These appear to be composed of amorphous or very finely globular quartz. The other part of the slide has a scant background of the same kind of globular quartz, but, as it is thickly set with granules and minute groups of *siderite*, the light which passes is sufficient to make the field quite illuminated. This slide shows a condition of the iron ore of the Mesabi range. One section.

Age. Animikie.

Remark. Macroscopically this sideryte forms granular bands or layers alternating with hematitic layers, the whole being probably originally water-deposited, but the hematitic bands cotemporaneously mingled with more volcanic ash and devitrified glass. This sideryte exists in quantities sufficient to make it of commercial value. It has the outward appearance of a fine, gray, stratified sand. N. H. W.

No. 205S. Quartzyte.

N. W. ¼ N. W. ¼ sec. 36, T. 58–21, Mesabi range.
Ref. Annual Report, xxii, page 132.

Meg. Granular quartzyte, grayish red.

Mic. Originally clastic, round grains of *quartz* have been enlarged by secondary silica in crystalline agreement with the various grains, making a compact rock. Amongst these are a few of *microcline* and of other feldspars equally rounded but not apparently enlarged. There is a dark narrow border of rejected debris which separates the enlarged grains from each other, and a less distinct one that separates the original grains from their enlargements. One section.

Age. Pokegama (base of the Animikie).

Remark. The "rejected debris" mentioned is sometimes in roundish shapes as if it had constituted original grains. It appears to be devitrified glass. It is usually crowded with indistinct, minute crystalliths and is largely isotropic. N. H. W.

No. 226S. Quartzyte.

S. W. ¼ N. W. ¼ sec. 35, T. 58–21.
Ref. Annual Report, xxii, page 133.

Meg. Gray quartzyte.

Mic. Similar to No. 205S, but less coarse. The intergranular substance is green and apparently *chlorite*, and more abundant than in No. 205S. There are also a few minute *zircons*. One section.

Age. Pokegama (base of the Animikie).

Remark. This greenish substance is finely scaly, like chlorite. It may have resulted as a detritus from ferromagnesian Archean rocks. N. H. W.

No. 227S. Hornblende Schist.

N. W. ¼ N. W. ¼ sec. 35, T. 58–21.
Ref. Annual Report, xxii, page 133.

Meg. Fine, dark, schistose, hornblendic.

Mic. In this schist with much *hornblende* are *zoisites* which are small and usually permeated by inclusions, among which is a vermicular form of *quartz(?)* in the fashion of a micropegmatyte. *Epidote, muscovite, sphene* are accessory, the last surrounding small grains of *ilmenite.** One section.

Age. Keewatin, metamorphosed. N. H. W.

No. 228S. Mica Schist.

N. W. ¼ N. W. ¼ sec. 35, T. 58-21.
Ref. Annual Report, xxii, page 133.

Meg. Muscovite schist.

Mic. *Quartz* is abundant; *muscovite* and *biotite* with a little *chlorite* give the rock a schistosity, and *epidote* lies nearly parallel with the structure, elongated sometimes positive and sometimes negative (as cut) and showing conspicuous cross fractures. One section.

Age. Keewatin, metamorphosed. N. H. W.

SPECIMENS COLLECTED BY A. D. MEEDS.

No. 8M. Mica Schist. *(Siliceous.)*

S. E. ¼ S. E. ¼ sec. 35, T. 60-13, two miles south of Iron lake.
Ref. Annual Report, xxii, page 88.

Meg. Dark, granular, hardly schistose.

Mic. In an interlocking, rather coarse mosaic of *quartz, oligoclase* and perhaps other feldspars, are enclosed many *biotites*, which cut the quartzes independently, and occasional *muscovites*, the latter being apt to be clustered in or about certain feldspar grains. The quartz varies greatly in granular dimension. Some of the larger grains often involve many small ones which are globular, and so small sometimes or so nearly amorphous that in convergent light they transmit little or no light between crossed nicols. One section.

Age. Animikie.

Remark. The structure is granular and much like that of muscovadyte.

N. H. W.

* *Gneiss à Pyroxène.* Lacroix, p. 57, fig. 22.

No. 21M. Quartzyte.

Sec. 18, T. 59-14, near Mesabi station.
Ref. Annual Report, xxii, page 88.

Meg. Micaceous quartzyte, fine grained.

Mic. Interlocking quartz, as in No. 8M, but more angular, with some *oligoclase*, makes up the most of this rock; the interlocking structure, however, is secondary, the rock having been originally a clastic one. There is a band of darker color crossing the slide, caused by finer quartz grains and by the presence of dark minerals (iron, *hornblende* and *sphene*) accompanied by some *mica* which lies parallel to the band. One section.

Age. Animikie. N. H. W.

ROCKS COLLECTED BY A. H. ELFTMAN.

No. 158E. Diallage.

Sec. 26, T. 61-11, Harris lake.
Ref. Annual Report, xxii, page 185.

Meg. Dark-green, nearly black pyroxene, conspicuously cleaved.

Mic. One section was made approximately parallel to a cleavage (100) and shows an optic axis nearly perpendicular. The extinction is not exactly parallel with the other cleavages. The crystal is crowded with dark inclusions in plates between the basal cleavages and more scattering ones in the clinopinacoidal cleavages (010). It is not perceptibly pleochroic. The crystal includes, however, small quantities of *plagioclase, magnetite* and *biotite.* One section.

Age. Cabotian.

Remark. Owing to the orientation of the section the diallagic lamellation (100) is not visible. N. H. W.

No. 178E. Gabbro *(with hypersthene)*.

N. E. ¼ sec. 9, T. 58-10, Greenwood lake.
Ref. Annual Report, xxii, page 186.

Meg. Rather coarse-grained gabbro.

Mic. The rock presents a fine show of various minerals. The *augite* and *olivine* were apparently slightly earlier than the feldspar, the former having taken on the diallagic parting and been resorbed while still in the magma, thus presenting roundish grains of various sizes, sometimes very small. The *hypersthene* was latest of the mineral generations. This surrounds the diallages completely, and also partly embraces some of the olivines. It has four cleavages, and is plainly pleochroic. The diallage has also the four cleavages, viz., two 110 and the vertical pinacoidal cleavages. Its small optic angle contains n_g, and measures about 45°, which is a peculiarity of augite seen in the gabbro from the larger masses in the central parts of the great gabbro area. The rock embraces but little magnetite. Two sections.

Age. Cabotian. N. H. W.

NO. 429E. DIABASE (*with olivine*).

Top of the high Sawtooth ridge west of Temperance river.
Ref. Annual Report, xxiv, page 159.

Meg. Dark diabase, rather coarse.

Mic. The *augite* has a pinkish-purple color and is ophitic in its relation to both *olivine* and plagioclase, while the *olivine* has the same relation to the plagioclase, a structure not very common. One section. Compare No. 258.

Age. Cabotian. N. H. W.

NO. 455E. DIABASE (*with olivine*).

Near Poplar river, from the hill west of the hay marsh, and known as "the rock pile."
Ref. Annual Report, xxiv, page 159.

Meg. Dark gray; rather coarse.

Mic. A coarse ophitic rock, with some *olivine*, the olivine showing the common alteration along fissures and about the margins, producing the familiar yellow substance which is supposed to represent bowlingite. One section.

Age. Cabotian(?) N. H. W.

NO. 456E. DIABASE. (*Coarsely porphyritic.*)

South slope of the first Sawtooth hill north of Lutsen (Poplar river).
Ref. Annual Report, xxiv, page 159. (Compare No. 796.)

Meg. Coarse diabase, with conspicuous tabular crystals of labradorite.

Mic. The porphyritic *plagioclases* which are taken for *labradorite*, are accompanied by many of the second consolidation. *Augite* is in rather small amount, and in form of small grains which are for the most part of independent forms, but one is rarely cut by one of the second-date plagioclases. Olivine once existed in this rock, but is now altered to a yellowish substance. Magnetite not abundant. One section.

Age. Cabotian. N. H. W.

PART III.

MINERALOGY AND PETROLOGY OF MINNESOTA.

By N. H. WINCHELL.

(a) THE ROCK-FORMING MINERALS.

(1) *The White Minerals.*

Quartz. That mineral which is one of the most abundant, and which ordinarily appears most refractory, being infusible and insoluble in ordinary conditions, is one of the most mobile under the conditions that obtain in the rocky strata, and especially under the forces that cause metamorphism. Its changes are visible even in the most friable sandstones. When no other alteration is visible in some of the clastic rocks, the quartz grains are seen to be enclosed in a new sheath of quartz oriented in the same directions as the original grains. This has been shown by Irving and Van Hise in the case of many of the rocks of the lake Superior region,* and had been noted earlier by Sorby and by Bonney in the case of various European rocks. As this change is the first symptom of metamorphism in any clastic rock containing quartz, so it continues throughout the progress of metamorphism to be the most important and the most active. It proceeds so far that the first clastic grains, whose forms are wholly obliterated and which are entirely recrystallized, are those composed of quartz, and, when the alteration of the rock is completed, the last mineral to have been located in the new crystalline mass is uniformly quartz. It encloses all the other minerals, or at least it occupies those spaces that were last filled. When the feldspars are also metamorphosed, it sometimes penetrates them and fills the openings between their cleavages.

Quartz grains not only undergo enlargements by very slow and sometimes by insignificant increments to their borders under the gentle influence of ordinary temperatures, but they are powerfully affected when they come under the influence of igneous contact. Here they can be seen to become bipyramidal and to take up the rôle of phenocrysts in a quartz-porphyry (Nos. 619, 783, 784), while in the same rock mass, at a short distance from the contact, the clastic structure of the quartz grains is preserved (Nos. 264, 1838, 1839).

**Bulletin viii*, U. S. Geol. Survey, 1884.

It is obvious, therefore, that in many cases it is wholly impossible to state whether a grain of quartz seen in a given rock section is original or secondary, in the usual petrographical signification of those terms. There might be discovered, perhaps, by a very exhaustive study of the internal structures of quartz grains, and of the distribution of their minute inclusions, such differences between the original clastic grains and those grains which have been wholly rewrought under metamorphic agencies, that they could be distinguished, the one from the other. But we have not attempted any such examination. The fact that a quartz grain has been developed by new growth to fill the surrounding angular spaces, or that it encloses the other minerals of the rock, such as feldspar, mica or hornblende, has been considered sufficient indication of the later date of the quartz. In some such cases the borders between the old and the new quartz remain, marked by a more or less distinct band of ferruginous inclusions. Such borders, however, are found only in the least metamorphosed rocks. In far the greater number of instances the quartz of the crystalline rocks, whether metamorphic or igneous, is so completely changed that no trace remains of its original shapes.

Under metamorphism, quartz is quick to make its appearance. This seems to result in part from the dissolution of unstable compounds, such as volcanic ash, or undifferentiated volcanic glass, and in part from the superficial evaporation of silica-bearing alkaline waters. Fresh waters penetrating the rocks become alkaline. When heated, these waters not only take up silica, but also rise gently toward the surface, and, there evaporating, they part with their surplus silica, rendering the rocks through which they pass slightly more quartziferous. Thus veins are filled, and, to a limited extent, the enclosing rocks may have quartz supplied to their interstitial cavities. In the case, however, of the solid interior of a massive crystalline rock, such change, by the substitution of quartz for some of the constituent minerals, is so slow and so uncertain that it can be questioned whether it exist at all. No evidence of it has been found in the course of the foregoing petrographical investigation of the rocks of the state. When quartz is found to exist in any deep-seated crystalline rock, it seems to be necessary to allow that it existed there from the date of formation of the rock as such. It may be altered by metamorphic forces, as all the minerals may be, and new crystalline conditions and even new chemical combinations may have been imposed upon it, but it seems necessary to exclude the idea that changes of the relative amounts of the chemical elements have been effected. The interior of the oldest rocks known are exactly as fresh and as complete as rocks (excluding, of course, occasional abnormal conditions) as when they were first formed. When a deep-seated rock is metamorphosed its elements are recrystallized *in situ*; at least this is the case with the metamorphism of the Archean as exhibited in Minnesota.

We consider quartz as wholly a secondary mineral, when considered petrologically; that is to say, whether found in the acid rocks, such as granite, or in small amounts in the basic rocks, it has been through some earlier state and has been introduced into these places by some more or less fortuitous or accessory conditions in nature. In the acid crystalline rocks it is believed to have existed in clastic condition prior to the metamorphism, and in the basic rocks it originated either in the same way by the metamorphism of a basic clastic rock containing less quartz, or by contact with and the inclusion of some of the acid rocks. This opinion is based not only on the observations recorded in Part II of this volume, but on the results hitherto reached by experimentation in the artificial production of quartz by igneous fusion of other minerals and of rocks.* Never has quartz yet been found to result from the cooling of fused mineral matter, but its production through the action of natural pneumatolitic agencies is a matter of common observation. Artificially also quartz crystals have been produced in the presence of water at a high temperature under great pressure. Daubrée produced fine quartz crystals by subjecting common glass to heat in a closed vessel at a temperature of 320 degrees centigrade, the test extending through several weeks. The glass was transformed into a leafy kaolinic mass on the surface of which could be seen standing out so as to be perceived by the hand-glass hexagonal pyramids of quartz.

Friedel and Sarasin also produced quartz by employing a solution of gelatinous silica in a slightly alkaline liquid. In another experiment by the same chemists, conducted likewise in the presence of water under pressure, with a silicate of potash for the purpose of obtaining artificial orthoclase, crystallized quartz was formed. Tridymite and opal have also been formed artificially by various experimenters when operating in the wet way and under pressure. The only instance (which yet needs verification) of the production of quartz in the dry way is that of Hautefeuille, who produced a substance supposed to be quartz, but having different crystalline forms.

Quartz is therefore to be considered a mineral of that zone of the earth's crust to which water and the vapor of water are accessible. It seems to be precluded from the deep-seated original rocks, not only by the facts of field and microscopical observation, but also by the most obvious inference from the experiments that have been made for its production by dry heat. In all cases where, in the foregoing descriptions (Part II), quartz has been mentioned in an "igneous" rock, the rock containing it is either in immediate or approximate known contact with acid rocks, or the environment is such that such proximity of acid rocks is a reasonable inference (Nos. 672, 686). In numerous instances it occurs in the metamorphic clastic

*La plupart des nombreuses variétés de silice à structure cristalline, qui se rencontrent dans la nature, n'ont pu jusqu'au présent être reproduites artificiellement. On n'a pu refaire ni le quartz en large plages des granites, ni le quartz granulitique des granulites et microgranulitiques, ni le quartz globulaire, ni le quartz cunéiforme des pegmatites et micropegmatites, ni le quartz bipyramidé à formes raccourcies à angles arrondis, si commun et si caracteristiques dans les microgranulites, dans les porphyres et dans les roches volcaniques acides. *Synthèse des minéraux et des roches, p. 81. Fouqué et Michel Lévy.* Paris, 1882.

rocks and in the igneous rocks that have resulted from them through intense heat and pressure in the presence of moisture.

From this view of the origin of quartz, it follows that it is of secondary date in pegmatyte and micropegmatyte (Nos. 643, 672, 686) in the quartz mosaic that results from the devitrification of volcanic glass, whether acid or basic, and in the apobsidians and aporhyolytes of the Keweenawan. It also follows that in all rocks resulting from the crystallization of fragmentals, whether schists, gneisses or granites, quartz is in a secondary condition, however compactly and intimately it may be interlocked with the other minerals. The manner in which quartz develops poikilitically in the formation of granite from clastic debris is illustrated by rock No. 1039.

It follows, also, that there is very little "original" quartz. The only original minerals, in a broad sense, are those that composed the original and oldest rocks, viz., the massive greenstones of the Kawishiwin, or the oldest quartz-porphyry and its allies of the Lower Keewatin. Original quartz occurs in the latter but not in the former. By manifold chemical and mechanical transformations and perhaps by later chemical oceanic precipitation, the quartz that permeates all the later formations has been derived, whether those formations be clastic or igneous.

In a restricted sense, however, the term original is often applied to all the minerals of a rock perfectly and freshly crystalline, especially if it cooled from a molten condition, and the term secondary to those minerals that have resulted from the decay or alteration of the original minerals. There is, however, a degree of uncertainty and vagueness in the use of these terms in this sense, owing to the blending of the effects of original crystallization and of metamorphism and recrystallization.

Orthoclase is everywhere an accompaniment of quartz, and nearly all that has been stated regarding quartz is equally true of orthoclase. In one respect, however, they differ, viz.: an "altered" or a recrystallized grain of orthoclase is easily distinguished from an original one. In the quartz-porphyries of the Lower Keewatin (Nos. 2229, 2237, 2238) where quartz first appears, orthoclase also is found, but the crystals which it forms are fragmental, resorbed and clouded by alteration. They have the appearance of having suffered much abrasion and decay before they were finally embraced in solid rock. They are decayed throughout, evenly, as evinced by the uniform dissemination of many muscovite scales. While such a crystal is evidently *original* in all senses of that word, it is evidently not in its original condition. Pure, fresh orthoclase is free from such muscovite scales, and from all other alteration products, and is nearly as clear as quartz. So long as such a crystal of orthoclase maintains that flecked appearance evenly distributed through its whole mass it may be considered as an original mineral. But when, in a later period of its history, the rock mass in which it lies is subjected to metamorphic forces, becomes plastic, and is amenable to general chemical transformation, a great change takes place. The crystal becomes larger by the absorption of a portion of the surrounding matrix, which is also finely orthoclastic, and a rim of fresh, perfectly transparent orthoclase is formed all around the original grain. Such new matter also penetrates within the old crystal along its fissures, recementing the separated portions by fine lines of new orthoclase. It also creeps in between the cleavages, especially if they are open enough to serve as solution planes, and by depositing a cement of fresh material it regenerates the old crystal. At the same time while this general enlargement and reconstruction is going on, the muscovite scales and other alteration products tend toward the centre of the old grain. It is not impossible that this apparent greater centralization of these impurities in regenerated grains may be due wholly to the enlargement of the borders and the general restoration of the chemical integrity about the peripheries of the old grain, and that hence the exact *locus* of the individual muscovite scales in the body of the crystal is not changed by the regeneration; but in many cases, it certainly appears to be the fact that such impurities are crowded closer together and generally toward the centre. Such seems to be the case, at any rate, when in the same grain the impurities are gathered in two or three places by reason of some variation in the manner of influx of the fresh matter, instead of remaining, as at first, uniformly scattered throughout the crystal. These features of regeneration are seen in nearly all granites and gneisses. (See Nos. 1278, 1427, 1436, 1728, 1980, 1992, 2229, 2276.)

In general, the new orthoclastic material is perfectly oriented with the old. Indeed, it is probable that, as with quartz, the whole of the old crystal is revamped and undergoes a complete recrystallization, a change which would of course allow if not require the concentration of the inclusions at one or two places, in groups. But it has been noted, in a few instances, that the new feldspathic material is not oriented with the old. One instance (No. 1051) was carefully examined and it was found that the new feldspar had the optic characters of a "deformed orthoclase," *i. e.*, that the positions of the elasticity axes n_g and n_m were the reverse of those in the original grain. In several cases (illustrated by rock No. 1515, and plate V, figure 7) it also appears that this manner of interpenetration by new orthoclase presented a rather spreading microclinic arrangement, and such arrangement only appeared in certain areas in the old grain (Nos. 1992, 2194). The idea that the microline structure is wholly caused by such new intercleavage growths in an old feldspar was rather strengthened when it was observed that the microcline structure itself is uniformly most prevalent in such regenerated rocks (granites, etc)., and that its crystals sometimes grade off into non-microclinic orthoclase.

This "altered" condition of the orthoclases in granites, etc., has sometimes been attributed to decay since the formation of the rock in which they are found, and the microcline structure to unequal strains in orthoclase caused by mountain pressure. As the two facts are frequently concomitant, such decay and such unequal strains have been believed to be complementary and nearly cotemporary.

Whatever may be the causes of such phenomena in other places, we have seen no reason to attribute them to recent decay nor to mountain pressure in the rocks we have examined from the Archean in Minnesota. Indeed, we place them at the opposite end of mineral genesis. The minerals presenting these features are fresh and chemically intact. They had passed through a primordial period of decay, but they are now fresh and pure, and the elements of that earlier decay are rejected by the new crystallization. The following considerations seem to preclude the idea that this alteration is due to recent decay, or even to decay since the present solid condition was acquired by the rocks concerned.

1. No such alteration is known since the Glacial epoch.
2. This alteration is not superficial, but universal and at all depths examined.
3. It is not marginal on the grains, but central.
4. It is not in the midst of decaying rock materials, but in minerals having a fresh and strongly interlocked granitic texture.
5. The rims that extend beyond the old borders are fresh and sometimes even glassy in their transparency.
6. The same distinctions can be seen in some porphyrel which is unquestionably a partially recrystallized clastic containing many large old feldspars, as well as in some graywackes.
7. The other elements, such as hornblende or biotite and muscovite, are wholly fresh. They seem to date from the generation of the new feldspar and quartz.
8. These elements, with sphene and epidote, are evidence of some former period of alteration, and their freshness denotes a later period of recrystallization.
9. Such central "alteration" is not seen in the diabases nor gabbros, nor in the greenstones, nor in the most of the graywackes and conglomerates, but in these rocks the feldspars, when partially decayed, are evenly sprinkled with the products of such change, or are chiefly altered about their margins.

In the "red rock" series a substance occurs abundantly which has frequently been assumed to be orthoclase, but which in some instances is a semi-devitrified acid(?) glass and in others is the result of change of some plagioclastic element. The former is most frequent in the aporhyolites and the latter in the contact rocks of the red series with the diabases (No. 686). In some instances there is left enough of the albite twinning to show that the feldspar, which is perhaps reddened by hematite, is really an altered plagioclase (Nos. 42, 45, 850). Sometimes, apparently, considerable rock masses, belonging normally to the basic series, have been so permeated by the acid elements and stained by hematite that they appear to belong with the red-rock series, and the cause of such an error is attributable to the orthoclastic aspect of the red feldspars, more than to any other feature.

Adularia, a form of orthoclase, occurs at the old Minong mine, on Isle Royale, where it is associated with calcite, forming a crystalline coating on metallic copper and lining geodes, the adularia being of later date than the calcite (No. 583). The origin of this mineral is probably due to solfataric action during the eruptive activity of the Keweenawan.

Oligoclase, andesine, etc. These intermediate lime-soda feldspars have a wide range but not great frequency of occurrence. They have been found in numerous acid and intermediate rocks. Oligoclase favors the granites, quartz-porphyries and syenytes, and the acid metamorphic rocks, but andesine is more allied to the basic series (No. 300). The former is more frequent in the acid mica schists and the latter in hornblendic. They occur in some of the conglomerates, especially those of Kekequabic lake (Nos. 1061, 1062), and in the esterellyte of that vicinity (Nos. 1094, 1399). Oligoclase is very often associated with orthoclase. Andesine has been found in the clastic greenstones (No. 1367C).

Albite. The pure soda feldspar has been identified but rarely (Nos. 403, 872, 2102 and 2243). Some part of the white feldspar in a coarse pegmatyte (No. 1997) is albite or oligoclase-albite. It is there associated with microcline. In all cases it seems to be a secondary mineral. It takes part in the formation of epidosyte (No. 842).

Labradorite in its broader sense is the prevalent feldspar of the basic igneous rocks, especially of the Keweenawan. Indeed, it may be said that in normal conditions it is the sole plagioclase. When other feldspars have been identified in the diabases or gabbro of the Keweenawan (No. 222) it has been in nearly all instances under circumstances warranting the presumption of endomorphism resulting from contact on the clastics, and this is especially true of the occurrence of andesine or of oligoclase and orthoclase. In several instances the feldspar of the Keweenawan diabases has been identified as bytownite (Nos. 810, 814) or labrador-bytownite, these determinations having been indicated by the extinction angles and not by chemical analyses. In such determinations throughout this work great reliance has been placed on the extinction angles in sections cut perpendicular to the bisectrices as established by Dr. Fouqué of the Collége de France.* An unequivocal occurrence of anorthite in the Keweenawan has been so rare that it produces little or no effect on the proper description of the Keweenawan basic rocks.

*Contribution à l'étude des feldspaths des roches volcaniques. *Bulletin de la Société Française de Minéralogie.* Tome 17, p. 283, 1894.

Aside from the Keweenawan, however, labradorite is comparatively rare in Minnesota. It is found in connection with the rocks intermediate between the gabbro and the greenstone of the Keewatin, *i. e.*, in the muscovadytes, where it is often associated with very unusual companions, but in other parts of the Keewatin it is so modified by decay or regenerated by subsequent new growths, or is rendered so indefinite in its optical characters that it may be said to be practically wanting.

