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New York State Museum

JOHN M. CLARKE, Director

Museum Bulletin 170

GEOLOGY OF THE NORTH CREEK QUADRANGLE, WARREN COUNTY, NEW YORK

BY

WILLIAM J. MILLER

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

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New York State Education Department

Science Division, March 12, 1913

Hon. Andrew S. Draper LL.D.

Commissioner of Education

SIR: I have the honor to transmit herewith a manuscript entitled *Geology of the North Creek Quadrangle, Warren County, New York*, which has been prepared by Dr William J. Miller, a member of the temporary staff of this Division. Accompanyiing the manuscript are the necessary maps for its adequate illustration.

I recommend the publication of this manuscript as a bulletin of the State Museum.

Very respectfully

JOHN M. CLARKE

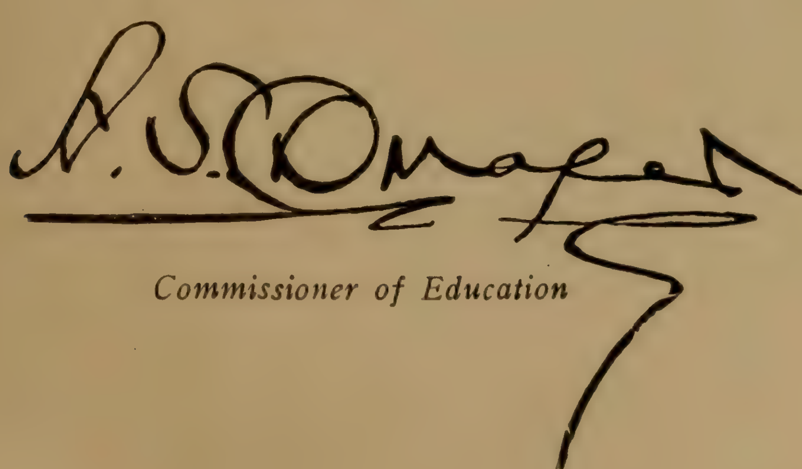
Director

STATE OF NEW YORK

EDUCATION DEPARTMENT

COMMISSIONER'S ROOM

Approved for publication this 18th day of March 1913



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INTRODUCTION

The North Creek quadrangle comprises an area of approximately 215 square miles in the southeastern Adirondacks. The map[1] covers one-sixteenth of a square degree which lies wholly within Warren county. A branch of the Delaware and Hudson Railroad from Saratoga Springs passes through the region from southeast to northwest, with a terminus at North Creek village. This railroad is an important entry into the southeastern Adirondacks, especially for summer tourists.

The principal villages of the quadrangle are North Creek, Horicon, Pottersville, Chestertown, Wevertown, and Johnsburg with Warrensburg very close to the southeastern corner. Considered as a region so distinctly within the Adirondack Precambric rock area, it is unusally thickly settled and well supplied with roads, which have been a great help in making a detailed study of the complicated geologic features of the quadrangle. Agriculture is the principal industry, though during the summer months a large number of visitors come to the numerous hotels and summer boarding places, especially those in the larger villages and around the lakes. This region, like the Adirondacks in general, was formerly heavily forested but the first growth timber has largely been cut off so that the lumbering industry is now nothing like that of earlier years.

[1] See map in pocket of back cover of this bulletin.

GENERAL TOPOGRAPHY AND GEOLOGY

As compared with the general Adirondack area, the North Creek quadrangle presents a rather unique assemblage of topographic forms. Long, prominent mountain ridges, usually with northeast-southwest trend, which are so common in the eastern Adirondacks, are practically absent from the quadrangle, and instead the dominant topography form is the separate, rounded mountain mass or dome which stands out conspicuously above the surrounding country. Such domes, which are numerous and widespread especially in the southern two-thirds of the region, are commonly from 500 to 800 feet high. The highest and largest of these domes is Crane mountain which rises 2000 feet above the immediately surrounding country. Among the other more notable examples are Hackensack,[1] Moon, Potter, No. 9, Little, Huckleberry, Kelm, Chase, Prospect, Mill, and Stockton mountains. These domes always form striking features of the landscape. Ridges do occur but they are seldom more than two or three miles long and do not assume their usual importance in Adirondack topography. This peculiar North Creek topography has largely been produced by a very irregular system of numerous faults in combination with a rather widespread though "patchy" distribution of comparatively weak Grenville strata. In the succeeding pages these matters are described in detail. The maximum range in elevation is from about 640 feet, where the Hudson river leaves the quadrangle, to 3254 feet at the summit of Crane mountain. Many of the mountain tops show altitudes ranging from 1200 to 2000 feet.

The Hudson river, which is the largest stream in the southeastern Adirondacks, passes through the midst of the quadrangle from the northwest to the southeast. The Schroon river, which is one of the chief tributaries of the upper Hudson, cuts across the northeastern portion of the area and thence along the western side of the adjoining Bolton sheet to reenter the North Creek sheet at the extreme southeastern corner near Warrensburg. It is worthy of note that the Schroon river, in the northern portion of the area, flows at a level 200 feet below that of the Hudson to which it is tributary. All the drainage of the quadrangle passes into the Hudson, though that of fully two-thirds of the region does so by first entering the Schroon river. Within the map limits, scarcely a stream of any consequence enters the Hudson from the east, while several streams of considerable size, such as Patterson brook, Glen brook, and Mill creek, enter it from the west.

[1] On the map the name of this mountain is misspelled.

Quite typical Adirondack lakes and ponds are fairly abundant, about thirty of them being represented on the map. The largest is Schroon lake, only the southern end of which lies within the map limits. The others range in size from small ponds to lakes two or three miles long such as Friends and Loon lakes.

From the geologic standpoint, the North Creek quadrangle is of more than the usual interest because of both the rock types and structures. With the single exception of the anorthosite, all the important rock formations of the eastern Adirondacks are abundantly represented. Except for the superficial glacial and recent deposits, the rocks of the quadrangle are all of Precambric age, and nearly all are highly metamorphosed, foliated, and folded.

Following is a list of all the rock formations, except the Pleistocene, given in the regular geological order of relative ages:

5 Diabase: wholly nonmetamorphosed, occurring in comparatively small, narrow dikes, and clearly cutting all the other rocks of the region.

4 Pegmatite: wholly nonmetamorphosed, dikelike masses cutting all rocks except the diabase.

3 Gabbro: more or less metamorphosed, occurring in stocks or dikes and cutting all types of the syenite-granite and Grenville series.

2 Syenite-granite group: distinctly gneissoid rocks, representing several facies of a single great intrusive mass, and clearly younger than the Grenville.

1 Grenville series: highly metamorphosed and foliated sedimentary rocks, including crystalline limestone, quartzite, and various dark to light colored gneisses. These are the oldest rocks of the region.

In spite of the rugged character of the topography, the accessibility of all parts of the quadrangle and the general excellence of rock exposures have afforded an unusual opportunity for detailed field work. Many important geologic relationships are very clearly exhibited.

Following are the principal papers which have a more or less direct bearing upon the geology of the quadrangle:

1842 Emmons. Geology of the Second District, N. Y.

1897 Kemp & Newland. Preliminary Report on the Geology of Washington, Warren and Parts of Essex and Hamilton Counties. In 17th Annual Rep't N. Y. State Geologist.

1898 Kemp, Newland & Hill. Preliminary Report on the Geology of Hamilton, Warren, and Washington Counties. In 18th Annual Rep't N. Y. State Geologist.

1899 Kemp & Hill. Preliminary Report on the Pre-Cambrian Formations in Parts of Warren, Saratoga, Fulton, and Montgomery Counties. In 19th Annual Rep't N. Y. State Geologist.