Labradorite in the Keweenawan shows a peculiarity—which is not confined, however, to this mineral—in having not only two dates of generation, *i. e.*, that of the "first consolidation" and that of the second, but different relative dates as to the accompanying minerals. It is sometimes earlier than augite, as in all the ophytes and in some portions of the gabbro, as the latter term has been used, and is sometimes later or cotemporary with augite. The former structure is illustrated by figures 2 and 12 of plate I, rocks Nos. 108 and 820, and the latter by figure 4 of plate I, rock No. 122 and by rock No. 137. It also sometimes occurs that the same rock section shows two dates of labradorite, with respect to the augite associated with it (Nos. 802 and 2064, plate V, figure 6). Labradorite is usually later in origin than olivine, in the basic rocks of the Keweenawan, but there is a large central area of the gabbro mass in which it crystallized earlier than the olivine. This rare structure is illustrated by figure 7 of plate I, rock No. 258, and by figure 1 of plate V, rock No. 1829, and it has been noted in numerous other rocks, viz., Nos. 512, 560, 603, 703, 787, 819, 1275, 1828, 1829, 1842.

In the muscovadytes labradorite sometimes embraces poikilitically the other minerals and sometimes it is in globular small grains embraced in them. The anorthosyte masses of the Keweenawan are composed, so far as observed, of labradorite (Nos. 113, 128, 200A, 223, 637).

Bytownite, for petrological consideration, is to be classed with labradorite, and may exist in the Keweenawan in greater frequency than is known. Sometimes it has been identified distinctly (Nos. 770, 810, 814) and in other cases it seems to be labrador-bytownite (Nos. 128, 258).

Anorthite, which is theoretically a pure lime feldspar, has been but doubtfully recognized in the Keweenawan (Nos. 133, 176, 222, 637). An impure anorthite was discovered in a fragment in clastic greenstone (No. 1367*b*).

Anorthoclase. This mineral, which can be considered the result of a variable combination of the molecules of orthoclase and of albite, has been identified several times in the rocks of the red rock series, especially in the granites (Nos. 1B, 292, 511). It occurs also as a porphyritic constituent in the red aporhyolyte of the "Great Palisades," No. 140(7), and in the associated granophyres at Pigeon point.* The same feldspar has been identified with more or less certainty in the granites of

*W. S. Bayley. The eruptive and sedimentary rocks of Pigeon Point, Minnesota. *Bulletin cix, U. S. Geol. Survey*, p. 52, 1893.

Kekequabic lake (Nos. 551G, 1061, 1399), in the granite of White Iron lake (No. 953) and in the granite quarried at East St. Cloud (No. 835). In all these cases it is so environed, either microscopically or taxonomically, that it appears as the result of contact of basic molten rocks on some acid rocks, and in the aporhyolyte it originated by crystallization from a molten acid magma, itself the result of fusion of acid clastics.

Cordierite, silicate of alumina and magnesia, with a small amount of iron, is one of those colorless secondary minerals which resemble the acid feldspars in affecting the zones of metamorphism and igneous contact. There is no doubt that it has escaped observation in many instances, as it might be taken for feldspar or even for quartz, unless specially examined. It not only occurs in the Animikie when modified by the gabbro to a fine mica schist (Nos. 1708, 2055, 370H), but in the biotitic muscovadyte where it is associated with other magnesian minerals and with quartz and labradorite, as well as much magnetite. In the former case it is plainly divided into vertical sectors (No. 370H) which is not in keeping with the general rule lately stated by Teall,* which requires this feature in cordierite of volcanic rocks rather than in metamorphic. It is evidently frequently of later origin than the most of the minerals of the rocks in which it occurs, as it embraces them in a micropoikilitic manner (No. 1708). In the muscovadyte, *i. e.*, the modified basic clastics of the Keewatin (Nos. 1039, 1042, 1090, 1092), its habit is like that of the other minerals, viz.; roundish granular, or granulitic, but it sometimes is wholly surrounded by quartz, by biotite (No. 1042), or by some feldspar. In all cases, therefore, in Minnesota, so far as known, cordierite has resulted from metamorphism.

Muscovite. This term has been applied to a light-colored mica seen in large, sometimes porphyritic, scaly masses (Nos. 923, 2263, 387H, 390H). In this mica silica, alumina and potassa are in greater amounts than in biotite, and magnesia is wanting. It hence affects the alkaline and acid rocks, whether metamorphic or plainly fragmental. In the metamorphic schists (No. 431) it is of late origin and embraces the quartz poikilitically (No. 2061). It is uniformly the product of alteration of alkaline feldspar.

Sericite differs from muscovite only in being in minute scales. It is the basis of the sericite schists, and is very abundant. It is the most conspicuous element in the rejected products of recrystallization of the old feldspars in the metamorphism of clastic debris (Nos. 1278, 2194, 2229) and remains at the centre of the old grains. It has probably been called kaolinic in numerous instances in the microscopical descriptions, although not having the vermicular grouping of the scales of kaolin, and perhaps holding too much of the earthy or alkaline bases for kaolinite.

* J. J. H. Teall. The Natural History of cordierite and its associates. *Proceedings of Geologists' Association*, vol. xvi, Part II, pp. 61-74, 1899.

Epidote. This is a very common but not very abundant mineral. Its earliest appearance is as small grains or groups of grains in the Lower Keewatin greenstones, where it is plainly the result of alteration of the feldspars in presence of iron. It is essentially a silicate of alumina, lime and iron. From this primary source (and by analogous production in later rocks) it is disseminated amongst the later rocks that are dependent on the oldest basic crust for their essential characters. It is also common in scattered grains in the more acid of the schists of the Archean, which also probably received the elements of which it is composed from the basic rocks of the earlier Archean.

It is a rather common mineral in the Archean granites, quartz-porphyries (?) (No. 914), and gneisses (Nos. 435, 994, 995), and especially in the "intermediate" series represented by the diorytes and by the amphibolytes (Nos. 401, 403). It here forms isolated crystalline grains, and its date appears to be as early as that of any of the constituent minerals of those rocks. Whether it was incorporated as epidote into the original clastic materials of which these rocks are believed to be primarily composed, or has originated through metamorphic recrystallization, it is difficult to affirm with present data, but from its general absence from the graywackes and other non-crystalline detritals of the Archean (see, however, No. 488), it appears to have been in the main the product of recrystallization under the action of metamorphic forces. It is therefore probable that, in the Archean, epidote is one of the distinctive metamorphic minerals.

It does not, however, depend wholly on metamorphism, for it is found in the Keweenawan basic rocks, where it seems to have been produced by ordinary weathing, or by the action of heated solutions on the lavas during the period of cooling, after congealation (Nos. 567, 569, 697).

In a single instance (No. 842) has it been found abundant enough to control the nomenclature of the rock (epidosyte). It is there associated with albite.

Zoisite. Zoisite is allied to epidote, but is practically free from iron, and it is probably less the product of metamorphism. It is rather the direct product of simple feldspathic alteration produced by solfataric exhalations or by heated solutions (Nos. 868, 872, 922, 1802). Accompanied by more or less of chlorite, mica and new feldspars, it constitutes very largely the impurities that pass under the general name saussurite. A saussuritized feldspar may be, and is frequently, embraced in the detrital rocks. Under such conditions, on the advent of metamorphism zoisite seems to maintain its identity in the resultant schist or dioryte (Nos. 861, 881).

Zeolites, of which a considerable number of species have been identified, are likewise the result of alteration of eruptive basic rocks or of their debris. The index may be consulted for reference to the important discussions.

Tourmaline, which indicates the near action of volcanoes, containing boracic acid and sometimes lithia, with varying amounts of magnesia, soda and iron, is primarily a silicate of alumina. It has been found in microscopic crystals in the greenstones and in Archean schists, as follows: Nos. 395 in clay slate, 473 in graywacke, 737 in conglomerate, and 2162 in a quartz schist. It cuts the quartz in a vein in No. 352. It is in syenyte in No. 993, in quartz-porphyry in No. 2237, and in gabbro in No. 773. It occurs in the Pokegama quartzyte, base of the Animikie, at Pokegama falls, No. 1525(a), and in the quartzyte and black slate of the Animikie in No. 1852.

Apatite. The occurrence of this mineral in greater abundance along the zone of contact of the Keweenawan basic eruptives on the clastics than elsewhere in the state, so far as known, is indicative of the causes that have promoted its origin. In these situations it is always idiomorphic. It is sometimes surrounded by hornblende and sometimes by orthoclase or by quartz, and these are all secondary minerals in the broader sense of that term, as already defined; and result from the transference of the acid elements into the basic rock. Apatite resembles sphene in the vigor with which it asserts its crystalline boundaries. Wadsworth has contended that apatite in these conditions is secondary, and the writer is inclined to indorse that view, but from different considerations. It is customary to place apatite amongst the earliest of the phenocrysts to appear in a magma when cooling. This is probably true of acid magmas (Nos. 858, 1025A, 1032, 1061, 1094, 2215), to which the larger crystals of magmatic apatite appertain, but it has but little application to basic magmas, because apatite is generally not found in them except at contact zones, where it has apparently been produced by endomorphism from the older rocks (Nos. 1B, 5, 459, 512, 531, 595, 540, 789, 1684, 1685A, 1802). When it is seen in the Archean granite (No. 368G) or dioryte in large crystals, it is likewise idiomorphic, and appears to have been one of the earliest crystals to form from the acid magma (Nos. 425, 805, 339B). Such crystals are, however, nearly always much worn, or "corroded" at the angles, and they may have been of still earlier date, *i. e.*, they may have been grains of clastic origin deposited in the debris from whose recrystallization the granite is supposed to have been formed. Such clastic apatite occurs in rocks Nos. 311, 2262, 366H. Apatite occurs sometimes in diabase (Nos. 221, 1076).

Barite is known to occur only in some veins that cut the quartzytes and slates of Pigeon point (Nos. 272, 288A and 288B), where it constitutes a large percentage of the vein matter.

Calcite, besides forming the chief constituent in many veins (Nos. 272, 423) and the filling of much amygdaloid, exists in microscopic particles in most of the clastic greenstones (Nos. 1015, 1018, 1068), in the graywackes (Nos. 473, 494), in the quartz-porphyries, so called (Nos. 387, 376), in the greenish conglomerates (Nos. 874, 908, 1070), in much of the mica schist (No. 422), in many diorytes (Nos. 424, 731, 1410, 1318), and occasionally in granite (Nos. 730, 1100, 2263), and rarely in gabbro (No. 1802).

Calcite shares with quartz the distinction of existing in all rocks except the unmodified original massive greenstones and the similar basic igneous rocks of the Keweenawan. It never, however, forms crystals of perfect form—except in cavities where it has room to develop without contact with other crystals (No. 60A)—but it is minutely disseminated widely where it can be detected only by the microscope.

Siderite. The earliest known appearance of siderite is in the quartz-porphyries of the Archean (Nos. 426, 428) and in the jaspilytes (Nos. 385, 388, 903, 907, 1565). It is also a frequent minor ingredient in nearly all the associated rocks of the Keewatin, whether of the Lower or Upper (Nos. 319, 326, 389, 473, 747, 910, 911, 2266, 39S). It appears uniformly as perfect, or approximately perfect, crystalline minute rhombs, and it is not preferably associated with any of the other minerals except hematite, with which it has an intimate connection. Sometimes these rhombs are aggregated in groups (No. 903), in which case they are more correctly styled grains, and exhibit that globular form and small dimension which is characteristic of many minerals in an incipient state of crystallization in metamorphic rocks. When the crystallization goes further, larger rhombs appear, and these larger crystals are seen to surround one or several of the small globules, usually with different orientations. Sometimes the whole rhomb seems to be made up of an aggregation of minute siderite globules, but usually (as in No. 907) there are three or four distinctly outlined, clustered or isolated, round which the darkened border due to the high refractive index comes out markedly on lowering the condensing lens. These globules as a rule do not break the borders of the rhombs, which are straight and extinguish simultaneously, but they lie somewhat away from the borders, not having exactly the same orientation as the borders.

These minute rhombs are also secondary to the minutely granular quartz which usually, in the jaspilytes, constitutes the most of the rock. These granular masses not only displace the quartz so as to make sometimes a spotted rock, of which its quartz grains are of about the same size, but these patches surround and embrace the quartz grains, and quartz grains are also to be seen, occasionally, in the midst of the isolated rhombs. Indeed, the siderite acts the rôle of a poikilitic mineral, embracing the quartz. This is not conspicuously the case, but usually the siderite is independent of the quartz. Yet it is so frequently seen that it is plain that the siderite was developed later than the quartz, or was nearly cotemporary with it. These siderite globules are easily distinguished from the quartz grains that lie within the siderite by the use of the Becke white line, and by the marginal lines of color which surround the included quartzes, due to the high double refraction of the adjacent edges of the siderite, both of which are absent from the siderite globules when quartz is not adjacent. It is owing to their globular composite structure that these rhombs seldom give an interference figure, however cut by the section.

In some of the best sections of jaspilyte that have been examined (Nos. 903, 907), all the iron ores are present, the magnetite, pyrite and siderite in somewhat coarse crystals, and the hematite in minutely fine particles disseminated amongst the finest quartz. If any distinction as to priority of origin can be drawn from this section, it is in favor of hematite, since it is distinctly embraced in the siderite as nuclei of the fine rhombs of that mineral (No. 1565). The magnetite is in distinct octahedra and the pyrite in cubes. These must be later than the hematite, which is in dust-like scales and powdery aggregates distributed amongst the fine jaspilitic quartz, and appears to be the cotemporary of it in origin and like it in manner of deposit. The hematite and quartz are non-differentiated by independent coarser crystallizations. The pyrite, magnetite and siderite are in large (microscopic) crystals and crystalline aggregates.

As to the origin of this early siderite it is to be attributed to some source which allows for the access of carbonic acid to the iron which was taken up by its formation. If the jaspilytes were formed in the bottom of the Archean ocean by chemical precipitation,* carbonic acid may have been derived from the atmosphere primarily, and secondarily from the ocean. It will be seen, however, below, that it is not improbable that this siderite originated in the manner similar to that which permeates the iron-bearing rocks of the Mesabi Iron range, and that those rocks were not the product of oceanic chemical precipitation.

The mineralogical environments and the petrographic structures of the siderite of the Mesabi Iron range are, in general, so much like those of the siderite of the Vermilion range that it seems necessary, in the light of the detailed examination presented in Part II, to consider them one in origin though differing widely as to date. The greater recentness of the Taconic ores seems to have been favorable for the preservation of some of those bonds of alliance with attendant conditions by which their origin and history can be traced out, but which, in the Archean ores, are so far destroyed that the relations of cause and effect cannot be detected. It is by reason of the microscopical and other examinations of a wide series of iron-bearing rocks of the Mesabi range, extending from Gunflint lake to the Mississippi river, that the writer has been led to regard the origin of those rocks very differently from the view formerly entertained by him, and quite different from the opinions presented by other geologists. At this place, however, it is designed to discuss only the sider-

*Bulletin vi of the Minnesota Geological Survey.

itic condition of the ore of the Mesabi Iron range. The general question of the origin of the rocks as such will find place in the next succeeding chapter.

The writer finds that in certain parts of the Mesabi Iron range the iron of the iron-bearing member is largely sideritic. This condition prevails about Gunflint lake and continues to a greater or less extent westward as far as to the vicinity of the Mallmann mine in T. 60–13 W. It gradually changes, and the oxides of iron are substituted for the prevalent carbonate. The change is not complete, for some carbonate is found at the western end of the range (No. 158S) in the same manner that the oxides also are found about Gunflint lake. With this exception, and with the further exception that the iron ingredient is more abundant toward the west, the iron-bearing member is, itself, essentially a uniform terrane. There is this further difference, viz.: Toward the west the Pokegama quartzyte generally separates the iron-bearing rocks from the Archean, while toward the east, *i. e.*, at Gunflint lake, the iron-bearing member lies sometimes directly on the Archean, and no representative of the Pokegama quartzyte has ever been seen there *in situ*. It appears, therefore, that such a variation from siderite to hematite must be due to some variation in the nature of the conditions attending the formation of the rock itself, such that oxide of iron was formed more abundantly in one part of the state, while in the same terrane, in another part, a carbonate of iron prevailed.

This carbonate of iron about Gunflint lake makes small rock masses, and it has been called sometimes limestone (Nos. 312 and 1310). One of the first samples collected (No. 312) is represented by the photograph, natural size, seen in plate VI. It here embraces many angular masses of flint, or chert, which the writer regards as devitrified glass of volcanic origin, originally of basic composition, but now composed largely of quartz. Such flint is abundant about Gunflint lake, not only as fragments in this siderite, but in horizontal thin beds that are intimately interstratified with some Animikie "slate," and taconyte (Nos. 1276, 1277). In other words, the flint, the volcanic glass and the taconyte are intimately associated, and their elements are variously involved in the siderite (No. 1289).

Again, the sideritic rock (plate VI) exhibits sometimes a parallel, streamed (or sedimentary?) structure seen in No. 1 of the plate referred to, and in No. 158S, and in other parts this structure is replaced by a more confused sideritic rock. The siliceous flinty pieces are placed in all positions in this confused part of the mass, but in the streamed parts they tend to parallelism with the direction of the streaming. This structure may be due to an original lava under flow, carrying many pieces of obsidian previously hardened.

That the sideritic rock was once a lava and is simply changed by becoming ferrated and carbonated or is a product of leeching from it, is indicated by a series of observations, accompanied by microscopical study of thin sections, made at a point about one mile west of Gunflint lake (S. E. ¼ sec. 24, T. 65–4), and of the taconitic structures seen about Gunflint lake. The former locality is represented by the following sketch. The rock seen in the isolated hill at the right consists of sideritic

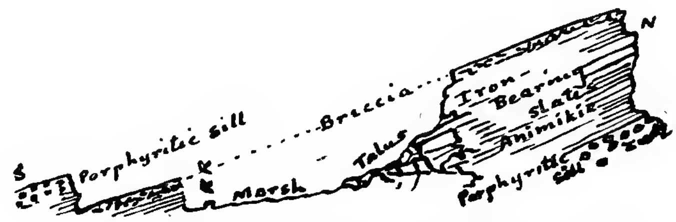

FIG. 54. PORTION OF THE ANIMIKIE CONTAINING IRON.
S. E. ¼ sec. 24, T. 65–4, near Gunflint lake.

slates, more or less magnetited, constituting the iron-bearing member of the Animikie, passing upward into a flinty breccia of iron-bearing beds. This breccia descends with the dip to the railroad track (No. 1897), where it also is underlain by unbrecciated slates. "It is from five to six feet thick and is composed of Animikie slate and quartzyte, some of the pieces being over two feet long." The cement of this breccia is a greenish fibrous matter, largely actinolitic and also sideritic, and weathers to a rusty surface in the same manner as the sideritic rock No. 312. Indeed it cannot be questioned that the breccia No. 312 (plate VI) was derived from a stratum in or near the bottom of the Animikie, as represented by the above figure. In making an examination of the cement of this breccia, which cement grades into the iron-bearing (sideritic) member of the Animikie, it was found to assume the characters of an igneous rock (Nos. 2052 and 2053), in which, while siderite still exists, yet cummingtonite and devitrified glass abound. As a lava it seems to have given birth on cooling to many nodules of more crystalline rock matter which, on the weathering away of the intervening matrix, stand out on the surface as black balls in a manner like the balls in a surface trap seen on Grand Portage island (No. 544). These balls now consist almost wholly of cummingtonite or some other amphibole, and the intervening matrix which surrounds the balls is a partly devitrified basic lava or chloritic zirkelyte.

It appears, further, that while the ores, siderite and magnetite, are found in all parts of this breccia, the carbonate is abundant in the matrix of the breccia and the oxide in the fine or flinty portions which form the angular pieces in the breccia. In other words, the carbonate formed later than the oxide, and in such free access of carbonic acid that, in some cases, nearly the whole rock is composed of siderite. There must have been also a free leeching process possible in the concentration of the elements of the lava to siderite, in order to have removed the silica and its bases, while in the concentration to the usual ingredients of a devitrified basic apobsidian the environment in some way restricted the free access of carbonic acid.

The writer cannot at present explain this curious difference in the transformation from basic lava, but he has surmised that some of the lava may have congealed on a land surface and some beneath the water of the ocean, and that the flow breccia(?), in which the matrix is largely siderite, may have been originally a surface lava. (Compare No. 1298.)

Further, if the igneous rock was poured out on a land surface, it is apparent not only that conditions would be favorable for the local formation of fresh-water pools and sometimes of small lakes, but also that, in case of organic matter flourishing in such pools, there would be a deposition of carbonate of iron which might have enclosed, in the manner represented by plate VI, much of the glassy debris of the lava sheet. On this hypothesis the mass of the lava proper is not changed to siderite, but the chilled upper surface is devitrified and its debris is preserved with its characteristic features; about the borders of such lakes, and along the sea beach, much volcanic glass sand must have mingled with the carbonate deposit, and sometimes replaced it entirely.

The further consideration of this presumed igneous origin of the iron-bearing member of the Animikie is deferred till the discussion of the iron ores and the taconyte. It is intended by the foregoing to call attention to the practically simultaneous origin of the oxide and the carbonate of iron in the iron-bearing rocks of the Mesabi range, and to the microscopical priority of the oxide. Genetically neither depends on the other, but they had a prior common cause of existence, and took different chemical conditions because of differing environments. This accords fully with the descriptions above of the relations between these minerals in the Vermilion range. That the ore of the Vermilion range was not derived from siderite is proven by rock No. 1572, since that mineral here not only surrounds and embraces the hematite, but forms veins that intersect the red jaspilyte in all directions, one vein being a quarter of an inch wide.

Dolomite, which is a common amorphous ingredient in the limestones in the southern part of the state, has been found to constitute a dolomyte in one instance (No. 824), where its crystalline form is finely exhibited by nearly every grain. It is the upper portion of the matrix of the upper conglomerate at Taylor's Falls, belonging to the Upper Cambrian.

(2) The Colored Minerals—Augite.

This is the most ubiquitous of the ferromagnesian minerals, especially in the basic igneous rocks. Under this designation may be embraced, in a general way, all the pyroxene which has been included in the foregoing microscopical descriptions, although in a few instances some varieties have been specially noted. These will be mentioned below.

In the oldest rocks (the Kawishiwin igneous rocks) augite is found with its optical characters usually destroyed, but its ophitic relation to the associated feldspars still preserved by the resultant uralite (Nos. 1011, 1078, 1758, 1759, 1760). In the Kawishiwin clastic greenstones it is uniformly converted to some form of hornblende (Nos. 356, 997, 1003, 1014, 1071), except where for some favorable conditions it has been partly preserved as augite. In the Upper Keewatin, about Kekequabic lake, where it is markedly affected by ægyrine characters, whether in the green schist or in the granite and porphyry (Nos. 1399, 1767) it is sometimes well preserved (Nos. 1094, 86G) and is sometimes partly converted into hornblende (Nos. 1400, 1047, 1060) or disseminated in the alteration form of actinolite spicules throughout the schist (Nos. 1419, 1421). In most places in the clastic greenstones of the Upper Keewatin it is wholly lost by alteration to hornblende and to chlorite (Nos. 1345, 1788, 1799) and this is universally true of the acid clastics which frequently embrace hornblende that may be supposed to have been derived wholly or partly from augite.

There are some hornblendic intrusives in the Keewatin which contain phenocrysts that afford curious and characteristic phenomena, presenting alliances with camptonyte (Nos. 872, 877, 915, 1318, 1786). Such are found about Vermilion lake and at Ely (No. 1786) and indicate that even in such conditions the original augite grain, or fragment, has been through such mechanical and chemical stress that it has taken on the hornblendic crystalline form, but has retained an impress of its prior state. Such ancient augitic areas seen in hornblendes are indicated by the greater absorption which appears at the centres of the hornblendes, or which spread irregularly through them (Nos. 872, 1047, 1786). This feature appears not only in the distinct dikes at Vermilion lake and at Ely, but also in much of the intrusive, recrystallized rocks of Kekequabic and Snowbank lakes. Such alteration and intrusion, when seen in the Upper Keewatin, was probably pre-Animikie.