1911 Miller, W. J. Exfoliation Domes in Warren County, N. Y. In N. Y State Mus. Bul. 149, p. 187–94.

1911 Miller, W. J. Pre-Glacial Course of the Upper Hudson River. In Bul. Geol. Soc. Amer., *22*: 177–86.

ROCKS OF THE REGION

GRENVILLE SERIES

General statements. The Grenville series comprises the oldest known rocks of the area. They consist of a great mass of highly metamorphosed and crystallized sediments such as original limestones, sandstones, and shales which have been changed to crystalline limestone or marble, quartzite, and various gneisses. Since it has not yet been definitely determined whether these rocks should be classed as Archeozoic or Proterozoic in age, the noncommittal term " Precambric " is employed. The weight of evidence is on the side of their Archeozoic age and it is certain that they can not be of late Proterozoic age.

Among the proofs for the sedimentary origin of these rocks within the quadrangle are: (1) the very character of much of the material such as limestone and quartzite which can not possibly have been of igneous origin; (2) the arrangement of the rocks in distinct beds of widely different composition and often sharply alternating; and (3) the common occurrence of graphite (crystallized carbon) as flakes scattered through much of the rock, such graphite being almost certainly of organic origin.

Grenville strata are known to be of common occurrence throughout the Adirondack mountain region and this, together with the facts that the total thickness of these strata is very great and that they extend over not only the Adirondack area but also a vast extent of Canada, make it certain that those very ancient strata are of marine origin. It is evident that the Grenville sediments were laid down upon an ocean floor of even greater age but, in spite of twenty years of painstaking field work by several investigators, no trace of that ancient floor has certainly been recognized. Nor has any trace of that very ancient land, whose wearing down by erosion furnished the Grenville sediments, been found. It seems probable that those

Pregrenville masses were either engulfed by the later great intrusions or that they were changed beyond recognition.

Areal distribution of the Grenville. About four-ninths of the surface rock of the quadrangle is Grenville, provided we include the Grenville which makes up considerable portions of the areas of mixed gneisses. It should be noted that the Grenville here assumes much more prominence than is usually the case in the Adirondacks. Also, as the accompanying map shows, the Grenville is very widespread in its distribution, it being least prominently developed in the central and northern portions. A striking feature is the "patchy" character of its distribution, this being due to the very irregular manner in which the great igneous intrusions broke through and cut to pieces the Grenville strata.

The three types of Grenville which are sufficiently different to allow of separate representation on the geologic map are:

1 Crystalline limestone which is generally associated with dark hornblende gneiss, this latter rock often being garnetiferous.
2 Quartzite in thin to thick beds and usually more or less interbedded with thin layers of biotite gneiss or sometimes a little limestone.
3 Other gneisses, chiefly gray feldspar-garnet or dark gray biotite-garnet-feldspar or white feldspar-gneiss. Occasionally a little limestone, quartzite, or hornblende-gneiss may occur closely associated, especially where the glacial drift is heavy.

The largest area of Grenville occupies the western portion of the quadrangle and by far the greater part of it consists of limestone and its associated hornblende gneisses. A considerable area of quartzite lies south of Sodom and a smaller one east of Little mountain. The only distinct area of mica-feldspar gneiss covers a few square miles south of Thurman.

Toward the southeast occur two irregular shaped areas of Grenville which are almost entirely made up of limestone and associated hornblende-garnet gneiss, the limestone being especially thick and well shown in outcrops just west of the Potter-Birch mountain ridge.

The large and very irregular shaped area along the eastern side of the sheet consists mostly of various gneisses with one considerable area of quartzite south of Pottersville and another east of Chase mountain. The only mappable limestone belt there is a small one extending eastward from Valentine pond.

A patch of Grenville gneiss lies at the extreme northwestern corner of the sheet and another at the northeastern corner, while a belt of limestone just enters the northern map limit at the Natural Bridge. The Grenville around Loon lake consists mostly of white to gray gneisses.

A number of small patches of Grenville are shown within the igneous rock areas and these usually represent actual inclusions of the Grenville which are large enough to be indicated on the map. No attempt has been made to show the many smaller inclusions. The Grenville occurring within the areas of mixed gneisses will be discussed in connection with those gneisses.