In the Keweenawan augite is a more abundant mineral than in the Archean, owing probably to later origin and to less of mountain-making vicissitude, as well as to the preponderance of basic igneous rock in that formation. In the Keweenawan also, as a rule, it is nearly unchanged. Its clearness and purity are evinced in every thin section taken from such portions of the interior of the rock where it has received only the normal influences. In other words, time has had no noticeable effect, denoting metasomatic alteration (Nos. 639, 820, 1137). It is only where the Keweenawan rocks containing augite have experienced an unusual history, either before or after consolidation, and usually prior to final cooling, that augite has been altered. It is then sometimes changed to chlorite, or magnetite and chlorite, or its elements are so scattered in the production of new secondary minerals and mingled with those from other sources that they cannot be traced to their present resting places. In such cases the causes of these alterations, inherent in the accidental environment, are easy to see. The chief of these is plainly solfataric activity, penetrating and attacking the lava during the cooling period. Its purveyors were hot solutions and gases, the chief of the latter being steam. Secondly should be mentioned endomorphism from the contacts on the surrounding acid rocks. These agents were cotemporary and complementary. They had their greatest effect where the augites are wholly altered to hornblende (Nos. 554, 1848, 1849) and where the plagioclases are reddened. This is a combination which is sometimes accompanied by widespread interfusion and mingling of the basic magma with extensive areas of the acid, the two becoming completely and mutually mingled so as to produce igneous rocks of intermediate type in the Keweenawan (Nos. 5, 648, 650, 674, 675).

There are also some petrographical peculiarities appertaining to augite examined in the Keweenawan and in the muscovadytes:

(1) Its optic angle is sometimes very small, being apparently not over 5°, but varying to 45° (Nos. 126, 223, 291, 297, 1828, 2001, 178E), and it has been noted that this is accompanied in the same rock by the ophitic relation of olivine to plagioclase (No. 1828).

(2) It appears sometimes to have two generations in the same rock, *i. e.*, it is both granular and earlier than, or cotemporary with, the generation of the plagioclases, and is ophitic in its relation to the plagioclases (Nos. 89, 133, 222, 228, 229, 515, 517, 615, 820, 2064). In other cases it is wholly granular (No. 122) or wholly ophitic (Nos. 53, 106, 108, 625). The ophitic structure is uniformly the latest to form, at least it is later than the granular when both exist in the same rock (Nos. 515 and 517). The granular condition prevails in the muscovadytes and in the gabbros proper, but it is not confined to the coarser grained rocks. It appears in the finest of the diabases (No. 654), even in zirkelyte or glassy diabase (Nos. 540, 541). In No. 547 augite is porphyritic in a glassy base. In the muscovadyte it graduates apparently into the "globular structure" (Nos. 1334, 1347) described below. It is plain that the granular structure cannot, of itself, be said to be characteristic of gabbro, nor the ophitic of diabase. On the other hand, this intimate association of the granular and the ophitic structures in the same rock destroys the usefulness of this distinction as a character on which to base nomenclature, and points to the conclusion that diabase and gabbro cannot be dissociated on a genetic basis.

(3) It has been customary to account for these two structures of augite on the assumption that the granular was formed under a state of flow in the rock when the crystallizing points were continually separated, and the ophitic after the rock came to rest. There are, however, some facts that can hardly be explained in that way. (a) The ophitic structure prevails in the surface lavas and dike rocks, which are admit-

tedly the most likely to have been affected by such action, since they were in a condition of flow as long as possible (Nos. 7C, 7D, 23, 38, 206), and are wholly ophitic. (b) The granular prevails in the deep-seated, such as the granular gabbros, which must have been least subject to flow (Nos. 1784, 857G). (c) The granular is found in the muscovadytes which have never been in a condition of flow, but stand in their original, often bedded, relations to each other, preserving their original Archean dip (Nos. 667, 698, 767, 857G, 857aG). (d) When both structures exist in the same rock, the earlier augites are sometimes embraced poikilitically in the later (Nos. 515, 2064). It would hence appear that the granular condition is not dependent on the commencement of cooling. (e) The earlier augite is apt to be diallagic (Nos. 291, 292). This indicates that diallage is not a product of late generation, but a feature of the deeper portions of the rock. (f) The granular augites are about equigranular. If the ophitic augites resulted from crystallization after a state of rest was acquired, the question arises, Why did the earlier augites wholly cease growth, and, while maintaining their existence, refuse to serve as nuclei for the fresh later augites? *i. e.*, why did they not all simultaneously resume the augitic growth, and why did certain new larger crystals of the same mineral start an independent development?

(4) Augite is frequently seen in a globular, or infantile, condition (Nos. 1092, 1334, 1347). This is usually the case in much of the rock muscovadyte (or noryte) and in the gneissic muscovadyte which has resulted from the recrystallization of basic clastic rocks of the Keewatin. Where the original clastic material was more acid, diopside is more common.

(5) The augite of the granite of Kekequabic lake, and in part at least of that of Snowbank lake, is so supplied with soda that it may be styled ægyrine-augite. It is fully described in connection with Nos. 1094, 1105, 1106, 1399.

Diopside. In several instances the pyroxene examined has exhibited characters of diopside, *i. e.*, has a cleavage parallel to 010, but in all such cases it is in circumstances that have indicated the secondary origin of the pyroxene. In No. 132A it is fresh and green, being in one of the augite granites. In these granites it descends (as in No. 643) to globular dimensions and is scattered in that form through the altered feldspars. Without having made careful examination in the "augite granites" of the Keweenewan, it is here only suggested that it is probable that this form of pyroxene prevails in these rocks. (Compare No. 1805).

It has also been identified in some of the spherulitic and micro-pegmatitic secondary growths at the contact zones of the Keweenawan (Nos. 132A, 667 ?), where it forms long, somewhat acicular crystals which pierce the altered feldspathic elements with great freedom and in a conspicuous manner. In the diabases where modified by such contacts the same petrographic character has been noted in the pyroxene (No. 137).

Diallage. The diallagic cleavage of augite is common in the diabase and in the gabbro of the Keweenawan, as well as in the muscovadyte. In the diabase it is seen in Nos. 115, 222, 1605, 1287. In the gabbros in Nos. 1C, 698, 985, 1136, 1137, 1287, 1678, 1749. In the muscovadyte it is conspicuous in Nos. 122, 1287, 2199, 2201. Diallage has not been observed in the Archean rocks.

From all that has been observed, the diallagic characters of augite appear to have an early date. Far from being due to secondary causes, and hence a secondary feature of the pyroxenes of the Keweenawan, the characteristic lamellation appears rather to be one of its primordial characters. It is most frequently seen in those pyroxenes that antedated, or were coeval with, the plagioclase and olivine (Nos. 1C, 1287). It is in the muscovadyte that it is intertwined in a lamellar succession with enstatite (Nos. 1340, 2199) and with hypersthene (No. 2202).

There is, however, a diallagic structure which results from late alteration of augite, and in some instances it has been accepted by petrographers as the true structure of diallage (No. 300), but it should be kept distinct. There is no doubt that this confusion of two structures under one name has been the cause of much difference of opinion as to the nature, origin and date of the mineral diallage. That diallagic lamellation which is of later date and is attributable to natural decay from weathering or other influences is fine and fibrous, is parallel to the base of the augite crystal, and it destroys the orientation of the augite which is affected by it. It is described and illustrated by Wadsworth in Bulletin ii of the Minnesota Survey, plate VII, figure 1, and page 80. But that lamellation parallel to 100, which is the structure that characterizes the oldest diallage of the gabbro and of the muscovadyte, does not destroy the orientation of the augite. Non-diallagic, ophitic augite often exists in the same rock with true diallage (No. 222), and true diallage is sometimes also ophitic (Nos. 115, 847G).

There seems to be a fundamental difference between diallage and diopside, viz.: The true diallagic lamellation 100 perpendicular to the optic plane is original and primary, and exists in the gabbro the result of refusion of the (usually) clastic greenstones, but that of diopside (010) parallel to the optic plane is a character of the pyroxene developed later, as in gneiss and crystalline schists, as well as in some of the so-called augite granites, both of the Archean and of the Keweenawan.

Hypersthene. This is the most common of the orthorhombic pyroxenes. It is, however, practically restricted to the muscovadyte series, *i. e.*, to the zone involving the transition from the old Keewatin clastics to the gabbro of the Keweenawan, whether considered genetically or geographically; but it also continues slightly beyond the transition, on the gabbro side of that zone, and thus gives name to a rare rock called "hypersthene gabbro" (Nos. 1037, 692, 1710, 178E). It here exists in all stages of development, from the initial "globular" form (Nos. 1042, 1037, 1710; 1784) to crystals of large size (Nos. 692, 1042, 1037, 1362, 1364, 1712, 2197, 397(a)H), which frequently embrace all the other minerals poikilitically (No. 618). In the globular state it is found entirely surrounded by biotite in No. 1042, by hypersthene in No. 1037, by magnetite in No. 1040, by feldspar in No. 1784.

Enstatite and bronzite. The former has been noted in muscovadyte (Nos. 705, 983), but the latter has only doubtfully been identified.

Bastite, which is perhaps an alteration product of enstatite or bronzite, at least a secondary mineral, was once noted in a hypersthene gabbro (No. 1710). This is at or near a muscovadyte horizon, noted for the novelty and the multiplicity of its mineral associations, and hence it is reasonable to suppose that it is another of the curious creations of this zone of metamorphism, rather than an alteration product after another mineral.

Hornblende. Among the colored minerals hornblende to a notable extent plays the rôle of quartz among the white ones. It is easily formed, either under ordinary decay of some of the other earlier minerals, or under metamorphism. It is hence present, in some of its varieties, in nearly all rocks that have been examined. The green color of all the greenstones is almost wholly due to ordinary hornblende. It is abundant in all the crystalline schists, even in the mica schists. There is scarcely a granite that is free from it, nor a syenyte, while in all the diorytes it is mainly hornblende that gives the dark, or spotted-dark, color to the outward aspect, sharing it only with some epidote or a monoclinic pyroxene, which latter is usually diopside. It passes through all the stages of development from the globular to the idiomorphic and porphyritic. It is necessary here to mention only some of the most important of the features it presents in Minnesota and to enumerate the varieties that have been identified.

Globular stage of hornblende. Beginning with the earliest recognizable condition in which hornblende has been seen, the globular forms which are mentioned in Nos. 1345, 2104, 2264, 19H, are fair illustrations. It here occurs in incipient granite, resulting from the metamorphism of a clastic debris, in a sphene crystal, likewise formed in the regeneration of a more basic debris and in a muscovadyte which has an alliance with dioryte in the abundance of hornblende which it contains. In the last the globular composite structure of some of the larger hornblendes is still evident in the patchy coloration between crossed nicols, and in the varied shades of green which fleck them when rotated over a single nicol. In the main hornblende has so strong a crystalline independence that the initial globular grains are perfectly arranged in uniform orientation, thus building up the prismatic columns into which hornblende is cut by its cleavages, and it is only in rare instances, such as seen in No. 1345, that the individual globules retain any distinguishing form or coloration. Of all the rocks this feature is most common in muscovadyte.

Hornblende fringes. That hornblende in all its varieties is invariably the result of some secondary forces which have changed other minerals, usually augite, into hornblende, is abundantly shown in the details of the foregoing descriptions. The "porphyritic" hornblendes are simply developed fragments or crystals of augite. This is true not only in some of the green schists, as those seen about the western confines of Long lake (Nos. 2104, 2125), about Fall lake (No. 139W) and in the region of Kekequabic lake (Nos. 1047, 1049), each of which contain other evidences of their clastic origin, but even in the more massive bosses of "hornblende porphyry," and in the narrow (camptonyte?) dikes, seen at Ely and at Stuntz island (Nos. 872, 877, 1786), which are intrusive in the Keewatin. The most clear instance of the conversion of augite to hornblende was seen in a Keweenawan diabase (No. 1847). Here the hornblendic product forms a "fringe" surrounding the augite at its extremities and having separate orientation. This enlargement in other cases is converted to an encroachment, and gradually the whole augite grain is converted to hornblende (No. 872), there being left occasionally only a small remnant, or several globular remnants near the centre (No. 1060), to show the original augitic nature of the grain. This graduated series of changes shows that the "fringe" is the first to form, and that the latest hornblendic molecule was that which replaced the last augitic molecule. That is, it is evident that the hornblendic fringes are not "frayed ends" of hornblende due to dynamic action, as supposed by Williams, nor yet "enlargements" of original hornblende crystals, as suggested by Van Hise, but are the oldest parts of the hornblende grains to which they belong. The outline of the original augite is sometimes preserved by a patch of irregular shape occupying the central portion, which has greater absorption than that which surrounds it, and also between crossed nicols gives a different color of double refraction (Nos. 1047, 139W, 15H). In many, and probably in most, cases, the augitic characters are wholly obliterated and hornblende appears to be an "original" mineral, due to the profound transformation which the entire rock mass has experienced, as in dioryte.

"Original" hornblende. Some hornblendes, in massive rocks, especially those about Epsilon lake, have the aspect of being "original," *i. e.*, that they formed in a molten magma on consolidation. These are Nos. 751, 792G–797G. Some of these have been carefully re-examined, with the following results:

No. 751. So far as can be seen the hornblendes are original.
No. 792G. Has distinct augite remnants within the hornblende.
No. 793G. Shows some central nuclei or remnants, but not of augite.
No. 793aG. Original, so far as can be seen, but with two or three central nuclei, though not of augite.
No. 794G. Original, so far as can be seen; indistinct nuclei, as in No. 793aG.

No. 794aG. Hornblende lost by decay, either chloritized or magnetited.

No. 794bG. Clastic rock, probably tuff; fragments angular, embracing some quartz; no hornblende.

No. 795G. Distinct augite remnants. Hornblende is green.

No. 796G. Much augite remaining as grains in the hornblendes.

No. 797G. Some hornblendes are apparently original, but some have central nuclei not of augite; others are wholly chloritized except at the centre, where are apparently augitic grouped grains, which grains appear to be in part epidote.

The central grains not augite (above) are largely leucoxene, but embrace, apparently, some feldspar and and perhaps some chlorite, while the general hornblendic orientation runs through them, causing imperfect extinction.

It seems likely, therefore, from the occasional existence of augite remnants in these hornblendes, that they are modified conditions of augite. There is no doubt that this rock acts the part of an igneous intrusive, in the same manner as the granite and massive porphyry of Kekequabic lake, and in consonance with that fact the hornblendes appear almost entirely "original," in the usual petrographical sense. In the broad sense, however, that has been indicated (page 940), they are in a secondary rock, and are not original. They are to be considered original only in the sense that quartz and orthoclase are original in granite.

So far as the writer has observed, hornblende appears in the Archean only as a result of alteration of augite or some other minerals under conditions of profound metamorphism.

The varying amounts of alumina and of iron present and available under the conditions that promote such alteration seem to be the prime cause of the different varieties of hornblende that have been noted. *Brown hornblende* is a frequent accompaniment of the gabbro rocks where they carry notable amounts of magnetite, and especially where the gabbro is shading off to muscovadyte (Nos. 703, 1288, 1292, 1711).

Cummingtonite. This name is preferred, on the authority of Hintze,* who, on account of chemical composition, has assigned that mineral, which in Michigan is apparently the analogue of that found in Minnesota, to this species. The mineral here referred to was named actinolite by the geologists of Michigan and Wisconsin, and the rocks to which it gives character were for several years known as actinolite schists, or actinolite-magnetite schists. Subsequently, after the more minute examination and analysis by Lane and Sharpless,† they were known for several years as grünerite schists. This mineral is known microscopically, amongst the amphiboles, for its multiple, narrow twinning, its high double refraction and its fresh, light-colored appearance. It is common on the Mesabi Iron range in connection with the iron-bearing member of the Animikie (Nos. 437, 766, 976, 1365), where the rocks have been somewhat metamorphosed by proximity to the gabbro revolution. It has also been seen several times in the highly metamorphic iron ores of the muscovadyte zone (No. 397(a)H) and occasionally elsewhere (Nos. 1365, 1710).

**Handbuch der Mineralogie*, p. 1230.

†*American Journal of Science*, vol. xlii, p. 505, 1891.

Actinolite, however, of all the fibrous, or fibro-lamellar amphiboles, is most common. It is very abundant in all the green schists, and especially in the green schists about Kekequabic lake. It is probably this mineral that prevails in all the green, altered, basic clastics of the Keewatin, where it has frequently been passed under the simple designation "hornblende."

Pargasite differs optically from the other hornblendes in having n_g for its acute bisectrix (Nos. 1043, 1049). It is probably more common than has been observed, especially about Kekequabic lake, where it occurs in the green tuffs of the region, resulting, as already stated, from alteration of a soda-bearing augite. These hornblendes have not been analyzed, but it is very probable that they would show a small percentage of soda.

Tremolite has been named occasionally, but its optic characters are so similar to those of actinolite that this distinction must be considered as provisional (Nos. 18A, 1137, 1453).

Uralite is the name that has been applied sometimes to a hornblende whose dependence on augite as its source is very evident, sometimes in the preservation of the original ophitic relation of the augite (Nos. 1386, 2255, 2258).

Biotite. There seems to be an easy gradation in optic characters as well as in chemical composition between muscovite and biotite. The alteration of the feldspars is the prime source of both. When such alteration is in the presence of ferromagnesian minerals likewise undergoing change, the mica partakes of the iron and magnesia, thus affording biotite. A simple decay of the feldspars would hardly produce these results, but it must be understood that some agent is acting to promote recrystallization. Such force may be heat, or pressure, or both, accompanied by moisture, and the process may be slow or rapid. Without such forced recombinations the soluble elements of the feldspars would be removed entirely, under ordinary decay, and the result would probably be a pure kaolin (Nos. 1449, 1700, 1701, 1704).

There are, moreover, instances in the igneous rocks (gabbro) in which biotite appears to have been one of the original minerals (Nos. 291, 954).

Muscovite and biotite, often in large crystals, are hence found widely in the granites, diorytes and syenytes that have resulted from the recrystallization of Archean debris. In a strictly petrographical sense they are here original minerals, but they are secondary in the broader sense that they have resulted from the decay of earlier less stable mineral compounds, and have recrystallized under the stress of metamorphic forces.

Biotite occurs porphyritically in a kersantyte which acts as an intrusive in the vicinity of Moose lake (Nos. 2158, 2261).

Chlorite. Including under this term all the chlorites that have been observed (clinochlore, pennine, strigovite, thuringite, ripidolite, delessite), the general remark may be true that they result from the same sort of alteration as mentioned under biotite, but in the process of formation took also water into crystallization. Their alkaline base varies much, embracing also sometimes a notable amount of protoxide of iron.

As the microscopic characters of muscovite and biotite are not always distinctive, so the chlorites fade also into biotite. Chlorite sometimes replaces muscovite or biotite (Nos. 2265, 2277), one lamella after another, in whole or in part, in the same way that biotite is intimately associated with muscovite. Indeed, there seems to be an easy gradation from one end of the series of these foliated secondary minerals to the other, *i. e.*, from muscovite to chlorite, the specific names depending on the varying amounts of the bases present and ready to enter into combination at the moment of crystallization. As water and magnesia increase, the mineral *thalite* (No. 91B) seems to represent the extreme of the series over against muscovite.

Glauconite. The greensand of the Taconic iron ore was fully described and discussed by Mr. J. E. Spurr, in Bulletin x of the Minnesota Survey. He showed the various microscopic changes that transpired in that substance which resulted in the production of the ores of the Mesabi Iron range. The acumen with which he ferreted out this as the primordial element in the taconyte and showed that both the silica and the oxide of iron resulted from the transition from unstable chemical composition to silica and hematite, the most stable condition of those elements, is worthy of all admiration, and his process and his result will not here be called in question. He presumed, as an ulterior source of the greensand, that it may have been of organic origin, and perhaps depended on Foraminifera, and the writer has given in this volume (page 366) further facts that tend, with a little idealization, to indicate the foraminiferal origin of this greensand. But the greensand was not probably glauconite of foraminiferal origin. According to descriptions and illustrations contained in Part II (Nos. 1276, 1294, 1530, 1630A, 2052, 2138), it is rendered highly probable that this greensand was a more or less devitrified volcanic glass sand. The full discussion of the origin of the taconyte of the Mesabi Iron range is given under that head in the subchapter devoted to petrology.

Sphene. This mineral, when in the metamorphic rocks, is plainly the result of secondary forces, and has resulted from the presence of titanium in older, or original minerals, usually ilmenite or titaniferous magnetite. Such titaniferous minerals result from the disintegration of the original basic rocks, *i. e.*, the greenstones, and have permeated, in greater or less quantity, all the later rocks. That this mineral is, in this sense, secondary also in the igneous rocks in which it occurs, is indicated by its absence in the original rocks, and by its morphologic relations to the minerals with which it is associated. To a large degree sphene has a powerful crystallizing autonomy by reason of which it not only quickly acquires its idiomorphic outlines and remains small, thrusting aside all other elements, but it seldom embraces any other minerals in a poikilitic manner. Yet it is observable, in numerous instances, that it gives way to the outlines of other minerals. In one instance (No. 19H), it was noticed in a dioryte that it was secondary to hornblende, which not only deeply indented its margin, but was enclosed in it in the form of several isolated grains. In No. 1515 it surrounds apatite and apparently some feldspar.

Sphene occurs in nearly all the crystalline rocks except the oldest greenstones, whether igneous or metamorphic, and especially in those with considerable amounts of the dark silicates. It is also found in the clastic rocks, apparently as detrital grains.

Leucoxene represents that form of the alteration product of ilmenite or titaniferous magnetite which is most common in the original basic rocks and in the green schists when they have partially decayed (Nos. 567, 1021, 1022). It is apparently amorphous and remains in this state till metamorphic action recrystallizes it, when it assumes the crystalline characters that are more definitely and usually designated sphene.

Rutile is characteristically a mineral of the crystalline and subcrystalline schists, appearing sometimes in clay slate (No. 395). It favors those rocks in which also exists quartz. It likewise is apparently wholly a secondary mineral, resulting from the recrystallization of the alteration products of ilmenite or of sphene after the abstraction of the lime. The so-called sagenite net of rutile was observed in Nos. 422, 567, 896, 1750, 1814. Twinned rutile was noted in a chlorite schist at Tower, in No. 869, and in an altered or contacting diabase at Wauswaugoning bay (No. 265).

Garnet is one of the metamorphic minerals of the Pewabic quartzyte at Chub (Akeley) lake (No. 1895) and of the mica schists at Little Falls and Pike rapids (Nos. 1670–1673) and occasionally of granite (No. 2189).

Staurolite likewise is found abundantly in the metamorphic rocks at Pike rapids and elsewhere in Morrison county (No. 849 and Mus. Reg. No. 2689). In an altered state it was identified at the contact zone of Animikie slate with a diabase intrusive (No. ——).

Zircon is a mineral of the intensely modified clastics under the action of basic intrusion where gases and solutions were quick to penetrate (Nos. 552, 1902); it also is found in later detrital rocks and gravel.

Fluorite is a constituent of granite at Saganaga lake (No. 2046), and was found in connection with the Keweenawan basic rocks in their contact relations with Animikie, and in veins in the Keweenawan (No. 64A) and in the Archean granite (No. 318).

Olivine. Normally olivine seems to have existed in all the original basic igneous rocks, but it was scattered in small grains or crystals without existing in large quantities. It is also in the secondary basic igneous rocks of the Keweenawan, but in some large areas it is quite sparse in the gabbro, as in the anorthosytes. It is sometimes found in great abundance in the muscovadyte, where it is surrounded with unusual mineral associates.

In the original basic rocks of the Keewatin, supposed to be the representative of the first crust of the earth, and hence the oldest rocks in the state, olivine cannot now be recognized as such, but has been destroyed by the vicissitudes of the long history which it has experienced, some of its serpentinous alteration products only being left to bear testimony to its earlier existence (Nos. 349, 2158).

In the Keweenawan, olivine is not always one of the earliest of the minerals. This occurs in some of the coarse gabbros, or coarse diabases (Nos. 258, 512, 603, 787, 819, 1275, 1828, 1829, 429E) quite frequently, and occasionally it has been noted in narrow dikes (No. 757). This late generation of olivine, compared with that of the feldspathic individuals of the basic Keweenawan, therefore, is not due, apparently, to any batholitic conditions of consolidation, but to chemical conditions inherent in the magma.

Fayalite. That form of olivine which is characterized optically by its negative bisectrix and a distinct cleavage (010) has been recognized in several instances in the muscovadytes (Nos. 1041, 1336, 1343, 1365, 1829, 2058, 2199). This seems to be most common where the rock contains also considerable magnetite.

Bowlingite. Olivine has been seen transformed not only into an indefinite more or less fibrous substance which usually is denominated serpentine, and sometimes into a more definitely characterized mineral (antigorite), but also to the mineral named by Hannay* bowlingite (Nos. 193, 560, 703). Sometimes a grain of olivine is wholly transformed to bowlingite, which takes the form and place of the original, and sometimes a rim of bowlingite surrounds feldspar grains which are also embraced in magnetite, separating the feldspar entirely from contact with the magnetite. This occurs in the cumberlandyte of Mayhew lake (No. 703).

The iron ores—Ilmenite, magnetite. These are mentioned in conjunction for the reason that they seem to be equally old and intimately associated, and have not usually been separately determined in the course of the microscopical examinations. Whether the titaniferous element seen in the secondary minerals, rutile, leucoxene, etc., is dependent on ilmenite or a titaniferous magnetite, or whether the iron ore that occurs sometimes in large masses in the gabbro and in the muscovadyte is ilmenite or titaniferous magnetite, in the majority of cases cannot be stated. On the other

Mineralogical Magazine, vol. i, p. 154, 1877.

hand, it is quite certain that in some instances the ore is almost or quite free from titanium, and usually carries less than the standard amount for ilmenite, and in many of the Keweenawan diabases there is no evidence whatever of the presence of ilmenite, while the cubic crystalline form plainly points to magnetite.

In the original greenstones of igneous origin, these minerals are frequently seen, not only as minerals, but in the form of diffused leucoxene. In the secondary greenstones, when unmetamorphosed, *i. e.*, the clastics either of the Kawishiwin or of the Upper Keewatin, they are very rare, but magnetite in scattered minute crystals has been noted in intimate association with hematite in the jaspilyte ores. When, however, these ores and the rocks containing them are converted to crystalline schists, the Coutchiching, so-called, or the gneisses and mica schists in general, magnetite is the sole form of iron ore that has been observed.

In the Keweenawan gabbro are large masses of magnetite which usually, so far as observed, but not always, carry titanium. Similar iron ore is disseminated through the adjacent gabbro rock in crystals and small masses that vary largely in size and structure. In but few cases in the gabbro, and none in the muscovadyte, has this magnetite been seen to present unequivocal evidence of being of primary or original date, as if crystallizing from a cooling magma amongst the first phenocrysts. On the other hand, it has exhibited in many cases clear proof of its secondary, or at least of its late, origin (Nos. 1, 1C, 5, 6). The original forms of magnetite constitute but a small moiety, and are of microscopic dimensions as crystals. The secondary masses are large, constituting ore bodies that are of promise in economic value. The original crystals are widely distributed in general through the body of the gabbro, or are absent; the secondary masses are usually associated with other evidences of contact relations, and are especially frequent, so far as observed, in association with muscovadyte. The large masses are, in general, believed to be the result of transformation of older jaspilyte lodes existing in the greenstone from which the gabbro itself was derived, while the original minute crystals, having independent cubic outlines, were probably from magnetite (or ilmenite) originally distributed as an essential ingredient in the mass of the same greenstone. In neither case has the iron ore been transferred in any noteworthy amount from the position it occupied in the original greenstone.* It has been subjected to entire recrystallization and has acquired, perhaps, some chemical characters which it did not possess before.

The following figure, drawn from rock No. 1C, shows some relation between the supposed original crystals of magnetite and the secondary accretions. The crystal-

*In *Bulletin vi*, where these ores were discussed, a distinction was made between titaniferous and non-titaniferous magnetites from the gabbro, and it was assumed that the former was indigenous in the gabbro, and the latter masses had been derived from the Animikie as foreign inclusions. Such distinction seems, however, not well supported by field evidence, and cannot be maintained from any other evidence. There is reason to believe that both belong to the gabbro.

line forms of magnetite (a) are surrounded by feldspar (bytownite) and must have had an early date in the formation of the rock. The secondary magnetite is arranged in sheets apparently coincident with the lamellation of the diallage, and penetrated the diallage in proportion as decay of the diallage went on. This alteration probably dated from the cooling period of the rock. It would be interesting to know what relation subsists between the titanium content and the primary or secondary nature of the magnetite, but no investigation has been directed to that point. From the fact that only a *trace* of titanium is reported by Prof. Dodge in the analysis of No. 1, where most of the magnetite is of secondary origin, and that Mr. J. H. Kloos reported that he found "no trace of titanium" in the gabbros at Duluth, it appears that titanium must be of the magnetite dating from the earliest generation. The general absence of leucoxene in No. 1 also accords with this.

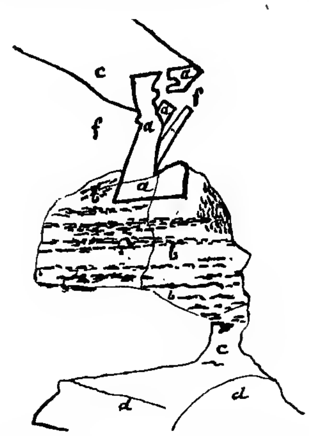

FIG. 55. PRIMARY AND SECONDARY MAGNETITE IN ROCK NO. 1C.

a. Dense magnetite, original(?)
b. Secondary magnetite, in the laminations of altered pyroxene.
c. Changed pyroxene (diallage).
d. Unchanged pyroxene (diallage).
f. Feldspar grains.

Magnetite, therefore, so far as it constitutes rock masses in the Archean, or in the gabbro, is the result of secondary causes, and was concentrated probably from other minerals (largely hematite) by some unusual forces acting at epochs of great metamorphism, applied locally to some preëxisting rock. Such forces have long ago ceased to operate at those localities, and therefore magnetite is no longer in process of formation, but rather of destruction.

Hematite. The oldest recognizable oxide of iron, aside from the magnetite (or ilmenite) of the igneous greenstones of the Archean, is hematite. It constitutes masses of great economic value in the Keewatin, as seen at Soudan, Ely and elsewhere. It is the ore of the jaspilyte, with only microscopic exceptions, where jaspilyte becomes so rich in iron as to be called ore. In the Keewatin it has been presumed by some to be secondary after siderite, and this hypothesis has been applied extensively to explain the origin of the hematite ores of the Taconic. Microscopical examination has shown clearly, however, that it existed prior to the associated siderite, earlier than the magnetite and earlier than pyrite, all of which are found to have had a very early origin in those ores. This is discussed in connection with siderite, foregoing, and it is only necessary at this place to call attention to the prior existence of hematite in the jaspilyte of the Keewatin. This is seen in Nos. 903 and 907, and better still in Nos. 1565 and 1961.

Pyrite. The sulphide of iron at no place in Minnesota, so far as known, is so abundant as to constitute rock masses. It is, however, very widely distributed, extending from the quartz-porphyries of the Lower Keewatin (No. 2238) to those of the Upper Keewatin (No. 387), and from the Archean granite (No. 2248) to the red rocks of the Keweenawan (No. 292), while in nearly all the Archean clastic rocks it is frequent in form of cubic crystals (Nos. 340, 356, 473, 726.) It is so common that it has not been considered necessary to mention it in many of the microscopical descriptions. In connection with the jaspilyte ridges at Tower pyrite seems to exist in considerable quantity, especially in the "south ridge," since its oxidation is palpably the cause of water carrying sulphuric acid, which issues from a drift on the southern side of the ridge. It was also encountered in the (Lee) mine, as evinced by Nos. 1547, 1549 and 2280. In many respects the environments as well as the crystalline perfection of pyrite where seen in the Archean resemble those of magnetite, and there is evidence that it originated in the Archean, where associated with magnetite, at about the same date and by reason of similar or identical physical conditions.

In concluding this sketch of the rock-forming minerals of the crystalline rocks, it may be well to enumerate some general principles brought out forcibly by the examinations detailed in Part II, but which are sometimes not recognized fully by petrographers.

1. *The globular state of incipient minerals.* That quartz assumes a globular form at the commencement of its separation from a magma, and passes through various structures by the extension or the multiplication of these units, was fully announced with illustrations by M. M. Fouqué and Michel Lévy.* These incipient and imperfect forms of quartz appear to arise under metamorphism and continue their development under conditions which obstruct normal growth and especially in the presence of other elements which simultaneously are stimulated to incipient crystallization.

In the course of this investigation several other minerals have been noticed to undergo the same or similar succession of stages. Especially has it been noticed that the globular form is acquired as the first step in the formation of minerals due to metamorphism. We have not had so favorable opportunity to study minerals formed directly from magmas, although many dust-like globular forms have been noted in the zirkelyte resulting from the Keweenawan eruptives. In the devitrification of Keweenawan obsidians, the first forms developed seem to acquire at once angular outlines or thread-like projections.

In the rocks formed from metamorphism which did not reach fusion, it is so common to observe the globular form in the first stage of all the minerals that it seems to be a general law. Owing to the nature of the case this phenomenon is

* *Minéralogie Micrographique*, 1879, p. 193, plate xii, figure 1. The description and illustration given by the authors hardly apply to the globular quartz here referred to, but to a more advanced state of growth. M. Fouqué, however, in his lectures at the Collége de France, has amply discussed the globular form of quartz here referred to.

most common in the muscovadyte, or noryte stage of the gabbro. In this rock, in proportion as one or the other mineral is able to develop more rapidly, it grows beyond the globular state and poikilitically surrounds the globular incipient grains of all the others. This is true of biotite (Nos. 1092, 1777, 638G, 740G), of quartz (Nos. 1039, 1339, 1340, 8M), of magnetite (Nos. 677, 1340, 1343, 2201), of olivine (Nos. 916, 1367, 1343, 505H), of labradorite (Nos. 677, 767, 1345, 1366, 2203, 638G), of cordierite (No. 1092), of augite (or diopside) (Nos. 677, 767, 1092, 1336, 1341, 1089, 2197), of diallage (Nos. 1340, 847G, 857G), of hypersthene (Nos. 960, 1343, 1364, 2203), and of amphibole (Nos. 767, 1345, 2197, 2209, 638G). These included globular grains cannot be considered in all cases as the infantile starting points of the minerals they represent, but in many cases they are grown beyond the infantile dimensions, though they have retained their infantile roundness. It can be seen also that in some instances the formation of a large crystal which poikilitically embraces several others, is made to embrace many minute globular forms of its own kind (Nos. 1092, 1343, 2198, 2209). These latter are very evident when they do not stand in the same orientation as the enclosing crystal (Nos. 2198, 2209), but when they have placed themselves in the same orientation they appear to be lost in the general growth. In case of porphyritic crystals developing from a magma, such increments to the growing crystal would be free to arrange themselves in accord with the polarity of the main crystal. In a plastic or semi-plastic mass, or in a solid undergoing a forced, slow transformation, the various points at which crystallization might simultaneously spring up would be so obstructed by their surroundings that they could not all assume crystalline agreement with each other.

This feature has been observed also in the rhombs of siderite that appear in the jaspilyte of the Lower Keewatin (Nos. 388, 903, 907, 1565) and in that which accompanies the taconyte of the Taconic (No. 1307).

It appears justifiable, therefore, to regard this early globular state of the constituent minerals of a rock as an evidence of metamorphic origin of the rock. Even if this character be seen in but one of the minerals of a given rock, it is evidence of transformation, and all the minerals of such a rock could be looked upon as probably having been developed from an earlier state of the rock.

Owing to the irregular manner of growth which minerals under metamorphic forces are compelled to follow, such grains might be mistaken for "crushed" crystals, and the roundish small parts which have not been able to unite with the larger crystals in uniform orientation might be, and have been in some cases, taken for the debris formed by such crushing. They have also been ascribed to a supposed peripheral action of a flowing igneous rock, the cause being presumed to be the motion of the mass in separating, if not actually breaking, the initial crystals of the different minerals.

2. *"Primary" and "secondary" minerals.* These conventional distinctions have been found insufficient and inapplicable in numerous instances; though they have been employed in the foregoing descriptions, it is only with some misgivings and with a certain amount of recognized vagueness. In general, whenever these terms have been employed, the "secondary" minerals designated are plainly those which have resulted from alteration of other minerals which have been assumed to have been "primary," or "original."

Three different considerations have conspired to render it insufficient, and sometimes incorrect, to apply these terms to the minerals of a crystalline rock.

1. There are three critical epochs in the history of an igneous rock, viz.: the passage from the molten condition to the crystalline, *i. e.*, the solidification, the epoch of cooling subsequent to solidification when it is permeated by gases and suffers rapid metasomatic alteration, and the epoch of atmospheric weathering, Circumstances may be such in the environments of the rock mass that either one of these may be very long, and the changes produced very slow or very rapid. The last mentioned, however, is quite insignificant in Minnesota. Any sample of rock ordinarily procured in the field for examination will be found to pass below the weather effects unless those effects have been abnormally intensified. The glacial abrasion removed the weathering effects and left the surface fresh, and since the glacial epoch, in the northern part of the state at least, the alteration of the exposed minerals has been almost *nil.* It is only in exceptional conditions, such as the local weathering of pyrite or other sulphide, or the oxidation of some carbonate, such as siderite, that the minerals of the crystalline rocks can be seen to be affected by post-glacial decay. Pre-glacial decay is sometimes preserved, and, as will appear, even Archean decay, enters into the history of many rock masses.

Therefore, in so far as the alterations seen in the igneous rocks of Minnesota are able to be classified, they must fall within the two epochs first mentioned above, and they must be referred to the agencies that were then in action. The first epoch (the passage from the molten condition to the crystalline) is not an epoch of alteration which can be said to produce secondary minerals in any sense. There is, therefore, nothing left but the cooling epoch which can be invoked for the explanation of the occurrence of most of the secondary minerals in such rocks in the Keweenawan, viz., quartz, hornblende, orthoclase, chlorite, hematite, most of the zeolites, probably most of the apatite, bowlingite, most of the magnetite and all of the pyrite. In the Archean igneous rocks no secondary minerals coördinate with the foregoing in method or relative date of genesis are known. Considered only from the point of view of Keweenawan history, it can be seen at once that, in ordinary usage, petrographers would differ widely as to the secondary or original nature of many of the foregoing mentioned minerals. The basic magma might acquire acid elements, both before and during the stage of cooling, and the resulting minerals might date all along from the moment of initial solidification to the moment of complete cooling. Quartz, in particular, would be very facile under these forces, and it would be utterly impossible to say at what stage in the history of the consolidation and generation of the rock it took its place in the mass. Again, if the basic magma surrounded and incorporated fragments of acid rock, to what extent would the resulting minerals justly be called original, and to what extent secondary? Some of the included acid material would so penetrate some of the pre-existing minerals as to change them to others. Some basic plagioclases appear thus to have been converted into red feldspars which pass for oligoclase and orthoclase. Augite, under such circumstances, is converted to hornblende and to chlorite. Therefore, as to date and method of genesis there is no criterion to guide in the determination whether such minerals should be called primary or secondary. They are essential parts of a recognized rock mass and they are chemically more stable and enduring than some of the other minerals of the same mass which are recognized as original. The rock in which they exist sometimes is of large amount, and it may have been given specific name, a circumstance which requires that they be regarded as original, whatever their origin or date.

Whatever the uncertainty and confusion that may have attended the generation of these minerals, when considered from the view points of *original* and *secondary*, there seems to be one common element in which they share, and which might furnish them a classificatory designation, viz.: they are the product of mineralizing agents during the cooling stage of the rock.

In order to make plain the ideas of the writer, and not to disturb the prevalent practice of petrographers in the use of the term secondary, the following sketch of the successive dates of the minerals of the igneous rocks of the Keweenawan may be presented:

1. The primary minerals in these rocks are those of the first consolidation, usually porphyritic.

2. Those of the second consolidation, composing the mass of the rock not altered by gases incident to the cooling epoch.

3. Minerals produced after consolidation, during the process of cooling.*

4. The latest minerals formed, *i. e.*, those resulting from atmospheric agents after cooling, *i. e.*, the minerals resulting from atmospheric decay.

*Teall speaks briefly of the fact that the cooling period of an igneous rock must necessarily be one of long duration, but he does not make it, so far as noticed, the birth-date of any of its minerals.

M. M. Fouqué and Michel Lévy, though they make provision for two secondary stages of mineral generation (Minéralogie micrographic, 1879, pp. 151, 152), confine their exposition to primary and secondary stages of *consolidation*, without even giving a definition of the secondary processes, which are simply listed:

"3. Actions secondaires immédiates.

"4. Actions secondaires médiates."

5. Another class of minerals, which may have any date subsequent to those of No. 3 above, are due to dynamic metamorphism in presence of moisture.

The feldspars, labradorite and bytownite, would be *primary*, when porphyritic, also olivine, some apatite and some magnetite.

The most of the rock, including most of the feldspars, usually the augite, occasionally olivine and perhaps biotite, and basaltic hornblende, would come *second* in order, and in this scale would be secondary minerals.

Tertiary minerals would embrace most of the magnetite, the orthoclase, quartz, apatite (in large part), chlorite, bowlingite, epidote and any amphibole.

Quaternary minerals would be such as calcite, limonite, chlorite, sericite, quartz and perhaps some of the zeolites, and numerous others.

Minerals of the *fifth class* are allied in cause and in kind to those of class No. 3, and also embrace some of classes 1 and 2, since metamorphism may be partial or complete and may take place with or without great pressure. When under great pressure the history begins again *de novo* and the primary minerals are reproduced.

These steps in the history of mineral genesis in the crystalline rocks are natural and essential to be recognized. They include all that has been seen and recorded in the mass of special descriptions foregoing in this volume, and theoretically might be expanded so as to embrace all minerals; yet the descriptions have not usually taken these steps into account.

2. The acid igneous rocks, most of which are in the Archean, constitute a very different category as to origin, and necessarily all their minerals share, each with its own ontogenesis in the characteristics of that different history. It is here that the terms original and secondary are specially inapplicable, for in one sense the minerals are all secondary, and in another they are primary, while in another they would mostly fall into the fifth class above. As will be seen in the discussion of the rock masses as such, the Archean acid igneous rocks are traceable to an earlier clastic condition. In many cases the remains of those clastic grains are preserved, and in many others they are so regenerated that but little or no trace of them can be separately detected. They acquire new forms, larger sizes and different composition, in whole or in part. Whether the term original should be applied to the earliest clastic condition recognizable, or to the partly or wholly regenerated condition, or to the earlier non-clastic condition of the (later) clastic state of the separate grains, is a matter which each petrographer would have to decide arbitrarily for himself, and in deciding which he might differ from his fellows.

3. Many metamorphic rocks pass into truly igneous rocks—the gneisses to granites and diorytes, the muscovadyte to gabbro. If principles be adopted for the application of the terms original and secondary to the minerals, say of a gabbro

where usually no trace of an earlier state of the constituent minerals remains, those principles would hardly serve in the treatment of a muscovadyte in which the same minerals can be traced to prior states, nor to the still earlier condition where metamorphism has been so slight that the new minerals can hardly be found, but where a wholly uncrystalline condition pervades the basic debris.

These three difficulties have sometimes been obviated by the non-use of the terms, or by a special description or qualification. If a term could be agreed upon to designate the permanent minerals of an igneous rock which originated during the cooling state of the rock, its use would promote exact definition and be of service to petrographers.

Rareness of shearing and crushing phenomena. The writer has found little reason to ascribe the present condition of the Archean minerals to shearing and crushing subsequent to their formation. These dynamic features are comparatively rare. The shearing and pressure which acted in Archean time seem to have completed their task, and very largely promoted, if they did not provoke, the recrystallization which characterizes the Archean minerals. Such recrystallization completed, the minerals have subsequently, almost without exception, preserved their crystalline integrity to the present day. In their perfection the minerals of the Lower Keewatin went into the conglomerate of the base of the Upper Keewatin, and, aside from the decay incident to the long-continued exposure which the formation of that conglomerate implies, they have persisted till the present, and are identifiable as having come from the Lower Keewatin. Again, the whole Archean, including Upper and Lower Keewatin, was buried under the Taconic, and where the Taconic has been removed or penetrated by drills, the Archean minerals are as perfect, apparently, as when they were so buried. The gabbro and the diabases of the Keweenawan, as well as the rhyolytes and obsidians, when not locally subjected to abnormal conditions, are apparently as perfect in their crystalline and chemical conditions as they were at the moment they acquired their normal temperature.* Throughout all the body of the crystalline rocks, whether of the Archean or of the Taconic, there is little sign either of shearing, crushing, or of decay. The slumber of unchangeableness seems to have settled upon them, awaiting the advent of some great convulsion to start again their energies by imposing conditions of non-equilibrium.†

While stability and long endurance are the characters most easily legible in the oldest crystalline rocks, it is necessary to admit that the Archean rocks have undergone many changes, but those changes are in great measure but local and temporary effects of special conditions or exceptional forces. Belts of folding and

*In rock No. 176 glass still subsists.

†Such instances as rock No. 1011, which may be assumed to be an old Archean diabase, and which contains no quartz, though much altered, rather show that when quartz does enter a diabase it is due neither to age, nor to surface exposure, nor to normal decay (even with dynamic action), and may hence be attributed to that source which is directly suggested in many cases, viz., endomorphism from contact on acid clastics.

of metamorphism have crossed them. Epochs of intense pressure and of crushing have passed over them. These epochs of revolution have been the birth-dates of new minerals. Metamorphism has been carried to complete fusion and the resultant molten rock has solidified as from the molten interior of the earth. But when these revolutions had subsided and the crust had resumed its normal quiet the new minerals and mineral enlargements took on the profound quiet and permanence which have lasted to the present. The changing temperatures of the atmosphere and of the superficial portion of the rocky crust have no perceptible effect below a few feet, and since the Glacial epoch their effect at the immediate surface is very insignificant under ordinary conditions.

Therefore, as a general rule, the Archean minerals are permanent. The only evidence of shearing and crushing pressure that is widely observable consists in the greater or less epochal metamorphism and in the local complete fusion which they have suffered. It will appear that many rocks that have been regarded crushed and sheared crystalline rocks, are more probably sub-crystalline pressed and sheared clastic debris. Permanence rather than change is the normal condition of the Archean crystalline rocks.

(b) The Petrology of the Crystalline Rocks.

The most important petrological conclusions drawn from the examination of Minnesota crystalline rocks, detailed in the chapter devoted to microscopical descriptions, are three in number, viz.:

1. The origin of the Archean granite, etc.
2. The origin of the Taconic gabbro, etc.
3. The nature of the greensand that produced the iron ores of the Mesabi Iron range.

Nos. 1 and 2 have been substantially presented in Part I of this volume, and at this place it will be necessary only to supplement that discussion by some further facts and collateral observations. No. 3 is a result reached later, and has taken final shape only in the course of the review and revision incident to the publication of the volume, though attended by the examination of some fresh material.

1. The origin of the Archean granites, etc.

Under the term granite are here embraced all the igneous rocks of the Archean, including dioryte and excepting such gabbros and diabases as are plainly of later date than the Archean, and all other igneous rocks that are not of too basic a composition to be included under the term granite. Quartz-porphyry is also excepted for special treatment.

In the preliminary discussion of this subject, included in Part I of this volume, devoted to "Structural Geology," it is shown that all the structural phenomena of the Archean can be explained on the assumption that the intrusive rocks are metamorphosed conditions of the clastic rocks near adjacent to the observed intrusions, rendered plastic by the forces of dynamic metamorphism accompanied by moisture. As an illustration of this transformation of the Archean clastics some of the field phenomena of the region of Kekequabic lake were enumerated, and in connection therewith is a statement of some of the petrographic facts that accompany and confirm such transition.* The structural relations have also been described in vol. iv, of this report (chapter descriptive of Lake county), and hence it will be necessary here only to mention other petrological facts and inferences bearing on that subject.

1. *Gradations in crystalline structure from granite to graywacke.* It is evident that, while it might be very infrequent to observe petrographic transitions from crystalline to sub-crystalline and to fragmental, *in situ,* owing to the easily movable nature of the plastic or fluid rocks when under the pressure and shearing that produced the assumed plasticity, yet there ought to be found more readily all the varying stages of recrystallization, when the rocks are studied in detail from different localities. Such is the case. One of the most common instances in incipient recrystallization is seen in the graywackes. If the reader will consult the descriptions of the following rock numbers he will find some of the details of this progressive crystallization, viz.: Nos. 341, 2184, 2244, 2245, 2264, 2269, 383G, 386G, 407G, 8H, 389H.

General statements concerning the behavior of the different minerals concerned have been made in the foregoing notes on the rock-forming minerals. It is obvious that under such conditions of alteration and subsequent recrystallization it is impossible sometimes to affirm unqualifiedly that the clastic rock was a typical graywacke. It might have been somewhat pebbly, like a conglomerate, or too fine to bear the name of graywacke. It might have been porphyrel—or arkose; but the special designation of the clastic rock is not important in this connection. Whatever the correct appellation for the rock, the kind of change, tending toward a granitic structure, is the same in all the clastic rocks when they encounter these physical conditions.