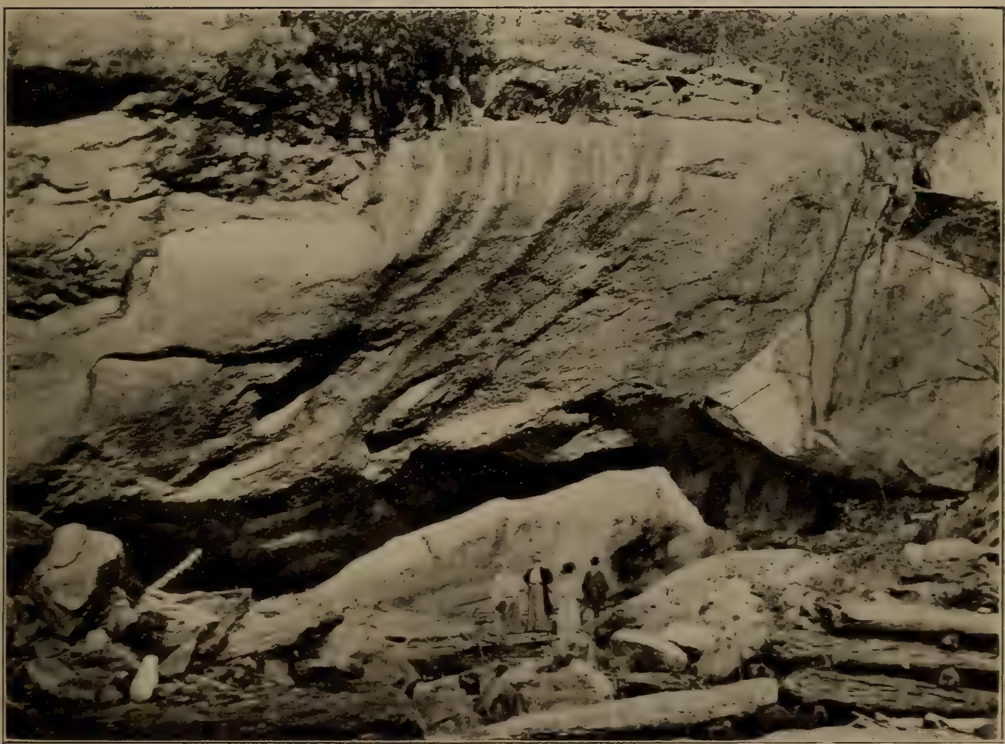
Grenville types. The Grenville types are described in considerable detail because, in the writer's opinion, if the broader structural and stratigraphic relations of the Grenville series are ever to be worked out, it is necessary to have these rocks carefully described and mapped over a much larger area than that of a single quadrangle. When a number of the other quadrangles of the southeastern Adirondacks, in addition to those of Broadalbin, Saratoga, and North Creek already published and the Lake Pleasant now being studied, are mapped in detail, it is quite possible that some of the larger structural and stratigraphic features may be made out.

Crystalline limestone. In common with the Newcomb and the southern portion of the Schroon lake sheets, the limestone of the North Creek sheet is much more prominently developed than is usual in the southeastern Adirondacks. The numerous outcrops of limestone (actually observed) are indicated on the accompanying map.

Perhaps the most abundant variety is a nearly white, medium to coarse crystalline, very calcitic limestone through which are scattered numerous flakes of graphite and phlogopite or biotite and occasional specks of pyrrhotite. The calcite crystals range from a few millimeters to more than a half inch across, while the graphite flakes are commonly several millimeters across. Other crystals less often seen in this rock are pyrite, nearly colorless pyroxene, and brown tourmaline. Rarely the limestone is rather dolomitic. This variety of limestone appears in many excellent exposures, the most extensive outcrops perhaps being on the small hill just south of Daggett pond.

A second very common variety is nearly white, medium to coarse-grained calcitic and with numerous irregular shaped, pellucid quartz grains, flakes of graphite, and specks of pyrite or

Plate I



Courtesy Moore & Gibson Co., New York

View of the Natural Bridge on Trout brook, 2 miles northwest of Pottersville. During the season of low water all the water flows under the arch here shown. The rock is banded, Grenville, crystalline limestone.

pyrrhotite scattered through the mass. The quartz grains usually range in size up to five or six millimeters and stand out as pale straw yellow or clear masses in very bold relief upon the weathered surfaces. Tiny garnet and green pyroxene crystals are rarely present. This variety is also widely distributed and among many other good outcrops are: just east of North Creek; at the Natural Bridge; just south of Crane mountain; and 1½ miles due north of Warrensburg.

A third variety which is rather widely distributed though not so common as those above described may be called serpentine limestone or green marble. One kind of this rock is medium-grained, nearly white, crystalline limestone but with many large blotches or irregular streaks of dark to light olive green serpentine scattered through it. A second kind has scattered through it numerous specks of serpentine or small pale green serpentinized pyroxenes. Different names have been applied to this green marble which has been briefly described by G. P. Merrill who says[1]: "The serpentine in the Warren county Ophiolite, Ophicalcite or Verdantique as it has been variously called, is an alteration or metasomatic product after a mineral of the pyroxene group. The original rock would appear to have been simply a pyroxenic limestone, the pyroxene occurring either in scattering granules or in granular aggregates of considerable size." Among other places this green marble is well shown in the quarries one-half of a mile southwest and three-fourths of a mile southeast of Thurman village, and in the prospect hole at the western base of Hackensack mountain.

Pure white tremolite crystals are sometimes closely associated with the limestone as in many outcrops about a mile east of Little mountain pond. One and one-half miles due north of Warrensburg irregular streaks or veins of tremolite, quartz, pyroxene, and titanite are closely involved with the limestone. The tremolite crystals are up to two inches long and the green pyroxenes up to one-quarter of an inch and perfectly formed.

Asbestos veins sometimes occur in the serpentine marble, these being best shown at the asbestos mine three-quarters of a mile southeast of Thurman where numerous veins attain a width up to three-quarters of an inch.

Green pyroxene or rusty biotite gneisses are sometimes involved in the contorted limestone in the form of streaks or inclusions which have been drawn out or broken by the pressure. See figure 9 and plate 12.

[1] Amer. Jour. Sci., Mar. 1889, p. 191.

A hand specimen, from the prospect hole 2½ miles south of Pottersville, is a very coarse-grained mass of calcite, brown hornblende, and graphite through which are scattered small flakes or crystals of phlogopite, pyrite, and pyroxene (mostly serpentinized). The hornblende and calcite crystals are as much as an inch across.

Quartzite. In the quartzite areas shown on the map south of Sodom, south of Pottersville, and east of Chase mountain, the rock consists almost wholly of distinctly bedded, pure quartzite (with layers up to 1½ feet thick) interstratified with thin layers of biotite-quartz gneiss.

The quartzite of the area southwest of Thurman contains many closely involved tremolite and limestone beds.

Thin layers of quartzite are occasionally present in the other Grenville areas but these are usually rather impure containing more or less feldspar, biotite, muscovite or graphite.

Hornblende-garnet-feldspar gneisses. Of the two principal facies of these gneisses, one is a gray, medium to fairly coarse-grained hornblende-feldspar gneiss in which are embedded occasional large brownish red garnets of the almandite type. The feldspars comprise both orthoclase and plagioclase and the hornblende is very dark green to nearly black. Biotite, magnetite, and pyrite generally occur in small amounts. The garnets never show crystal form but are always more or less rounded and highly fractured. These garnets commonly range in size from one to five inches and are often surrounded by rims or envelops of pure hornblende crystals. Fine specimens of such garnets, surrounded by rims of hornblende and embedded in the gray matrix, may be obtained at the old garnet mines near the top of Oven mountain and south of Holcombville.

Another facies is fine to medium-grained, darker gray (with reddish tinge), less feldspathic, and more garnetiferous but with the reddish brown garnets all very small and rather evenly scattered through the rock. Small amounts of magnetite, quartz, and pyrite are also usually present.

These hornblende-garnet-feldspar gneisses are almost invariably closely associated with the limestone beds, the two rocks often appearing in a single outcrop. Numerous fine exposures may be seen along the south and west sides of Crane mountain, 1 mile west of Pine mountain, just northwest of No. 9 mountain, and 1 mile east of Cherry ridge.