2. *The same kind of alteration of quartzyte* is described in connection with the following rock numbers: Nos. 609, 784, 1724, 1839, 1840, 1852, 1853, 1854, 436H. In this series No. 1852 is specially interesting, because of the favorable exposure and the association of the recrystallized quartzyte (Animikie) with a black mica schist which was produced from the Animikie slates under the same forces. The following is from the writer's field book, July 5, 1893:

"1854. I have been on the lookout for evidence to show what becomes of the black slates when subjected to the influences which make quartz-porphyry and red granite of the quartzyte, and I have only found that they

*An earlier discussion of the same subject by the writer was presented to the American Association for the Advancement of Science, August, 1898, and published in the *American Geologist,* November, 1898, vol. xxii, pp. 299-310.

become dense and hard, with much jointing, but here, near the boiler house [Susie island], is a dike of diabase running east and west through the slates. This dike is only ten or twelve feet wide, and, alone, its effect would not be so pronounced, as numerous such dikes have been seen without such effect, but, when its force was united with the deeper-seated action which developed the red granite adjacent, it strongly affected the black slates. In some places the adjacent slates are not only hardened, but on weathering they turn grayish-red, or pinkish, indicating the generation of a red feldspar. In one angular projection, on which the heat of the dike may be supposed to have acted more effectively, there are seen developed some red orthoclase crystals, which are scattered through the dense matrix like those of a porphyry. This sample (No. 1854) shows it. This is a step toward showing that the black slates, although less amenable to the change, can be made to take the crystalline condition by contact with the heated traps, and that they also could be made to assume the condition of porphyry and even red granite."

In the formation of a granite from a quartzyte it appears that coarse feldspars (orthoclase) are first formed, embracing the adjacent quartz grains poikilitically. It is obvious that under such conditions only the most acid feldspar could form. Rejecting the surplus of silica, such silica is, perforce, remodeled, and, being an easily mobile element under pressure and in presence of heat and moisture, it takes the spaces left between the feldspars, and thus always appears latest to "solidify." This is in part illustrated by No. 784. The feldspars, however, were a little later to take crystalline outlines than some of the quartz, which sometimes appears in bipyramidal shape quite perfect before the clastic structure is lost (vol. iv, pp. 516, 517). Compare, also, Nos. 609, 611.

3. *The "porphyrel" of the Upper Keewatin* has been one of the most interesting and most studied of the initial rocks that pass into granite. It is specially described, in connection with this change, under the following: Nos. 1061, 1062, 1769, 2189, 2266, 2268, 551G; and in connection with all the rocks named esterellyte, for it is evident that the features of the transition may be studied at either extreme. The megascopic condition of the feldspars in some of the granitic aspects of this transition is illustrated by figure 8 of plate V, taken from No. 776G.

4. Some of the microscopic phases of this transition from *distinctly conglomeratic rock* are mentioned under the following: Nos. 2189, 2245, 2266; and from a siliceous green schist (tuff) under Nos. 1046, 1051, 1052, 1092, 1104.

5. *The transitions from granite to porphyry* are geographical and local, due to absence of "phenocrysts" rather than to any difference in the contents or crystalline condition of the rocks. Compare Nos. 1061, 1094, 776G–777aG.

6. *Granite formed from arkose* is represented by Nos. 344, 923, 994, 995, 2265, but generally has not been specially noted. Of the rocks along the Kawishiwi river Nos. 994 and 995 specially illustrate the consolidation of granitic debris under aqueo-igneous forces and pressure. It is accompanied by the transformation of all the quartz, the generation of epidote and hornblende, and the general granitization of all the rock. The feldspars, while probably saturated by new feldspathic elements, and considerably clouded, are so identically of the same shapes that they can easily be interpreted as old clastic grains.

Gneiss frequently passes into mica schist.

7. *Gneiss, which frequently passes into mica schist,* has the composition and microscopic character of igneous granite. It is frequently intersheeted with mica schist over wide areas with great regularity, such that there is no possible way of reasonably explaining it, other than to ascribe it to a sedimentary origin and hence an original clastic structure. The straight lines of this stratification sometimes continue visibly without much deviation for the distance of half a mile or more.

This regrowth of feldspars (and other minerals) has not always been interpreted in this way. When seen in a plainly clastic rock such marginal growths have been simply referred to as "enlargements," and when in a crystalline or igneous one, they have been considered either as secondary growths in the original magma prior to consolidation, as zonal increments after the partial resorption, or as renewals of feldspars after partial fusion by a basaltic contact. The indication that springs from our study, however, points to the essential sameness of these renewals, whether in clastic or crystalline rocks, and to the continuance of this manner of crystallization through all grades of development from the most faintly metamorphic clastic to the most perfectly recrystalline igneous.

At the same time, when such regenerated feldspars have been seen in granites, with the "kaolinic" impurities that cloud them driven to or toward their central areas, they have sometimes been supposed to be instances of grains centrally altered through weathering, or some other agency. But several reasons have been given in the previous portions of this chapter for discarding that idea (page 942). It might be stated further that the weathering of a feldspar crystal would begin at the surface and remove its alkaline bases (No. 25Wbis); it would not recrystallize them as silicates in the centre of the crystal. Again, this weather effect, if it be such, appertains to the rock masses at all depths, and is not attributable, in Minnesota, to weathering since the glacial epoch. It is reasonable to ascribe the decay to weathering in Archean time, followed by a powerful reconstructing force by which the alkaline elements once disengaged by weathering were forced into silicated combinations such as muscovite, hornblende and epidote.

As to the effect of dynamic agents, there is no question that they have had great influence in producing the regeneration—*per se,* they could have had no effect in causing the decay. They could not centralize the muscovite in the orthoclases without a profound molecular rearrangement, resulting, when carried to completion, in a re-formation of the whole rock. Such force could have promoted the formation of the secondary silicates (muscovite, epidote, etc.), but could not have separated the elements of those minerals from their former combinations. They might break the crystals, thus facilitating the access of destructive atmospheric agents. It requires, however, both dynamic force and moisture to carry forward the changes which the history of the Archean crystalline rocks shows they have experienced, when all their microscopic phenomena are collated and adjusted into a systematic scheme of interpretation.

Quartz-porphyry. There are two quartz-porphyries to which it is desired to direct attention, as they differ considerably, and are of widely different dates, and are perhaps worthy of separation in nomenclature. One is the oldest known acid rock and the other is the youngest acid eruptive of the Keweenawan. These rocks differ not only in age, but in physical and mineral characters. The former supplied many pebbles for the basal conglomerate of the Upper Keewatin.

The Archean porphyry (Nos. 2229, 2237) is light-colored, weathering whitish. It is mentioned in vol. xiv of this report, where its field appearances are described (pp. 276, 290–293). It exhibits several features of a clastic, at least a sedimentary, or chemico-sedimentary origin. It is not known to act as an intrusive on the older greenstones which lie alongside of it, but it furnished many fragments to the greenstone next younger than itself. (See plate Z, figures 1 and 2, vol. iv. The succession of rocks in order of age is shown by figure 39, page 292.) Its position is between a conglomerate made up exclusively of debris from the Kawishiwin greenstones, and a conglomerate composed largely of debris from itself.

The place of exact transition from the underlying (or southerly) greenstone conglomerate could not be found, but, throughout an interval of a few feet the porphyry along the contact became fine-grained and green, but spotted with rounded fragments of white and red jaspilitic quartz referable to the older greenstone. The transition belt, however, was seen embraced in a boulder, found in the immediate vicinity, which was so suggestive that a faithful drawing and description were taken on the spot (vol. iv, page 291). From the gradually changing characters, whether the greenstone conglomerate or the porphyry be considered, the contact of these two rocks certainly exhibits features that indicate a sedimentary transition. They approach each other in color and mingle with each other in grain, there being three or four larger alternations of the evident characters of both rocks before the transition is complete.

This porphyry also appears, in the field, to pass to a graywacke (No. 2232) and its microscopic characters coincide with that hypothesis. In one place quite plain fragmental structures were seen in the body of the rock (No. 2237), these structures being plainly a part of the rock itself and dying out in all directions.

As to composition, the rock is peculiar for an igneous quartz-porphyry. Its superficial extent, north and south, which is across its width, is about 2,000 feet. Its extent east and west is much greater, but is not known. On the supposition that this rock came from a deep-seated magma, its great amount was sufficient to allow a slow cooling and a gradual crystallization such as to form the granitic structure, but nowhere was a granitic structure observed in this mass, except where it had obviously been regenerated by a later dynamic epoch (No. 2239). Its feldspars are greatly decayed, same as those of graywackes (noted above) and are permeated by calcite, muscovite, epidote, etc. This decay cannot have taken place since the consolidation of the rock, since it is seen uniformly in the rock at all depths and is the same as that often noted in the feldspars of graywackes, and of granites and gneisses resulting from the recrystallization of acid debris (page 942). It is not at the centres of the feldspar grains, but is disseminated uniformly and is much greater than that of the more changeable older greenstones underlying (No. 2227).

The quartz "phenocrysts" are sometimes an inch in diameter, and are rounded, and are sparsely associated with other fragments, such as greenstone, fine slaty greenstone, and of jaspilyte.

The feldspar "phenocrysts" are not wholly of orthoclase, but many of them are of some plagioclase, a fact which is not in keeping with the idea of a great magmatic mass which would have attained a stable and identical composition such as would give origin, on cooling, to a single feldspar as first consolidation.

The rock does not consist wholly of the usual minerals of a quartz-porphyry, but embraces a little biotite, sphene and hornblende (No. 2229).

There is a very striking resemblance in the amount and kind of alteration of the Lower Keewatin quartz-porphyry (No. 2229) to the debris of the same. This is very noticeable at Vermilion lake, where the pebbles of the Stuntz conglomerate can hardly be distinguished in thin section from the finer debris in which they lie. It is an indication that the elements of the oldest quartz-porphyry had already suffered a period of exposure and alteration analogous to that suffered by the debris of the Stuntz conglomerate. It was often remarked that the general aspect, aside from a difference of schistosity, of the thin sections of the original porphyry was so closely like that of those taken from the matrix of the conglomerate, that they could with difficulty be distinguished. There is, indeed, so far as known, no such thing as a fresh quartz-porphyry in the Archean. There is much fresh granite and dioryte and allied coarsely crystalline rock, but, in the quartz-porphyry referred to, the orthoclase, so far as observed, is much altered and crowded with sericites. These alteration products are uniformly distributed in the orthoclases except where the rock has been metamorphosed; then they are grouped centrally in the manner described for the orthoclase of granite.

In order to adjust the foregoing facts with others that show that this rock originated under the action of some great force which was widespread and probably of long duration, the hypothesis was entertained that this rock was due to oceanic sedimentation accompanied by chemical precipitation in Archean time. Its being preceded by a greenstone conglomerate* and followed by another conglomerate (No. 2230; also, plate Z, vol. iv) places it in the midst of rocks of fragmental origin. Its feldspars and quartzes may have been derived by crystallization from an alkaline and siliceous mud of great thickness, the same mud embracing more or less of the regular detritus from the pre-existing Kawishiwin greenstone and jaspilyte. This alkaline mud, following immediately after the primeval greenstones which are supposed to represent the first crust of the earth, was deposited in a hot ocean. It may be supposed that, up to this epoch, the crust had been too hot to allow the condensation of potassium from the surrounding atmosphere, as no potassium exists in the oldest greenstones, nor in the greenstone conglomerate mentioned; and that, cotemporary with the precipitation of potassium into the ocean, was its increased siliceous content of silica, and, later, the copious precipitation of both, the former in a silicated state.

The partial resorption of the phenocrysts of feldspar, the mingling of orthoclase with plagioclase, the fineness of the surrounding matrix, the greatly decayed state of the feldspars, the bipyramidal forms of the quartz, most of these characters usually accepted to indicate igneous origin of the rock showing them, may thus be explained in conjunction with the existence of other features that are usually interpreted as of clastic origin.†

Notwithstanding these facts and inferences, it is necessary to hold the oceanic origin of this quartz-porphyry as only hypothetical until further field examination can be made.

In numerous instances a porphyry which is somewhat granitic, but containing porphyritic quartzes, has been noted cutting the upper part of the Lower Keewatin, as at Ely (Nos. 2095, 2096), and at Vermilion lake (Nos. 2275, 2276), and occasionally the Upper Keewatin, as at Snowbank and Kekequabic lakes. Such "quartz-porphyries" are susceptible of two explanations as to origin, viz.: (1) A compacting and recrystallization of a clastic rock embracing many fragmentary crystals of feldspar and of quartz (Nos. 1062, 2184, 2187, 2189); (2) A transformation, through folding and fracture, of the old quartz-porphyry of the Lower Keewatin (Nos. 2229, 2237), and the production, in that way, of dikes in the later rocks.

The other quartz-porphyry has an origin less doubtful. It constitutes one of the forms of the "red rocks" of the Keweenawan. This is a class of rocks which the writer, following J. C. Norwood, in 1878 and 1879 in several publications showed was derived, as a group, from metamorphic action of the igneous traps on the clastic

*Of this rock, at this place, no sample was taken, but it is represented by rocks Nos. 532H and 626E.

†NOTE. Prof. W. O. Crosby has suggested a deep-sea origin for the red petrosiliceous rocks, comparing them with the jaspilytes of the Lake Superior region. *Proceedings of the Boston Society of Natural History*, vol. xx, March, 1879.

rocks of the Animikie. Later, Prof. W. S. Bayley made an exhaustive study of the field relations and of the petrology of the region of Pigeon point, and although his first opinion was adverse to that view,* he finally adopted it in full.† He arrived at the conclusion that the igneous quartz-porphyry of Pigeon point is derived from the fusion of the acid clastics, and gives diagrams in which the porphyry intrudes upon the quartzyte from which it is derived. He also shows that the same quartz-porphyry in the same vicinity takes the form of quartz-keratophyre and red granite. This view has already been presented for the origination of the granites of the Archean (above) where the same transitions are manifest on a grand scale.

Several rocks have been described from Pigeon point which illustrate the manner in which the sedimentary rocks are converted to quartz-porphyry. It is found that quartz is one of the first to be affected by metamorphism. It acquires a bipyramidal shape (No. 264) and that almost cotemporaneously orthoclase crystals form, the latter surrounding several clastic quartz grains in a poikilitic manner (No. 1842). Very soon all the quartz that remains is wholly recrystallized, much of it apparently being removed in alkaline solution. More or less biotite and hornblende appear, also nearly all the usual secondary minerals, which, however, here would be called original under the prevalent usage, and in the classification given on page 969 would fall into the fifth class.

There should be recorded here, perhaps, two or three caveats respecting some of the acid igneous rocks, viz.: 1. It is not sufficiently known what is the source of some of the "red rocks" and "augite syenytes" of the Keweenawan. Some of them may come from deeper sources than the Animikie, even from the Archean, although of the date of the Taconic. If they came from some deeper source they would be necessarily dependent on the Archean clastic rocks (perhaps also on some of the Archean igneous rocks) for their chemical composition. 2. It is not yet known how much of the "red rock" series, such as that of the Misquah hills, may be due to a reaction of the acid rocks on the basic of the Keweenawan. A widespread and apparently rather profound endomorphism has affected some of the larger masses of the basic Keweenawan, giving the impression of a later infusion of acid elements. These questions must be left for future students to investigate, but it appears to the writer that such silicified basic igneous rocks may owe their alteration to the fact of submarine extrusion and to the oceanic precipitation of silica which would accompany such conditions.

2. *The origin of the gabbro and its derivatives.*

It was after a conviction had been reached as to the origin of the Archean granites that careful investigation revealed a similar train of evidence leading to the

**American Journal of Science*, 1889, vol. 37, p. 57.

†*Bulletin cix, U. S. Geol. Survey*, 1893.

same origin for the gabbro of the Keweenawan and all its derivatives, viz., that the basic Keweenawan is derived from the metamorphism and complete refusion of the Archean greenstones and their attendants.

The lines of evidence leading to this result are three:

1. Structural field relations.
2. Petrographic and petrologic.
3. General considerations.

The term gabbro as here employed covers all the varieties into which gabbro has been divided, viz.: orthoclase gabbro, quartz gabbro, hornblende gabbro, hypersthene gabbro, olivine gabbro, gabbro diabase, gabbro dioryte; also noryte and its variations, including muscovadyte and its varieties; also peridotyte and pyroxenyte, troctolyte, diabase and diabase porphyryte, and all the basic igneous rocks that have been discovered in the northeastern part of the state, excepting only the Archean greenstones. A rock consisting only of plagioclase and diallage, which are the minerals required to form a normal gabbro, has but rarely been found. From necessity, in the descriptions of Part II the term gabbro has been employed in a broad sense, and sometimes without precise definition. There is no character nor group of characters which can be relied on for persistence to precisely define this term, for the characters mingle confusedly as to structure as well as to mineral composition, if not in the same slide at least in the same visible rock mass, and if not in the same visible rock-mass, in the same general terrane or mountain mass. Over a certain area, or little hill, a group of petrographic characters may prevail. In the adjoining hill or on the slopes of the same hill, some of those characters are replaced by other characters, and on the third hill a slightly different change is noticed. On the basis of such variations a diversified nomenclature has arisen. Yet the great rock mass, extending for over a hundred miles in Minnesota, bearing the same taxonomic relations to adjoining rocks, must be considered as one geological entity, having one origin and one history.

There are some isolated areas of gabbro wholly detached from this mass, occurring in the midst of Archean rocks which may not be of the same date as the gabbro mass here referred to. Such are found at Little Falls, in Morrison county, at Knife lake on the international boundary and near Philbrook, in Morrison county. The diabases that compose the bulk of the effusive Keweenawan are considered as extreme derivatives of this gabbro mass; still, one of those diabases and some of the largest of the sills in the Animikie exhibit several gabbroid characters, and at Duluth the Beaver Bay diabase has uniformly been called gabbro.

There are at least three ways in which a normal basic igneous rock may have been modified by the conditions of extrusion, and some of the intermediate rocks above mentioned may have one and some another of these methods of derivation, independently of an intermediate acid state of the greenstones from which they were derived.

1. Complete fusion of contacting acid rocks and the perfect mutual transfusion and molten mixture of the two kinds into a homogeneous magma.

2. The penetration of the acid element into the basic along contacting zones through the agency of mineralizers, during the period of cooling.

3. Submarine extrusion, attended by oceanic precipitation of silica.

Some of the massive quartz-gabbro and augite syenytes appear to have had the first mentioned method of origin.

To the second method may be assigned those that show the micro-pegmatitic structure, and the uralitic state of augite, with chlorite and a reddened state of much of the feldspar.

The third class would include much of the "red rocks." When such basic extrusions were in great amount and were able to crystallize before modification, the resultant rock may have been such as seen in the Misquah hills. When the extrusions were in small amount, and were solidified before crystallizing, the glassy mass was wholly silicified. Thus resulted jaspilyte and probably much of the apobsidians of the Keweenawan.

1. *Structural field relations.* In repeated instances the recognized gabbro mass has been seen to grade into noryte, which (in its normal and usual type) is one of the forms of muscovadyte, the latter term being more flexible and general. This fact is attested by many observers, whether in Minnesota or in Canada, and need not be dwelt on to any length. Yet this noryte has no more stable composition and characters than gabbro, when considered as a rock mass, and in some of its variations it loses its right to the name noryte, and the rock has been given other designations. If the structural relations of noryte to the coarser gabbro be examined it will be found that the transition is both gradual and sudden. The gradual transition is that which has been most frequently observed (Nos. 983, 984), but there are many places along the northern border of the normal gabbro mass where the coarser gabbro rock exhibits a non-conformable contact on noryte masses, *i. e.*, on what have been denominated muscovadyte masses. There is a figure in volume iv (page 303) which illustrates this fact, although, in that instance, the included masses are not typical noryte, but approach a granulitic gabbro. At the time the sketch was made* no specimens were collected at this point, but later specimens (No. 847G) were obtained from the angular included mass by Dr. Grant, who makes the following remark:†

*By DR. A. WINCHELL. See *Fifteenth Annual Report*, p. 172.

† *Twenty-Fourth Annual Report*, p. 127.

"The shores of the island in N. W. ¼ sec. 6, T. 64-5 W. [*i. e.*, in Gabemichigama lake] are of coarse gabbro, except for the southern shore, which is composed of fine-grained, granular Keewatin rock, not stratified as far as seen. In one place the gabbro was seen within ten feet of this rock, and the former still retained its coarse grain. At the southwest corner of the island is the locality figured several years ago. The fragments included in the gabbro show no distinct stratification lines. The gabbro is still of coarse grain, even when in small stringers. The included fragments, represented by No. 847G (which also well represents this rock all along the southern shore of this island), are of various shapes and sizes, and many have rounded outlines."

The granulitic structure of the rock in these angular fragments is a "peripheral phase," so called, of the gabbro. This shows that that phase is not dependent on the peripheral action of the gabbro mass, as has been presumed. Again, rock No. 2001, a diabase dike, though having been shattered by contact (evidently) on the walls of a fissure, has a distinct angularity in its minerals, indicating that such friction was not the cause of the fineness and roundness of the grains in muscovadyte and noryte.

The same is indicated by rock No. 8M, which is a finely granular mica schist, produced by metamorphism of the Animikie. It has never been in a fluid state, but shows a similar granular structure, and outwardly resembles some muscovadyte.

At the south shore of Disappointment lake are many obvious transitions from the coarser gabbro to the finer. In some cases the finer rock might be called noryte, or granular gabbro, containing considerable orthorhombic pyroxene (Nos. 2201, 2202, 2203). These transitions are both gradual and abrupt. The rocks are favorably exposed and can be seen for many rods without much hindrance. On a single knob of rock five feet across, standing a little isolated from the main gabbro mass, can be seen on one side a well-developed coarse gabbro, embracing indistinct pebbly forms in smothered outline. Passing gradually across the front of the knob the grain can be seen to grow gradually finer, till, at the opposite side, the rock is quite different, and could be called granulitic gabbro, and embraces distinct pebbly forms. In the field, however, in this instance, this was called pebbly muscovadyte.

The foregoing is probably sufficient to show that in the field the coarse gabbro and the granulitic gabbro (or noryte, when hypersthene is abundant) pass into each other by insensible gradations.

It would now be in order to show that the muscovadyte becomes, when less alteration has taken place, the clastic greenstones of the Keewatin. This is easily ascertained by examining the greenstone belt about Gabemichigama lake and eastward to Flying Cloud lake. One may follow the greenstone eastward from the former lake by a series of small lakes and portages. It forms a conspicuous hill range which, eastward still further, merges into the Giant's range, and westward it culminates in the Twin peaks, south of Ogishke Muncie lake. The route gradually approaches the northern limit of the gabbro, which here has a more northward trend. Finally, making a more careful examination of this greenstone belt, one finds it presents a decided approach toward muscovadyte (Nos. 1778, 1780, 1781) and really becomes the muscovadyte of the region, the change being very evident on following the greenstone eastward till it comes into contact with the gabbro. A similar transition takes place at the northeastward extremities of the narrow lakes through which the Kawishiwi river flows, sections 15 and 16, T. 63-9 W. (Nos. 982, 983, 984), and also in the greenstone hills northward from Chub lake. Indeed it would be entirely correct and safe to state that it takes place wherever the gabbro in its recognized form comes onto or near the Keewatin greenstone.

Again, in some instances, the greenstone is conglomeratic, the pebbles being of different phases of greenstone, of granite and of slate. In such cases, where the original rock is basic enough, the complete transition is easily traceable through muscovadite to the normal gabbro, the pebbly forms being visible in all the rocks. This is notably the case at the point often referred to south of Disappointment lake, described in more detail in volume iv, page 303. Note, also, the pebbly aspect of the granulitic gabbro shown in plate MM, figs. 5 and 6, vol. iv. "This is a remarkable rock, as it resembles muscovadyte, which we suppose to be the result of a change in sedimentary rocks; it is a remarkable circumstance, also, that so far south within the gabbro area so much of this rock is found. It is heavily jointed, lies nearly horizontal and slides in sheets into the lake, toward the southeast, the sheets being from one-half inch to six inches thick. Small nodules weather out on the surfaces, and some larger, harder patches also appear, resembling some seen in the changed graywackes on Gabemichigama lake. This rock prevails about the shores of Muscovado lake, on the shores of the north half of Bashitanaqueb lake, and just north of the latter it forms some high hills."* This is rock Nos. 1784 and 1785. It is evident that here is a large area of the original greenstone, well within the gabbro, which has not suffered a complete conversion to typical gabbro, and that the original greenstone was conglomeratic and similar to that at Disappointment lake.

2. *Petrographic and petrologic.* The petrographic facts have been for the most part enumerated in an earlier part of this chapter in connection with the description of the minerals that compose these rocks. There is nothing more evident in reading the special descriptions of the rocks referred to in Part II, than the "air of family" that binds the gabbro, the muscovadyte, the noryte, or granulitic gabbro, in one genetic class. The ophitic structure of diabase is found to occur in the same rock in conjunction with the granulitic. Sometimes, in the granulitic gabbro, or muscovadyte, the pyroxene is simple augite and sometimes diallage. Frequently hypersthene is abundant and sometimes it is wanting. Sometimes hypersthene is twinned with a monoclinic pyroxene and sometimes it poikilitically embraces labradorite, quartz and globular hypersthenes. Olivine, and even magnetite (No. 695) and biotite sometimes prevail over all the other minerals, in the last making a mica

*N. H. Winchell. *Twenty-first Annual Report*, p. 160.

schist or biotite gneiss (Fifteenth Annual Report, p. 351, and rock No. 983). In all cases, even when a normal gabbro has resulted, the different minerals have a roundish habit, as if cotemporaneously developed. The ophitic structure prevails in those cases where there was a late consolidation or a second generation of augite, and this occurs especially in those masses that have moved more or less from their birthplaces, *i. e.*, in the diabases.

There is no single petrographic character that is unique in its mode or geographic place of occurrence within the whole zone, ranging from partially metamorphosed clastic greenstone to typical gabbro, and even to diabase; but the mineralogic composition varies according to some unknown law, or no law, and the contrasting structures often blend in one rock or are associated with minerals which usually are considered divorced from them. This singular rock, or series of rocks, included under the term muscovadyte,* seems to be explicable only on the hypothesis that a variable clastic, though comparatively basic in composition, was subjected to a variable metamorphosing force, the resultant rock being determined by the depth at which the force was applied, the amount of pressure and moisture, the degree of heat and the proportionate amounts of the chemical elements available from place to place for the production of the minerals which now are found in the rock. If at any place any of the oldest (originally massive) greenstones were involved in this metamorphism and refusion, it is probable that the resultant rock would be some of the more basic phases of the general gabbro mass.

In addition to the foregoing general statements as to the confused petrographic characters of the petrologic zone intervening between the Archean greenstones and the Taconic gabbro, there is need perhaps of some specific, recognizable case to which all geologists can be referred tending both to centralize the argument and to elucidate the diversified phenomena. Only referring, here, to the statements made in volume iv, pages 303, 304, respecting the transition studied at Disappointment lake, more direct attention will be called to rock No. 847G, already referred to.† This came from a definite locality and from a rock which has definite relations to a coarse gabbro. It is from the angular masses represented as embraced non-conformably by gabbro in the figure below (figure 56). This figure was drawn from nature by Dr. A. Winchell in 1886, at Gabemichigama lake. The structural relations are described by Dr. Grant, and have already been quoted (page 982). By both this rock was styled muscovadyte, and by the writer it has been described as muscovadyte (page 905), from two sections that have been examined. In the first section it appeared as an ophitic (diabasic) rock. In the second, along with but imperfect

*Two interesting extremes of the family of metamorphic rocks derived from the clastic greenstones are represented by Nos. 399H and 406H.

†The same structural evidence is presented by rocks Nos. 1287 and 1289, at Mayhew lake, the former being a granulitic gabbro unconformable below coarse gabbro.

ophitic structure it has the evident granular condition of muscovadyte. But, so far as the second section shows (it is a larger one), the contained minerals are almost exclusively labradorite and diallage, making the rock a normal and typical gabbro.

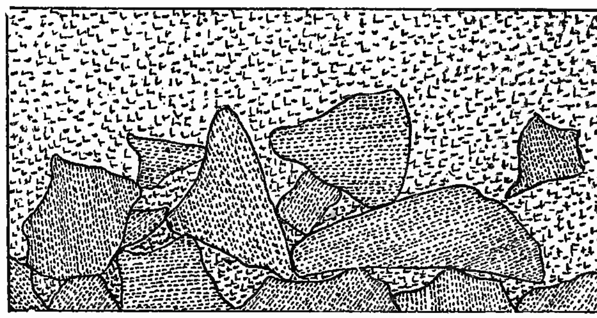

FIG. 56. GABBRO ON "MUSCOVADO" FRAGMENTS.

When it is understood that this rock at this locality is recognized as a part of the metamorphosed Keewatin of the region, and is seen in great amount along the shore of the island, and widely on the mainland, where (as has already been stated) it is traceable directly into the greenstones, it seems to afford unimpeachable testimony, concise and direct, of the change from the greenstones to the gabbro. The facts of nonconformity and intrusive action are only accidents of an epoch of general metamorphism and refusion, and hence do not necessarily separate the intruded rock from the intrusive by any break in genetic relationship.

3. *General considerations.* If these rocks be not thus genetically united, and derived from the Keewatin, there is no possible way known to account for their variations. They include not only the basic rocks that are distinctively greenstone or diabase and gabbro, but more acid phases. Quartz occurs in the gabbro sporadically, likewise orthoclase. In some places hornblende replaces augite, etc., etc. The names that have been given to these and other variations are numerous (see the discussion in Part I), but these various rocks, both geographically and petrographically, shade into each other and into normal gabbro. In order to explain these shades of variation on the hypothesis of differentiation from an intermediate or other primordial magma the different stages of change must have been lost in each other, and, furthermore, they must be allowed to have been cotemporary in the same magma and in opposite directions. This would require such uniformity, and at the same time such variety of primordial magmatic conditions in the same magma that the idea becomes self-contradictory and impossible of rational application. If these variations be supposed to be due to separate intrusion after progressive differentiation had supplied different types of rock for such a result, then those types would not, at the surfaces blend into each other, but one would intrude into the other and show a sharp contrast or contact with it. The general trend of all the facts, both petro-

graphic and structural, when apprehended after long field examination and exhaustive microscopical study, is toward a unity of origin, as to manner and date, of all these variations.

The intermediate rocks. The question may arise—what was the source of the intermediate crystalline rocks? Granite is at one end of the scale and gabbro and diabase at the other. It is true that these extremes have been most studied, both in the field and in the laboratory, and that the foregoing discussion applies essentially only to them. That was necessary. The prime types must first be explained on some rational hypothesis, and the intermediate rocks and all other attendant facts must be assumed to group themselves in some way in rational dependence on them. That seems to be the case. The intermediate rock types, both in the Archean and in the Taconic, blend into the end types. There is no abrupt distinction except locally, and everywhere vanishing distinctions.

If we may judge of the Archean rock terranes before metamorphism by what we see of the Archean now unmetamorphosed, the original rocks consisted primarily of very acid and very basic. There were graywackes (and slates) and greenstones. But there were also basic variations in the graywackes as well as siliceous gradations in the greenstones. Proportionately these geographic belts of transition were of minor importance. The change from a basic clastic rock to an acid one must have taken place somewhat as it does now in the Archean sedimentaries, rather rapidly, and the clastic rocks of intermediate character must have been as rare as they appear to be to-day. Hence, it is reasonable to suppose that, on metamorphism such as presumed above, the resultant igneous rocks would be prevailingly either acid or basic, but that in places there would appear smaller amounts of intermediate igneous rocks.

Consequences of this hypothesis, if true. One of the first and most obvious results springing from this discovery of the origin of Archean igneous rocks, whether acid or basic, is the non-applicability of the theory of differentiation of magmas. Whatever may be the case in other parts of the world, where igneous rocks have been examined from that point of view, there is certainly no standing room for its use in the Archean and Taconic of Minnesota.

Another result of this hypothesis, if true, is to lessen the value of chemical analysis of igneous rocks. Great variations can be found within the muscovadyte belt, running from peridotyte and pyroxenyte to quartzyte and to magnetyte. All these variations can be referred to the varied composition of the original Keewatin.

It also has a bearing on the origin of all the later igneous rocks. The universal greenstone crust would at any epoch in geological history furnish a diabase or a gabbro, should it be affected by such dynamic or other agents as to produce fluidity, and such resultant rock would be uniformly of about the same normal character as the Archean or Taconic diabases. On the other hand all later granites would show great initial variations. If they originate from the Archean they must show alliance with the Archean granites, and with their variations. If paleozoic sediments be fused, or even later rocks, great departures would ensue from the types of Archean granites, and these variations would be emphasized by the greater susceptibility of acid rocks to endomorphism, combined with their greater viscosity. The alkalino-acid element is easily transfused either into (No. 552) or from (Nos. 1B, 5, 648) a molten rock. The ferro-magnesian magma is chemically more stable in contact on acid rocks, but as a molten mass it is more fluid.

The so-called "peripheral phases" of the gabbro are peripheral only by accident. They might occur, and do, at other places in the great mass. The granulitic structure occurs about Muscovado lake, well within the gabbro. The concentration of iron is well known in the coarsely crystalline gabbro, making large deposits. The ferro-magnesian phase in the form of highly magnetited gabbro is the common feature at Mayhew lake and at Frazer lake (No. 1041), while olivine (fayalite) and magnetite sometimes compose important masses (Nos. 1336, 1343). These "phases" have been much noted and studied, but they seem to be phases both of the Keewatin greenstone and of the Taconic gabbro, representing an intermediate state of recrystallization.

The Oldest Known Rocks.

In Part I of this volume it is stated that the oldest rocks of the state are the Keewatin greenstones of the Kawishiwin, and in the preface is a diagrammatic scheme of the structural relations of the Archean as presented in this report.

It is only within a few years that American geologists have entered seriously upon the attempt to subdivide the rocks of the Archean upon a chronological scale. Mr. A. C. Lawson divided the sedimentary Archean of the Rainy Lake region into Coutchiching and Keewatin, the same year in which the writer divided it into Vermilion and Keewatin. In each case it was recognized that there was a later granite which is intruded into these rocks, and Mr. Lawson dwelt on the importance and the significance of this later intrusion. He showed that, either as massive granite or granite-gneiss, this later rock spreads over very extensive areas, and constitutes a large part of the mass which, under the term Lower Laurentian, embraces both metamorphosed sediments and intrusive granite. He restricted the term Laurentian, however, to this igneous rock which, while younger by reason of intrusion, yet structurally in many places lies below the sedimentary rocks of the Archean. The sedimentary division of the Archean was by Lawson designated Ontarian, this term covering both Coutchiching and Keewatin. The earlier division of the "Laurentian," by the Canadian geologists, into Lower and Upper, according to recent researches by Adams, seems to be invalidated, since the Upper Laurentian is found to consist principally of intrusives, such as anorthosyte and other gabbros. However, Logan's separation of the Lower Laurentian into Grenville series and Ottawa gneiss is a distinction which in literature has been maintained. The supposed lower portion, the Ottawa gneiss, is mainly igneous, according to Adams, and the Grenville series is mainly of sedimentary origin.

In the Rainy Lake region Lawson, in the same way, considers the "Laurentian" which invades the Coutchiching and Keewatin, as igneous, and as belonging normally below the Ontarian or sedimentary series. If, however, a careful examination be made into the nature and structure of the Keewatin of Dr. Lawson, it will be found, notwithstanding the apparent parallelism of the succession of the Ottawa region with that of Rainy lake, there is a notable disagreement in structure and succession. As described by Lawson the Keewatin consists of two parts, viz., at the bottom are basic rocks, diabase and hornblende schists. These are followed upward by more acid rocks, but without a distinct line of separation. The whole series is supposed by him to have been primarily of volcanic origin, the nature of the ejecta having changed from basic to acid. This volcanic series he believes is nonconformable upon the Coutchiching which consists of mica schists derived plainly from clastic materials by recrystallization, having a thickness of 22,000 to 28,000 feet. As evidence of this nonconformity he refers to a conglomerate which is nonconformable upon the Coutchiching and lies, as he supposed, at the bottom of the Keewatin. This nonconformity we never could find in Minnesota, but everywhere the Keewatin rocks pass gradually into mica schists. It is therefore a matter of considerable interest that Mr. A. P. Coleman has recently shown that the very conglomerate to which Lawson appealed contains much Keewatin material of older date, and that hence the horizon of the conglomerate is high up in the Keewatin itself.* It is to be noticed therefore, by the removal of this nonconformity above the mica schists, that the lowest known portion of the Keewatin consists, both in the Rainy Lake region and in Minnesota, of what in the Lake Superior region generally has been called *greenstones*.

According to Lawson, and also according to all observations made on this horizon in Minnesota, these greenstones are overlain by a series of volcanic detrital rocks of great thickness, and it is these volcanic detrital rocks, with their variations to true clastic sediments, which, in Minnesota, are extensively converted into gneisses and mica schists by metamorphism. They are parts of the Lower Keewatin. Putting these facts together, it is necessary to come to the conclusion that the mica

***Report of the Bureau of Mines* (Ontario) for 1897. Toronto, 1898, Part II, p. 153.

schists are later than the greenstones rather than earlier, structurally as well as petrographically, *i. e.*, that some portions of the Keewatin are metamorphosed. If the Rainy Lake succession can be adjusted with that of Minnesota, the order will be something as follows:

At the bottom is a greenstone, sometimes massive and igneous, but frequently passing into an agglomeratic condition, with which are associated various other fragmental strata, mainly "greenstone conglomerates," jaspilyte, greenwackes, but also slates and fine graywackes.

The first appearance of acid rock is in the form of a quartz-porphyry (No. 2229) immediately following or in the midst of the fragmental part of this greenstone.

In some places the clastic portion associated with the quartz-poryhyry reaches a great thickness (perhaps 20,000 feet), and by a gradual increase of acid materials through erosion of the quartz-porphyry, as well as by chemical precipitation from the ocean, it acquired a decidedly acid character. A metamorphic revolution accompanied by the production of granite and other crystalline rocks terminated this part of the Keewatin.

There accumulated then a great conglomerate which we have taken as the base of the Upper Keewatin, and which is presumably the equivalent of that described by Lawson and Coleman in the Rainy Lake district. This conglomerate lies sometimes on the earlier granite, and sometimes on the greenstones. Although it would be necessary to infer that it also lies on the strata intervening between the granite and the greenstones, whether they were metamorphosed or not, we have rarely seen it so superimposed, but from the facts stated by Lawson it appears that at Rainy lake it lies on the mica schists (Coutchiching) produced by the metamorphism of those strata. In Minnesota this conglomerate has been called at one locality Stuntz conglomerate, and at another Ogishke conglomerate, before it was sufficiently shown that it is at the same horizon at both places.

This conglomerate is variously mingled with greenstone debris where it lies upon the above mentioned greenstones of the Lower Keewatin, and by the gradual loss of the conglomeratic composition it becomes a clastic greenstone, and as such it acquires great thickness. It appears to have been augmented also by volcanic materials and by further chemical precipitation. In other places the conglomeratic composition is followed by great thicknesses of graywackes and slates. This epoch of the Keewatin was closed by another grand onset of metamorphism and igneous intrusion, which was followed by the Animikie.

Lastly, what the exact manner of transition was to the Animikie is not known, but the Animikie seems to have a basal conglomerate along the southern slopes of the Giant's range; volcanic action was resumed and was widespread at the opening of the Animikie.

While, therefore, in the region northwest of lake Superior we have in the Archean an enormous amount of acid igneous rock, as in Canada, it is found to be of at least two epochs, and in each case to be the cause of, or at least cotemporary with, a profound and extensive metamorphism of the earlier acid clastic rocks. It is not chronologically a part of those clastics, but as a rock mass it is later.

It is to be noticed that there are three epochs of greenstone, viz.: (1) The igneous basal mass which is believed to be the representative of the first crust of the earth. (2) The agglomeratic and fragmental greenstone which preceded and accompanied the first quartz-porphyry. This contains the jaspilyte iron ores at Town. Volcanic action added largely to this greenstone. (3) The greenstone of the Upper Keewatin. This is usually distinctly clastic, and is also in some part of volcanic ejecta.

The writer has elsewhere shown* that, as a mass, these greenstones are predominantly of fragmental structure and of volcanic origin, but also embrace truly massive rocks. The term Kawishiwin, used by the Minnesota Survey, embraces the first two above, being those of the Lower Keewatin.

3. *The nature of the greensand that produced the iron ores of the Mesabi Iron range.* It has already been stated that the original greensand of the Mesabi Iron range, the source of the hematite now extensively wrought in northern Minnesota, was probably not derived from organic agencies. It was the suggestion of Dr. J. E. Wolff, adopted by Mr. Spurr, that this substance is glauconite and hence might have been the product of foraminiferal organisms (Bulletin x) and that suggestion has generally been accepted, at least by the officers of the Minnesota Survey. It was through the careful inductive research of Mr. Spurr that the ultimate source of the ore was found in this greensand.

In the course of the microscopical work embodied in this volume several discoveries have been made which, at first disregarded or otherwise explained, have led to the abandonment of the idea that foraminiferal organisms were responsible for the greensand. When these new facts are adjusted with others that were known before, but which, appearing anomalous, were disregarded or otherwise explained, the greensand appears to have resulted from a volcanic sand, and the taconyte rock itself, both the granular and the massive, from igneous forces.

This conclusion is as much a surprise to the writer as it can be to any one, since he has formerly considered the origination of the hematite of the Mesabi range definitively traced to an organic origin.

Attention may first be directed to some facts, in part mentioned by Mr. Spurr, which unite with others since noted, to compel to the new view.

* *The origin of the Archean Greenstones, Twenty-third Annual Report, Minnesota Survey*, pp. 4-35, 1894.

Anomalous megascopic facts. 1. The iron-bearing rock is, as a whole, non-clastic in its present condition. It is only by inference that it can be said ever to have been clastic. This applies more forcibly to the rock known as non-productive taconyte than to the rich ore lenses, for there is in the ore bodies an overspreading, general, bedded structure which indicates sedimentation, especially in the granular portions. Both above and below the iron-bearing member are plainly clastic rocks, and occasionally some clastic grains are seen near the upper and lower surfaces of the iron-bearing rocks. These facts indicate the general prevalence of detrital agencies. It leaves room only for the inference that the iron-bearing rock itself was of a peculiar composition.

2. The unproductive iron-bearing rocks are divisible into two kinds, viz.: (1) A massive homogeneous, but rudely sheeted or bedded, gray or brownish-gray, fine-grained rock (Nos. 1688, 1692), in which appears very little or none of the characteristic globular or any other fragmental structure; and (2) The rock which is distinctly granular with colored or limpid round globules, one of the characteristic structures of taconyte (No. 852B). There are intermediate structures, apparently, and the globular forms, or others resembling them, occasionally are seen in No. 1. The globular form constitutes, when the iron is fully developed, the bulk of the "soft ores" of the western part of the Mesabi range. No. 1 prevails at the eastern end of the Mesabi range, where it also varies to a jaspilyte.

3. There is a marked basaltic, columnar structure which has been fully described by Mr. Spurr in Bulletin x, pp. 164–167 (Nos. 64S, 65S). His description in all respects, except as to his assignment of cause, could be applied to numerous basaltic obsidians or lavas. He says: "The typical jointing of the iron-bearing rocks has all of these characteristics," *i. e.*, the characteristics of the basaltic jointing of "igneous rocks of an effusive or intrusive nature." An instance of this columnar structure was noted at Prairie River falls in 1889 by the writer, and three of the specimens collected there by him (No. 1527) are shown, from photograph, on plate IV, figure 1. The columnar structure involves both globular-granular and non-globular forms of the taconyte.* The order of parts from Nos. 1530 to 1525, in descending order, when interpreted in the light of the latest developments, is as follows:

No. 1530. A coarse, evidently fragmental, rusty, siliceous, somewhat vesicular rock. The five samples of this rock collected, and now in the museum of the University, consist of globular taconyte, but with some spreading, irregular masses, suggesting breccia or lapilli in the midst of volcanic sand. One specimen shows a banding that might be due to variation in sediments. See plate III; also, page 739. Originally a volcanic sand.

No. 1529. Peculiar "streamed" and brecciated mixture of chalcedonic quartz, globular taconyte and geodic quartz, the last filling original elongated cavities, which are embraced entirely in a casing of white "chalcedonic" quartz. This seems to be from the superficial part of a lava flow where volcanic (glass) sand accumulated amidst the breccia. Some parts of this rock are like the banded jaspilyte of the Vermilion range; four specimens.

*Other interesting features of this rock at Prairie River falls are mentioned in the annual report for that year (the *Eighteenth*) p. 15.

No. 1528. Very similar to No. 1530. This is about at the horizon of No. 1527, but the specimen shows no basaltic jointage. Largely from volcanic glass sand, but showing original variations in the sand, some of it being still isotropic. Some of the quartz is coarse and may have been originally fragmental, but it is now wholly interlocked with the matrix; one specimen.

No. 1527. The globular structure is visible on most of the freshly fractured surfaces. This is basaltically jointed.

The whole thickness of these beds is, visibly, but about five feet. Between them and the first outcrop of the Pokegama quartzyte is a short interval unexposed, the rock of which is unknown. The quartzyte (Nos. 1525, 1525A and 1526) is supposed to underlie the foregoing, but it may overlie. In this quartzyte are isotropic globules and areas which are ascribable to volcanic glass, also tourmaline which indicates solfataric action. Compare the microscopical descriptions.

4. The description of the Pokegama quartzyte published in the Eighteenth Annual Report (pages 15–18) combined with a re-examination of specimens collected (Nos. 1525–1535) leads to the belief that it is not wholly below the iron ore, but cotemporary with and later than some parts of the ore. It was also later (on the evidence of pebbles which it contains) than some rock (not from the Archean) which appears to be from the Keweenawan. In short, the conglomeratic parts of the Pokegama quartzyte (No. 1532), which parts, so far as known, are near the upper limit of the quartzyte, are perhaps of the age of the Puckwunge conglomerate, and therefore later than an important eruptive part of the Keweenawan. The ore at the Diamond mine, eastward from Prairie River falls, is in a quartz sandstone (No. 1534) and is overlain by a fine red unctuous shale (No. 1533) that is like some seen in the Keweenawan.* This ore has not the distinct taconitic structure seen in the hematite at Prairie River falls (No. 1527) although it fades out in the fragmental sand in the form of roundish grains as if it had a taconitic (globular) origin. While it lies higher than the quartzyte, that which is seen at Prairie River falls and has a basaltic structure may belong below the quartzyte.

5. There is a suggestive slatiness parallel with the general dip, which is like that known to pervade surface igneous rocks. It is comparable with that seen in the igneous felsitic slates of Pennsylvania, discussed by Prof. George H. Williams,† and by Dr. F. Bascom.‡ This is also fully described by Mr. Spurr, in Bulletin x, pages 167–172. The minuteness of his description is so exact that one can easily attribute some of the characters to spherulitic parting planes in a surface lava, and in general the whole cleavage to that of a streamed surface lava on slow cooling.

6. A volcanic epoch on the south side of lake Superior has been described§ on the Penokee iron range (the parallel of the Mesabi) by Prof. C. R. Van Hise (No. 1939),

* See figure 2, *Eighteenth Annual Report.*

† *American Journal of Science*, third series, vols. 44 and 46, 1892 and 1893.

‡ *Bulletin cxxxvi, United States Geol. Survey*, 1896.

§ *Bulletin of the Geological Society of America*, vol. iv, p. 435, 1893 (distributed in 1894); *Monograph* xix, *U. S. Geol. Survey*, 1892, pp. 360, 379.

who states that the volcanic fragmentals are interbedded with the iron-bearing rocks. Of this region there has been a careful study of the structural relations. Clastic and non-clastic sediments are mingled with distinctly igneous materials which are sometimes in the form of lava flows and sometimes as "greenstone conglomerates," and sometimes non-conglomeratic. This volcanic material is sometimes embraced in a matrix of non-fragmental quartz, which is taken as evidence that the rock was formed under water.

7. The supposed glauconitic greensand is anomalous in containing little or no potash (Bulletin x, Minnesota Survey, page 242) and in approaching in composition that of a highly ferruginous basic obsidian.

8. Very much of the iron-bearing rock, especially the low-grade ores, is not taconitic (Nos. 1688, 1692), but irregularly stratified and amorphous (No. 1 under No. 2 above). Yet it exhibits the same kind of transitions from rock to ore as those parts which are distinctly globular in the characteristic taconitic manner. Mr. Spurr has collected some of these non-taconitic rocks, viz.: Nos. 128S, 148S, 149S, 204S, 210S. They are represented by various numbers in the series of all the geologists. Indeed, by far the greater amount of the iron-bearing rocks of the Animikie consists of this gray, non-taconitic, siliceous, non-productive rock. Besides this prevalent rock, the jaspilyte which is banded like that of the Vermilion range is non-taconitic. This is distributed from one end of the Mesabi range to the other, but occurs nowhere in so large amounts as in the Vermilion range. The question arises as to the origin of this rock, for the glauconitic source can apply as a whole only to the taconitic part of the series.

Anomalous microscopic facts. 1. One of the most interesting microscopic facts is the obvious and abundant origination of minerals, such as actinolite and epidote, containing important amounts of magnesia and of lime, from a supposed glauconite containing very small percentages of these bases, coupled with the non-occurrence of any alkali-bearing minerals, although a normal glauconite contains from two to seven per cent of potash (Bulletin x, page 227).

2. On the theory that the ore is derived wholly from glauconite, or from any substance undergoing metasomatosis, it is singular that in the resultant rock there should be not only more iron, taken in the aggregate, than there was in the total of the glauconite, but vastly more of quartz as well. This remark can be appreciated fully only by one who is acquainted with the field appearances. If the widest allowance be made for an imagined transference of these substances from one place in the rock to another, the concentration of quartz in one place and of iron oxide in another, the transfer still falls far short of accounting for the supposed result. The formation is now, practically, totally pure iron oxide or pure quartz. Had it

consisted originally of a substance containing, say 50 per cent of silica and 25 per cent of iron oxide, it has lost 25 per cent of its substance, and, without additional supplies, it should show evidences of reduction of bulk to that amount. No such contraction has been noted. On the contrary, Mr. Spurr discovered evidences of expansile movements, owing to the introduction of foreign substances, chiefly siderite, the whole increase in bulk, due to this cause, being estimated at "about one-tenth of its former volume" (Bulletin x, page 163).

A subsequent decarbonatizing he assumes to have been the cause of shrinkage which produced the prevalent columnar jointing—a phenomenon that we prefer to attribute to shrinkage caused by a loss of heat.

Again, in all cases observed microscopically, by Mr. Spurr or by the writer, when siderite is associated with the oxide of iron (excepting limonite), it has been found that the carbonate was later formed than the oxide. This assumed cause for the present megascopic columnar structure requires, on the contrary, that the carbonate precede the oxide.

Additional facts. When the iron-bearing rocks collected about Gunflint lake were first examined microscopically there were seen sundry things that suggested igneous origin, and others which strongly indicated the agency of volcanic forces in the vicinity. These were not fully understood at first, and were passed by as minor anomalies which might be due to other causes. But as these signs multiplied and were finally found to converge in an igneous rock, it was plain that it was necessary to reopen the whole question of the origin of the iron-bearing rocks of the Mesabi Iron range. It then became necessary to revise, before publication, the descriptions of numerous rock sections, incorporating and interpreting the anomalous facts and uniting them with other features observed later, and to point out more fully their significance. Such revision and its results are included in the foregoing descriptions (Part II), and they will be summarized briefly as follows:

1. The rock No. 307 first attracted attention. It is described (page 309) as a tuff, with a query, and is compared to a Carbouiferous tuff of King's county, Ireland, of which a small fragment had been obtained of Sir Arch. Geikie. This tuff is found near the northern limit of the Animikie on a point on the south side of Gunflint river, west of "the narrows." It is illustrated by the photograph, figure 9, plate V. This indicated the existence of volcanoes in the region at the time of the opening of the Animikie. This tuff is not silicified, and is believed to have rested on a land surface.

2. In rock No. 312, which is mostly composed of siderite, and which is represented from a photograph in plate VI, are found not only ragged pieces of rock like No. 307, but also many pieces of jasperoid or gray flint, or devitrified glass (Nos.

1310, 1311). This siderite is continuously coated with a rusty film from the oxidation of the carbonate of iron. The flinty inclusions are not thus coated. It shows a sedimentary structure. Hence it was formed under water, either oceanic or of some local lake, probably the latter. Into that water were carried pieces of volcanic glass from the adjacent land surfaces. These flint pieces are not taconitic. It was found afterward that a similar breccia-conglomerate is rather widespread, and sometimes becomes so fine that its constituent inclusions are globular grains no larger than those of taconyte (Nos. 818W, 436H).

3. The carbonate matrix is replaced by one of chalcedonic quartz (No. 436H), and in such form this conglomerate composes thick horizontal beds in the Animikie,* indicating that the siliceous matrix was formed in larger bodies of water, probably in the ocean from which was precipitated chemical silica. In other places the quartz matrix is mingled with the carbonate matrix. In the carbonate matrix is sometimes a thin layer of fine volcanic tuff similar to No. 307 but grayish green instead of black. This difference of color is attributable to its having been deposited in water instead of on a land surface.

4. This fragmental phase of the Animikie varies still further. It is composed sometimes mostly of rounded quartz grains (No. 1322) rather coarse; and in this rock are but few grains or pebbles of devitrified glass (figure 9, plate II). Such rock must have been formed largely from the Archean adjacent, but in part from erosion of silicified igneous rocks (of the Animikie ?). It demonstrates that, earlier than the fragmental parts of the Animikie, which include all globular taconyte, was a mass of glassy igneous rocks, and that that earlier rock was probably the same that supplied flint fragments to the siderite (No. 312) illustrated by plate VI.

5. There are all degrees of proportional gradation between rocks Nos. 1322 and 1319, one containing mostly fragmental quartz from the Archean, and the other mostly fragmental devitrified pebbles from silicified rhyolytes.

6. In No. 1319, as well as in many other taconitic rocks from the vicinity of Gunflint lake, are all degrees of proportional gradation between complete silicification of the component globules and an almost amorphous glassy condition. The same occurs generally in the taconyte of the Mesabi range, but not always in the same rock mass. This shows that the source of supply of these original globules was originally partly silicified and partly not silicified, and hence it is an indication that such may be the case widely on the Mesabi range. These globules are of the same size, originally of the same nature, and since incorporation in the rock have been under the same conditions. If they differ now, they must have differed when they were introduced into this rock, by the same reasoning as shows a difference of origin of the grains of

*H. V. WINCHELL. *Seventeenth Annual Report*, p. 104.

the rocks Nos. 1322 and 1319, mentioned last above. In both cases there has been an intergranular later introduction of interlocking quartz, cementing the rock into a dense taconyte or taconitic quartzyte.

7. In several instances this older rhyolitic rock has been seen in the vicinity of Gunflint lake. It is identical with that already mentioned at Prairie River falls (No. 1529), and is illustrated by No. 435H, and by several of those of No. 720W. This always lies near or directly upon the Archean. It is a jaspilyte, identical in all respects with the normal jaspilyte of the Vermilion Iron range, but varying to felsyte, and finally to less siliceous slate or flint, and to a dark rock which has not been carefully studied. This rock is never taconitic (globular), but streamed and striped like a fine-grained rhyolyte, showing white and red bandings, which are accompanied by thin sheetings of magnetite or hematite. It is this which has furnished the silicified pebbles of the globular taconyte, and it is the original (glassy) condition of this which furnished the non-silicified globules (or glauconite) of the granular taconyte.

The most remarkable exhibition of this rock is to be seen at a point on the shore of Black Fly bay, which is an appendage of Gunflint lake on the Canadian side, where it can be seen lying immediately on the Archean granite, presenting beautifully colored, sharp, fluidal contortions. A bluff which occurs a little further north, illustrated by rock No. 720W, consists largely of this rock in a brecciated condition, somewhat mingled with sedimentary debris of rock like itself, and in those places showing the characteristic globular composition. This bluff is thus described by A. Winchell:*

"S. E. ¼ sec. 18, T. 65-3, as of Minnesota, just south of the cape. A remarkable display. In a rounded, naked bluff, fifteen feet high, is seen the aspect of a conglomerate with many whitish constituents. Examination shows it to be a portion of the slate formation [*i. e.*, of the Animikie] contorted in a striking manner. The laminations are still preserved and serve to evince the disturbance. There are some quartzose layers, and some quartz veins. Much of the slate has assumed a flinty constitution, and some laminæ are of red jasper. There are patches of what I have called oölitic magnetite, and areas in which the spherules are sparsely scattered in a somewhat homogeneous matrix of undetermined character. In some places the crystalline magnetite sparkles brilliantly, and there are others in which it has been oxidized by water and burnings [of the forest] into a crumbling ferruginous mass, like the waste of a hematite mine."

The specimens collected, fourteen in number, show all these features.

8. There is a curious iron-bearing rock (Nos. 1896 and 879G) north from the line of strike of the recognized Animikie, near the late workings of the Gunflint Lake Iron company, lying in or on the Keewatin greenstone. Whether this belongs with the Keewatin or with the Animikie is immaterial to the point to be mentioned, since it is plain that the ores of the two formations had an identical manner of origin. This ore, while presenting some of the taconitic characters of the Mesabi ore, yet embraces igneous minerals, such as pyroxene. As an Animikie rock it may have been a lava which locally came into contact with volcanic glass sand (and perhaps other kinds) which it incorporated into its mass. On silicification the pyroxene was exempted from the usual change. As a Keewatin rock it may have been a detritus of jaspilitic sand and greenstone debris which, on metamorphism,

* *Sixteenth Annual Report*, p. 241.

gave origin to the poikilitic and globular pyroxenes. In either case the rock is a mixture of ferruginous (originally clastic) taconyte with elements that are distinctly igneous or metamorphic, suggesting close relations in the origination of the two kinds.

9. Lastly, the crucial evidence was found at a point about a mile west of Gunflint lake, described and illustrated by figure 54, on page 951 (Nos. 1897, 2052 and 2053).

A sideritic rock (No. 2052) makes quite a display in a conspicuous hill. It is the iron-bearing member or its representative, and shows red because of the oxidized surfaces. It is broken by later diabase intrusions which afford a varied manner of contact on the sideritic slates, the diabase being coarsely porphyritic. This sideritic rock passes with the dip southward and becomes a breccia of confused composition. In the hill (No. 2052) it is somewhat actinolitic. At the railroad cut (figure 54) it is almost wholly of actinolite, but still has so much siderite that it turns yellow with iron rust (Nos. 1897, 2053) and it contains many quartzose flinty masses, some being two feet long. In the matrix of this quartzose breccia the above sideritic rock becomes not only actinolitic but diabasic and glassy (No. 2053). So far as can be judged from the field-notes, and from the thin sections examined, the sideritic iron-bearing member passes through an actinolitic phase and afterward acquires the form of a basic volcanic glass, from which, on cooling, were formed small spherulitic segregated masses like those of the lava sheet of Grand Portage island (No. 544).

It is apparent, therefore, that the iron-bearing member has various phases, especially when it is not economically productive, viz.:

(a) It is a basic glass.

(b) It is a jaspilyte, or silicified basic rhyolitic lava.

(c) It is a sideritic rock (not fragmental).

(d) It is an actinolitic siderite.

(e) It is a sideryte (clastic or chemical precipitate).

(f) It is a breccia and a conglomerate of basic glass and of jaspilyte.

(g) It is a taconyte, or sand of volcanic glass and of jaspilyte.

(h) It is a nondescript gray, greenish-gray, or often brown, rudely bedded siliceous rock (allied to c).

All the foregoing anomalous as well as the additional facts may be explained by the following hypothesis:

A chain of active volcanoes, having explosive emissions, extended across northeastern Minnesota about where the Mesabi Iron range is found. This was near the shore line of the Taconic ocean, and was accompanied by land-locked bays, and perhaps by fresh-water lakes. Such marginal volcanoes had a chemical effect on the oceanic water, causing the precipitation of silica and probably of iron. Its basic lavas and obsidians were attacked by the hot waters and were converted by encroaching silica into jaspilyte. Near the shore such glassy lavas were eroded by wave action and distributed so as to form conglomerates and sandstones. Such action would have distributed lavas wholly silicified as well as those which were yet glassy, and the detritus of both would necessarily mingle with detritus from the Archean. Such lavas would exhibit great contortion, and in places great brecciation, the same as later lavas, and these breccias must have been mingled sometimes with the products of detrital action. After prolonged activity of the volcanoes most of the deposits and of the lavas which were submarine would be permeated by secondary silica, but carbonate of iron would permeate the mass where carbonic acid had freer access, as in the lagoons into which streams drained from the land surface to the north.

Consequences of this hypothesis.

If this hypothesis be true, certain results follow, bearing on the structural and chemical geology, and on the future economic development of the ores.

1. We probably see only the northern border of the iron-bearing rock. The original basic lava, as well as the resultant volcanic sand, would probably accumulate in greater quantity to the south of the volcanic belt than toward the north. We know nothing about the location of the original craters. They may have been to the north of the present line of strike of the Animikie or further south. Wherever they were, it is evident that the accumulation of the larger deposits of volcanic sand would be to the southward of the larger deposits of lava. Where the lava form of the iron-bearing rock subsists still in the Mesabi range, as through much of its eastern extension it is reasonable to look for globular taconyte toward the south further, even if the surface rock be of the slates of the Animikie.

2. This volcanic epoch may have a deep-seated connection with the Cabotian of the Keweenawan.

3. It renders it probable that the igneous layers in the black slate about Gunflint lake are not all intrusive sills, but may be in part cotemporary with the fragmentals.

4. An intimate alliance in mode of origin is shown between the ores and much of the ore-bearing rock, of the Vermilion and Mesabi ranges. This brings to mind the views of M. E. Wadsworth, who first argued for the igneous origin of the jaspilyte of the Marquette region. His evidence consisted of what he considered intrusive relations with the adjacent rock, and he supposed the present nature of the rock is that which it had when molten. The writer has shown elsewhere that both these ideas are incorrect, and that much of the Vermilion jaspilyte is a bedded oceanic precipitate, probably analogous to the bedded flints of the Animikie. However, Dr. Wadsworth is to be credited with the first suggestion as to the manner of origin of the igneous portion of the jaspilyte. This includes that which is much contorted

and banded in the manner of rhyolyte and not that which is interbedded with greenstone debris, or which passes into argillyte or other rock by slow changes.

5. Although these volcanoes may have begun as submarine, the surrounding areas must have been elevated gradually above the ocean level. Their lavas then would have remained largely unsilicified, and they may have flowed great distances.

6. Why are some lavas silicified and others not? Without going into this question any further, it may be well to suggest some causes for this difference: (a) Some flows may have been submarine and some terrestrial. (b) Some may have come from volcanoes, at first submarine, and some from fissures that never formed volcanoes. (c) Some lava layers may have been very thick—too thick for complete oceanic silicification.* In that way large bodies of "red rock" may have been formed. (d) The great dynamic fracture line may have been shifted, as stated in the preface of volume iv (page 17), to the south. Indeed, the Beaver Bay diabase and all later (Manitou) lavas may have been ejected from such later fissures.

7. The ore bodies are likely to be found in the vicinity of the ancient craters, where oceanic precipitation was most copious, and hence in varying amounts on the same stratigraphic horizon.

8. Although to a small extent the process of alteration may have continued to the present, the bulk of the iron, as of the quartz, of the iron-bearing rock, must have originated during the period of volcanic activity.

Note. Circumstances render it impossible to thoroughly digest the new issues involved in the adoption of this hypothesis. That it bears an intimate relation to the Animikie, the disappearance of which throughout a long tract in Minnesota has caused much difficulty of interpretation, and to the whole "red rock" series, especially to the more massive parts of the "red rock," is at once apparent. It brings the flinty layers of the Animikie, along the northern strike of the Animikie, into relation with eruptive causes, and suggests that the Cabotian age of igneous activity may have been (or at least begun) in early Animikie time; and that involves the definition of the Keweenawan.

*The silicification of trees, a common feature of some parts of the western United States, especially in Arizona, seems to be a similar phenomenon.

APPENDIX.

(A)

The Structure of the Keweenawan.

A large mass of notes has accumulated in the course of the field work, as well as in the subsequent study of the rocks of the Keweenawan, bearing on the succession of the parts of that formation. It was once designed to review that subject more thoroughly than has been done in the discussion in Part I. There are sundry references in the body of Part II to such intended review, but the chief points only will be presented, with short references to preceding pages where illustrative facts are mentioned.

1. The tendency of the evidence has been to increase the bulk of the surface lavas that preceded the Beaver Bay diabase, and hence toward the separation of the Beaver Bay diabase from the gabbro mass of the northern part of the Keweenawan belt in Lake and Cook counties, in chronologic birth as it is in geographic place. (Compare Nos. 522, 523 and 525.) It seems, therefore, that there are two main series of alternating traps, sandstones and amygdaloids, one in the Cabotian and one in the Manitou. The knowledge we possess of the geology of the country immediately back from the shore line of lake Superior is too meagre to warrant an attempt to define these two series.

The Beaver Bay diabase may be credited, therefore, with some of the phenomena which, along the lake shore, have been ascribed to the earlier gabbro, such as the production of red rock, as at Grand Portage, and perhaps at Pigeon point; the production of the great dikes at Grand Portage and the great sills of the international boundary in Cook county. This great mass has very widely been called a part of the original gabbro, and it cannot at present be separated from it either geographically or petrographically, although it seems to be separate from it stratigraphically. They both belong in the Cabotian, as defined, but the Beaver Bay diabase may have to be separated from the Cabotian.

2. *The age of the Logan sills.* The age of the sill north of Birch island (Nos. 263, 265) is the same as that of the great east-west dikes. The latter are earlier than the conglomerate at the base of Grand Portage island, as their debris and the "red rock" which they formed are in that conglomerate. Therefore, the sills of the region, and probably all the Logan sills, *are not later than the Keweenawan.*

(B)

Additional Petrographic Descriptions.

No. 1527. Hematite. (*Taconitic.*)

Prairie River falls, S. E. ¼ sec. 34, T. 56–25 W.
Ref. Annual Report, xviii, pages 15, 60; Bulletin vi, pages 120, 422; Final Report, v, pages 737, 991; also plate IV, figure 1.

Meg. Basaltic hematite.

Mic. The globular structure characteristic of taconyte is very evident. It becomes less evident in the crystalline massive hematite, but still it can be seen both in transmitted and in reflected light that the globular structure pervades the whole. The fine, scattered, angular spaces lying between the original grains, even in the massive hematite, are occupied by the usual fine *quartz* mosaic, showing that the same oceanic precipitate penetrated even amongst those grains which were converted entirely to *hematite*. One section.

Age. Animikie (iron-bearing member). N. H. W.

No. 1689. Tuff.

From the Cincinnati property, Mesabi Iron range, sec. 2, T. 58–16 W.
Ref. Annual Report, xxi, pages 118, 155; Final Report, v, page 760.

Meg. Coarsely tuffaceous; generally dark, or greenish-black, some of the original angular fragments being about an inch in longest diameter and of a flinty fineness. From this size these flinty pieces graduate downward in size and become the taconitic globular masses characteristic of the rock bearing the Mesabi soft ores. In some parts these taconitic globules compose the most of the rock, though with a liberal supply of magnetite.

Mic. The section made is so thick that the taconitic globules are for the most part wholly non-transparent. It serves to outline the globules, and to show the inter-granular *quartz* mosaic which is in part replaced, in a narrow border about each globule apparently by fibrous rusty *actinolite*.

Age. Animikie; iron-bearing member. One section.

Remark. This rock reveals the former activity of volcanoes in the region now occupied by the most valuable mines of the Mesabi Iron range. Connected with similar evidences presented for the extreme western and eastern ends of the Mesabi range, it is apparent that the chief feature of the whole range consists in the agency of volcanoes in the production of the rock that carries the ore. N. H. W.

No. 847G. Muscovadyte. *(Fragment in gabbro.)*

S. W. ¼ N. W. ¼ sec. 6, T. 64–5. Island in Gabemichigama lake.
Ref. Annual Report, xxi, page 65; Annual Report, xv, pages 171, 172; Annual Report, xxiv, page 127; Final Report, v, page 905.

Meg. Gray, granular, fine grained.

Mic. Owing to the extreme importance of the characters of this rock in their bearing on the question of the origination of the gabbro, two additional thin sections were made. The rock is distinctly a typical granulitic gabbro, but some of the large *diallage* masses, having a common orientation throughout, surround granular *feldspars*; yet, usually, the diallages are in isolated, small, roundish grains lying between the feldspars, or breaking the margins of two contiguous feldspars. Rarely a small diallage is embraced within a feldspar. Two sections.

Age. Cabotian (changed Keewatin). N. H. W.

No. 837G. Greenwacke. *(Tuffaceous.)*

S. W. ¼ N. W. ¼ sec. 12, T. 65–5. Shore of Cucumber island in Sea Gull lake.
Ref. Annual Report, xxi, page 64; Annual Report, xxiv, page 124. Compare rock No. 597W, Annual Report, xvi, pages 297–299.

Meg. A light-greenish, much decayed rock, with numerous subangular included rock masses, which are of lighter or of darker color. The weathered surface carries a rusty film, which is in some cases a sixteenth of an inch in thickness, evidently produced by the oxidation of the rock itself. Apparently tuffaceous.

Mic. The slide is largely isotropic. The rather radial arrangement of some of the much-altered older crystals suggests an originally igneous massive rock, at least for portions of the rock. These older crystals appear to have been mainly *feldspars*, and they are now replaced principally by *calcite*, *chlorite*, and rarely in part by *biotite*, but they are occasionally partly preserved. The biotite is interleaved with chlorite. The general isotropic aspect is due to the dissemination of chlorite rather than to the present existence of tuffaceous glass. The rock may have been a microlitic zirkelyte, passing locally into a fragmental tuff. Two sections.

Age. Probably Lower Keewatin.

Remark. It is in the midst of such rock as this that occurs the segregated marble of Ogishke Muncie lake. The fresh red mineral mentioned by Dr. Grant (Twenty-fourth Annual Report, page 124) is calcite, effervescing rapidly in cold HCl. N. H. W.

No. 1030G. Granite *(with hornblende and biotite)*.

Forms the barrier at the falls of Rainy river at Koochiching.
Ref. Annual Report, xxiii, pages 55, 221; American Geologist, vol. xx, pages 293–299, November, 1897.

Meg. Medium grained, with much biotite and hornblende, causing a dark speckled appearance, sometimes rather porphyritic. "It contains many dark masses, sometimes a foot or more in diameter; they are composed of the same minerals as the main part of the rock, but mica makes up a very large proportion of each dark mass." Specimens examined were taken from the excavation for a canal at Fort Frances, made by the Canadian government several years ago.

Mic. The following description is condensed from that of A. N. Winchell, published in the American Geologist (*loc. cit.*).

Orthoclase is quite abundant in irregular grains. They include biotite, apatite, quartz and hornblende, and occasionally show Carlsbad twinning, and micropegmatitic intergrowths.

Biotite also is abundant.

Andesine oligoclase is quite common. It is Carlsbaded, with albite twinning in both parts. No other plagioclase could be detected by the method of Fouqué.

Microcline occurs quite freely, embracing kaolin, epidote, quartz and biotite.

Hornblende appears rather sparingly, and sometimes shows zonal structure, with inclusions of other minerals.

Quartz is in irregular grains, with few inclusions, and occasionally as micropegmatitic growth in orthoclase and in andesine-oligoclase.

Epidote is abundant, frequently showing the crystal form, especially in the midst of biotite.

Kaolin is common in all of the feldspars, sometimes associated with secondary quartz and heterogeneous occurrences of epidote and sphene.

Apatite appears in needle-like forms and in short prisms, and sometimes is so thickly crowded in highly altered areas as to suggest a secondary origin.

Sphene is in small amount.

Tourmaline, in hexagonal crystal form and in shapeless aggregates, is identifiable in limited amount.

Pyrite is rare.

Calcite was unsatisfactorily identified in a few small grains.

Zoisite is about as abundant as apatite, and is distinguished from epidote, with which it is associated in origin and occurrence, by the smallness of its grains and its blue-gray interference color.

Muscovite was doubtfully distinguished.

By the use of a specific gravity liquid the constituent minerals were separated with the following approximate result:

Mica,	12	per cent.
Above 3.,	9.29	"
Between 3. and 2.661,	34.66	"
Between 2.661 and 2.642,	25.02	"
Between 2.642 and 2.58,	7.60	"
Below 2.58,	11.43	"
	100.00	per cent.

which warrants the following proportionate distribution of the minerals:

Biotite,	specific gravity 2.8 to 3.2,	12 per cent.
Muscovite(?),	" 2.75 to 3.2,	.....
	Above 3.,	9.29 "
Hornblende,	specific gravity 3.2 to 3.3,	.....
Epidote,	" 3.25 to 3.36,	.....
Zoisite(?),	" 3.25 to 3.36,	.....
Apatite,	" 3.16 to 3.22,	.....
Sphene,	" 3.3 to 3.7,	.....
Tourmaline,	" 3. to 3.24,	.....
Pyrite,	" 4.9 to 5.2,	.....
	3. to 2.661,	34.66 "
Calcite(?),	specific gravity 2.72,	.....
	2.661 to 2.642,	25.02 "
Andesine-Oligoclase,	spec. gravity 2.645,	.....
Quartz,	" 2.65,	.....
	2.642 to 2.58,	7.60 "
	Below 2.58,	11.43 "
Orthoclase,	specific gravity 2.54 to 2.56,	.....
Microcline,	" 2.56,	.....
Kaolin,	" 2.34 to 2.57,	.....
		100.00 per cent.

Hence, basing a calculation on the fairly accurate determination of the biotite, the minerals are approximately in the following proportions:

Orthoclase,	18.00
Andesine-Oligoclase,	16.00
Biotite,	12.00
Microcline,	12.00
Quartz,	12.00
Hornblende,	10.00
Epidote,	7.00
Kaolin,	5.00
Apatite,	4.00
Zoisite,	3.00
Sphene,	2.00
Tourmaline, pyrite, calcite and muscovite,	1.00
	100.00

The anomalous mineral figured by the author of the foregoing description appears to be a twinned hornblende with two central remnants of pyroxene. The hornblendic zones, surrounding the nuclei of pyroxene, embrace micro-poikilitically several grains of quartz oriented uniformly with the adjacent quartzes, but no inclusions are in the pyroxenic cores, except that about their margins hornblendic spurs crowd upon their boundaries. The hornblende seems to have been formed from two original augites whose cleavage and orientation do not agree either with each other or with the surrounding hornblende.

The confused aggregates above called kaolin are more likely to be of the nature of rejected but recrystallized substances embraced in the regenerated feldspars after complete metamorphism, consisting partly of mica and in part probably of fine-grained epidote. There is nothing in the rock that can be correctly attributed to decay since its final consolidation. Three sections.

Age. Archean. N. H. W.

No. 433H. Flint. (*Taconitic.*)

Gunflint lake, north shore, a few rods west of the entrance of a small creek which flows into the lake from the north just north of the mouth of the Boundary (Gunflint) river, about an eighth of a mile up the creek. This rock appears to be vertically bedded, and when collected was supposed to belong to the Keewatin.

Ref. Annual Report, xvii, page 104. This rock is of the same character as No. 1277, which occurs at the lake shore and lies nearly horizontal.

Meg. Black or greenish black, fine as flint, with conchoidal fracture, frequently jointed, but with a band of coarser grain running like a sedimentary layer through the middle, parallel with the sides. Petrographically this grades into rock No. 436H, below.

Mic. Plainly taconitic. The interstices between the globules are completely filled with the usual quartz mosaic, but the globules are only partly so occupied. Some are wholly replaced by quartz, but the majority are still rather amorphous or are crowded with dirty impurities through which, between crossed nicols, but faint light can be seen to pass. It is yellowish, and distributed in a mosaic fashion throughout the globules, showing probably the initial establishment of the same quartzose background. In other globules the circumferential iron rim is conspicuous, though rarely entire. The globules are all subangular, some are club-shaped, and some are crescentic. The intraglobular quartz mosaic is finer than the interglobular. Plate v, figure 10. One section.

Age. Animikie; iron-bearing (flinty) member.

Remark. There is a notable difference in the appearance of the different globules, as to coarseness and completeness of silicification, as well as between the matrix and all the globules. These contrasts can be explained by supposing that the sand itself was not a homogeneous substance, but contained grains of silicified rhyolyte as well as non-silicified, and that the oceanic precipitation of silica formed a coarser matrix which embraced them all alike. N. H. W.

No. 436H. Conglomerate. (*Taconitic.*)

Near the same place as the last, but about an eighth of a mile further up the same creek. Here the creek spreads out into a marshy lake. At the head of rapid water on the east side of the stream are thick beds of horizontal Animikie of the nature of a somewhat decomposed, fine, dark conglomerate, some of the pebbles, however, being about an inch long, but flattened horizontally. This conglomerate is unquestionably the same as rock No. 1294.

Ref. Annual Report, xvii, page 104.

Meg. A rusty conglomerate, but cemented by quartz, becoming finer and grit-like.

Mic. This is simply a coarse phase of the taconyte of the Animikie. It presents nearly every aspect mentioned under Nos. 1294 and 1530, and in addition has the character of being a conglomerate. One section.

Age. Animikie.

Remark. It is evident that these pebbles, when they were gathered into these conglomeratic beds, must have been harder than ordinary glauconite, and that they had an abundant source of supply. It is also evident that, in part at least, they were already silicified. They must have been derived from rhyolytes more or less silicified (or jaspilytes) which previously covered the Archean, and which can be seen lying on the Archean at the west end of Gunflint lake, at the east side of Black Fly bay.

Taken together the sections of rocks Nos. 1689, 433H and 436H afford an important demonstration, viz.: That in one direction the rock taconyte grades into a fine black flint, and in the opposite direction into a conglomerate in which the globular masses increase to pebbles over an inch in diameter. This shows that these rocks had the same source, as the microscope shows that they have the same composition.

N. H. W.

ROCK OF AGES.
Viewed 2½ miles from the North.

DESCRIPTION OF PLATES.

PLATE I.

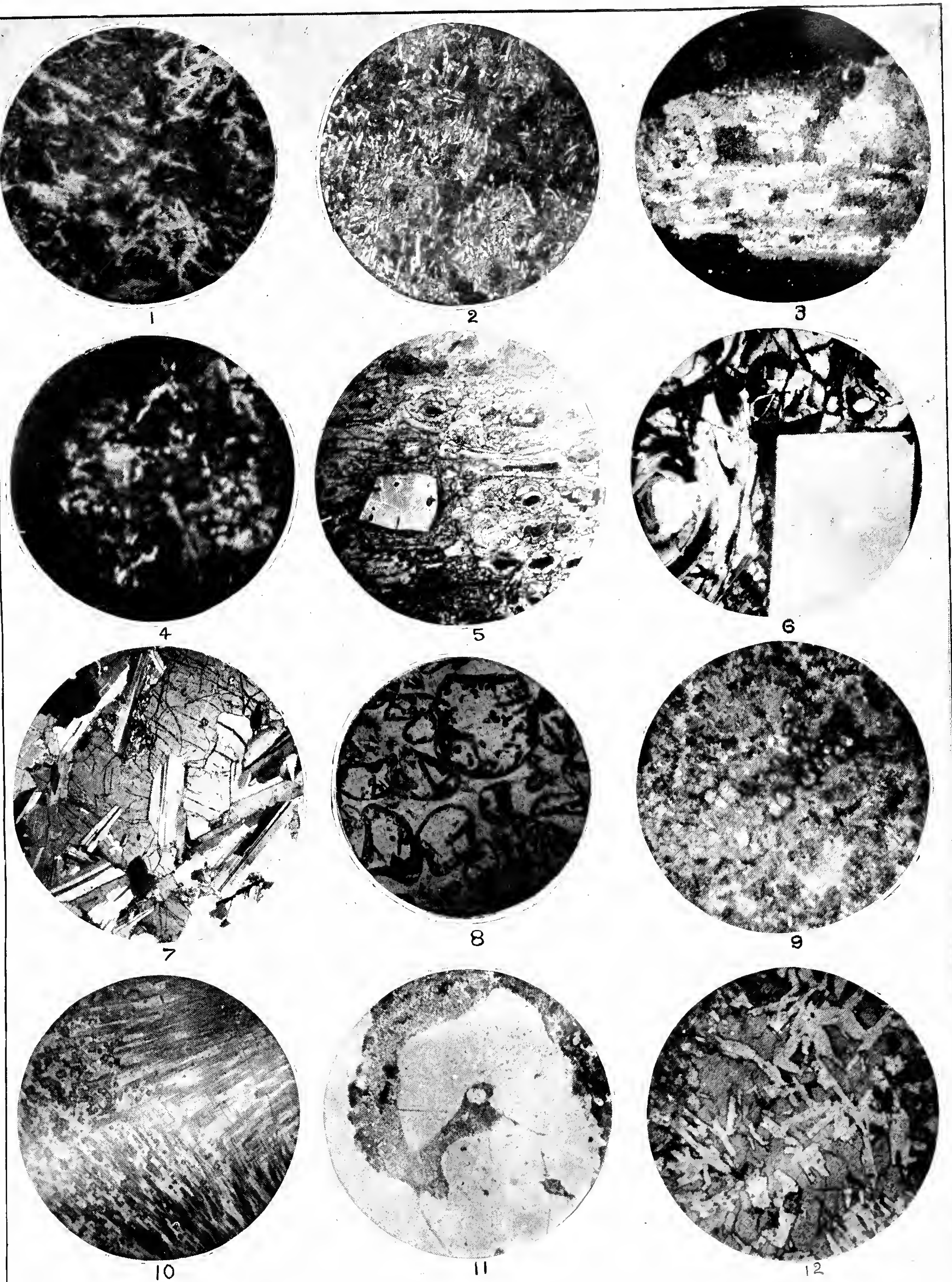
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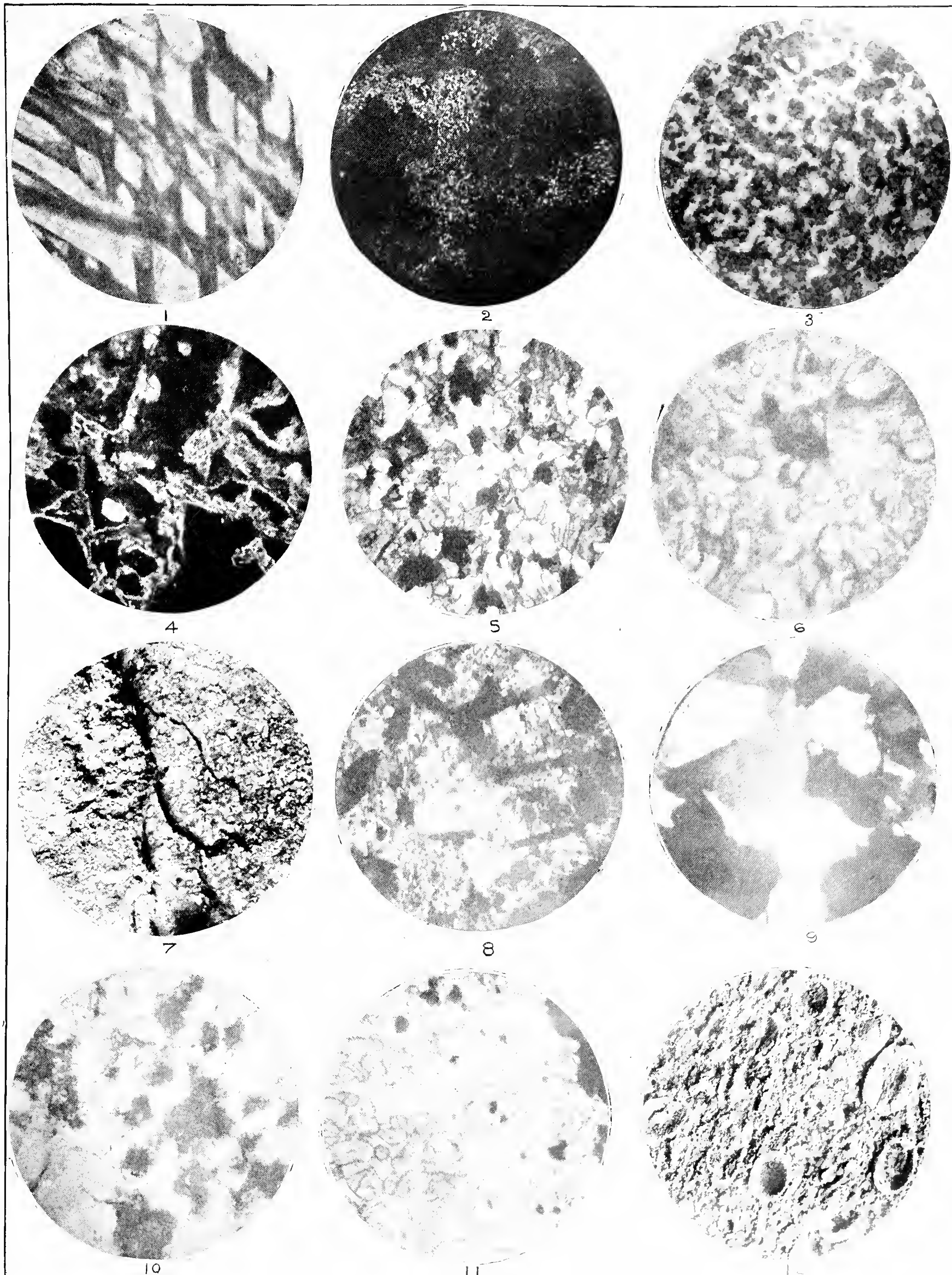
PLATE II.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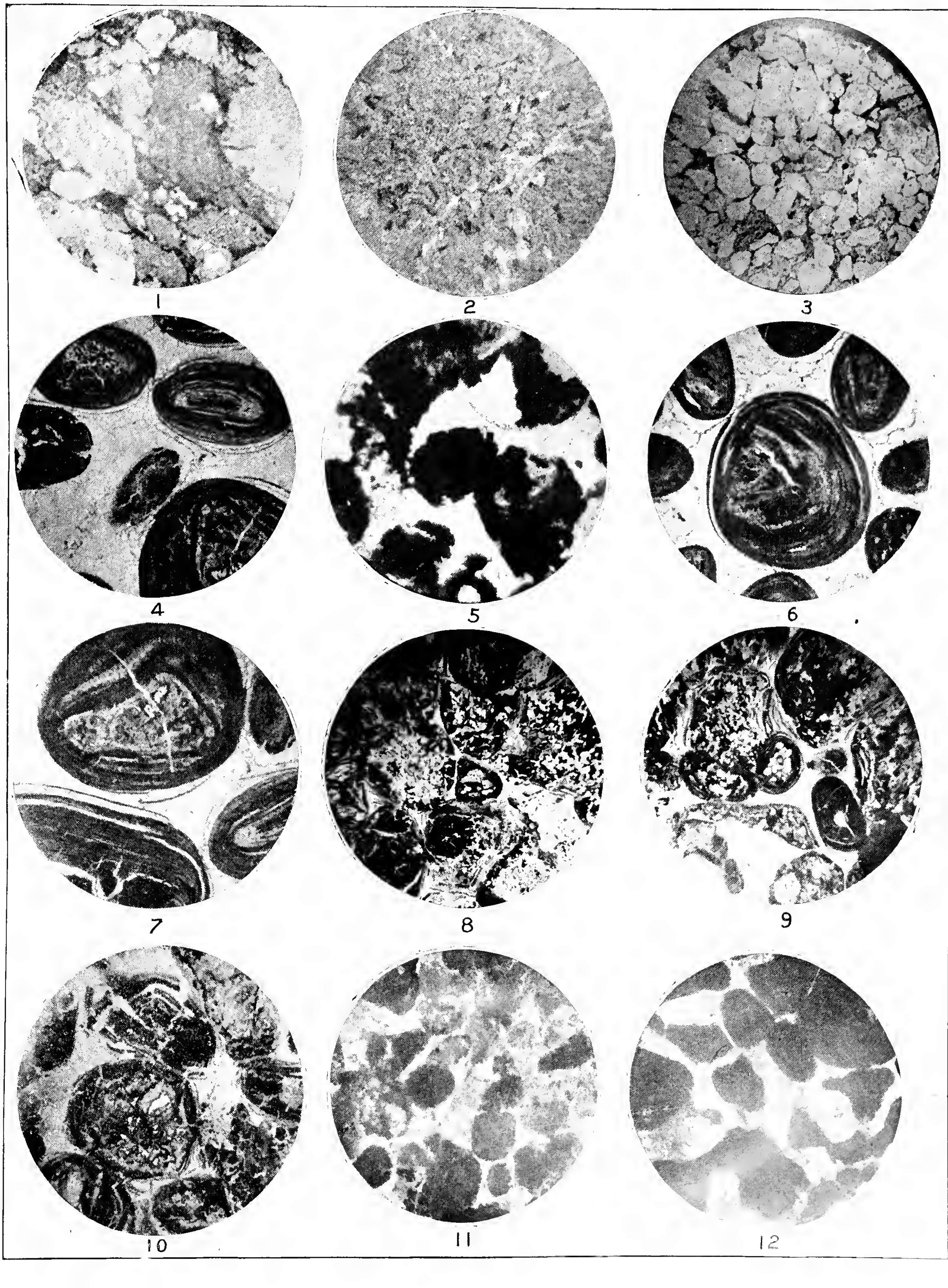

PLATE IV.

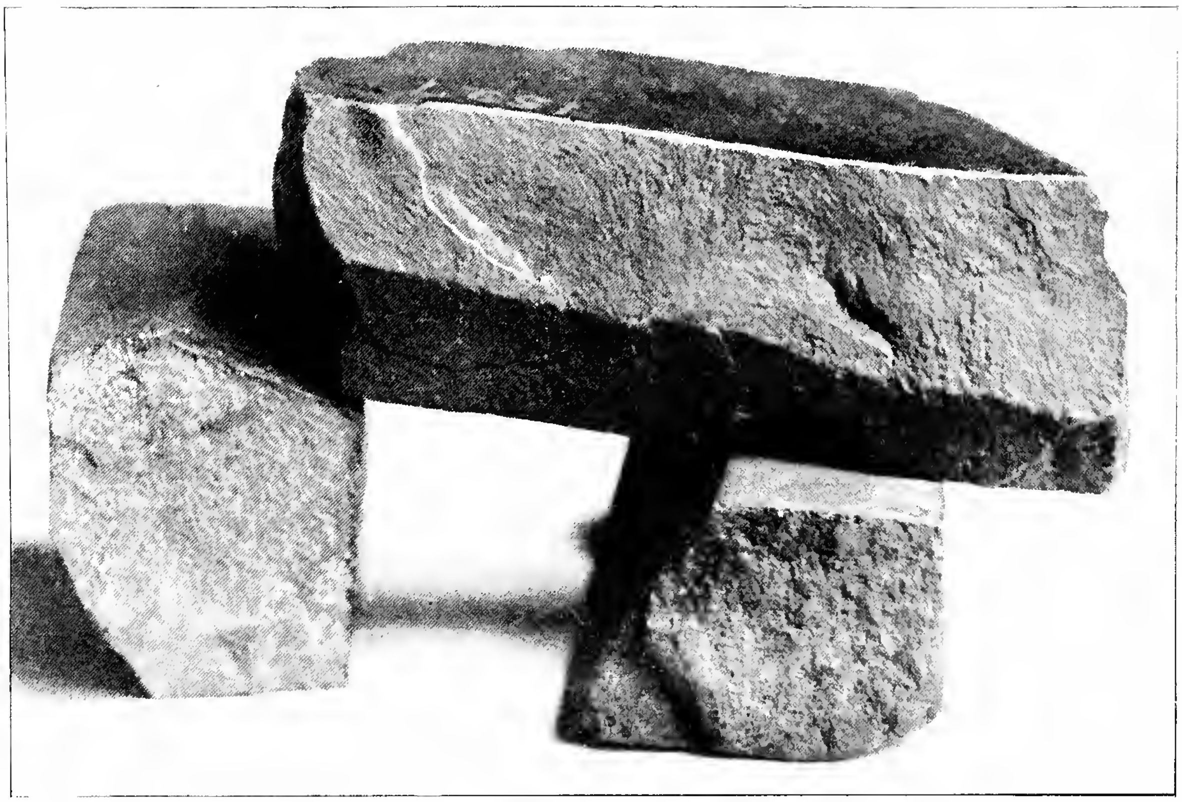

FIGURE 1.

FIGURE 2.

PLATE V.

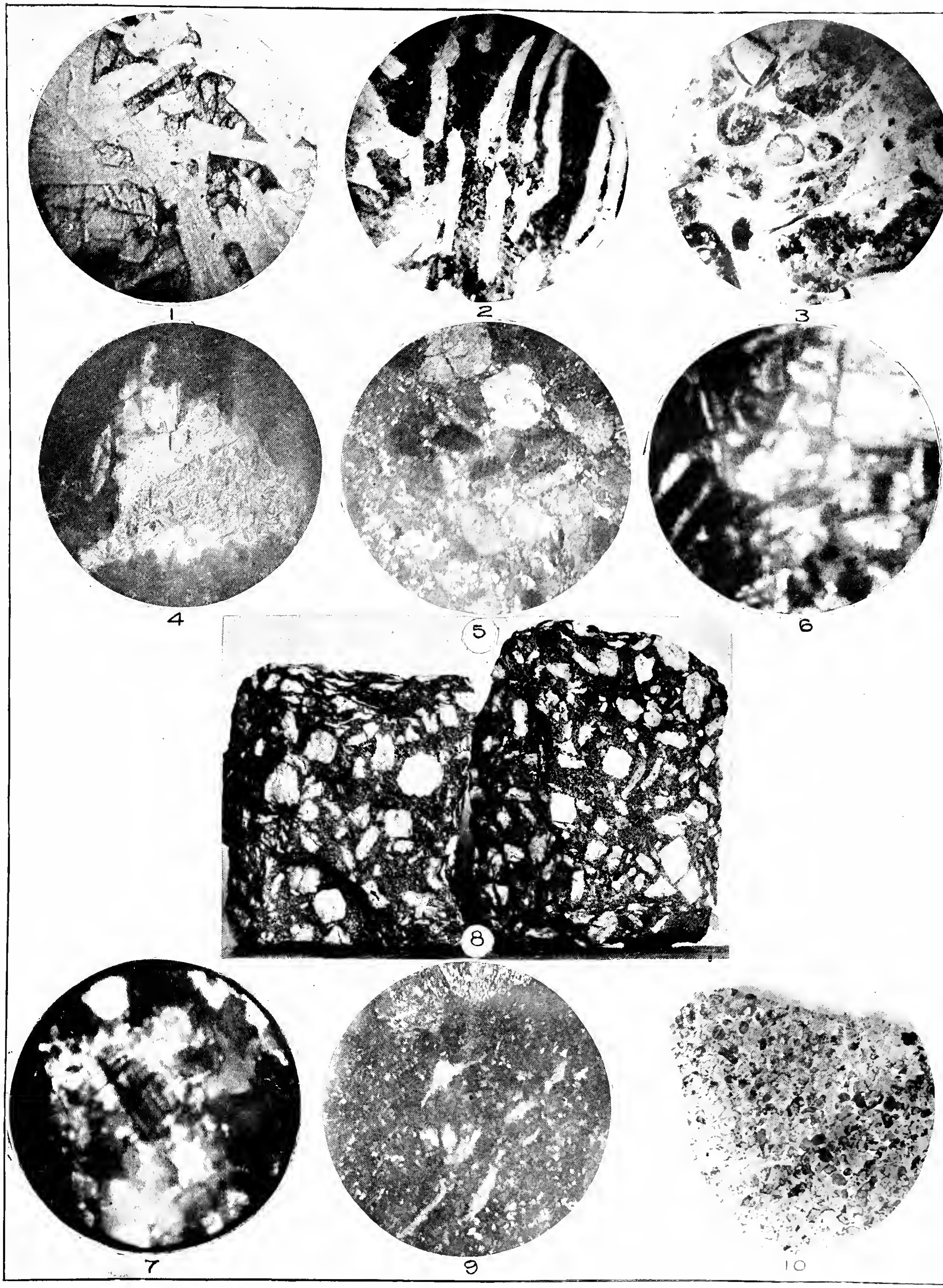
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PLATE VI.

No. 1. Sedimentary; mainly siderite, but mingled with much flint, like Nos. 2 and 3, in fine clastic grains.
No. 2. Flint, or apobsidian, in larger angular masses.
No. 3. Same as No. 2, but coarser, and weathering rough; distinctly vesicular.

The rock is essentially a breccia of apobsidian, cemented and charged with siderite. This mineral not only forms the matrix, but also fills the vesicular cavities of the apobsidian.

INDEX TO VOLUME V.

REFERENCES ARE TO THE PAGES.

[MOST OF THE ROCK AND MINERAL REFERENCES SHOULD BE LOOKED FOR IN THE ANALYTICAL KEY, WHICH IS AT THE END OF TABLE OF CONTENTS.]