Plate 2

W. J. Miller, photo

Grenville light gray, very quartzose gneiss, as seen in the quarry near the southeastern end of Loon lake. The banded and jointed character of the rock is well shown.

Feldspar-biotite-garnet gneisses There are a number of rather distinct facies of these gneisses which show all sorts of gradations from one to another. One common facies is a fine to medium-grained gneiss in dark gray and nearly white alternating bands. The biotite is wholly confined to the dark layers, while small scattering garnets appear in both. Such rock is common in the gneiss areas, being especially abundant on the mountain side east and south of Valentine pond and northeast of Fuller pond.

Another facies is medium to coarse-grained and not so perfectly banded. It is best shown in the small mountain 1½ miles north of Valentine pond.

A third facies is a fine to rather coarse-grained, gray to dark gray rock, clearly gneissoid, usually banded and with numerous pink to amethyst garnets up to five millimeters across. Such rocks are very common in the Grenville gneiss areas as, for example, in the quarry near the southeastern end of Loon lake and at the western base of Prospect mountain.

Hornblende-feldspar gneiss. The most common facies of these rocks is a fine to medium-grained, dark gray gneiss almost wholly devoid of garnets. It is very gneissoid and amphibolite-like but not at all banded. It is closely associated with limestone, sometimes with thin layers of that rock interbedded. The whole ridge extending for five miles southeastward from North Creek is practically made up of this rock.

Another but similar looking gneiss contains orthoclase, plagioclase, hornblende, and hypersthene together with small amounts of magnetite and graphite. This is a much more locally developed gneiss as, for example, immediately under the limestone at the Natural Bridge.

Feldspar-quartz gneisses. These are the white or very light gray gneisses of the district. Perhaps the most typical examples are found in excellent exposures along the road near the quarry at the southeastern end of Loon lake. This is a fine to medium grained, very light gray gneiss with some tiny biotite flakes and small brown garnets scattered through the mass. A slide shows about 80 per cent of orthoclase, microcline, and microperthite in nearly equal amounts; 13 per cent quartz; together with small amounts of plagioclase, biotite and garnet. This light gneiss is in thin to thick beds and repeatedly interbedded with biotite-garnet gneisses. A very similar light gneiss, but with graphite flakes, occurs a mile farther northward along the same road.

Feldspar-quartz light gneisses also occur three-quarters of a mile south of Thurman; at Starbuckville; and one-quarter of a mile north of Chestertown.

Pyroxene gneisses. These gneisses are much less abundant than those above described. The most common facies is a fine to medium-grained intimate mixture of small grains or crystals of green pyroxene and reddish brown garnet, with sometimes one and sometimes the other predominating. Such rocks are well exposed in the Sanders Brothers mine near the mouth of Mill creek, and at the old Parker mine just southwest of Daggett pond.

Another facies is a greenish gray to greenish gneiss which contains more or less feldspar in addition to the small garnets. Such rock makes up the inclusion 1 mile west of The Glen, and also occurs along the road one-quarter of a mile north of the north end of Loon lake. Interbedded with the rock at this last named locality is a schistose orthoclase, green pyroxene, phlogopite rock, with occasional graphite flakes up to 3 or 4 millimeters across.

Sillimanite-feldspar-garnet gneisses. Such rocks were observed at but two localities, namely, three-quarters of a mile west-northwest of Starbuckville and 1 mile south of South Horicon. A thin section and specimen from the large outcrop at the latter place shows the rock to be fairly coarse-grained, gray, moderately gneissoid and made up of a matrix of orthoclase, microperthite, and quartz in which are embedded many pale pink garnets, small prisms of sillimanite, tiny graphite flakes, and some small magnetite and colorless pyroxene crystals. At the first named locality the rock is well banded and contains fibrous sillimanite in irregular streaks and also some biotite.

Graphite schists or gneisses. As we have learned, graphite flakes are common in the limestone and sometimes present in the quartzites and various gneisses. True graphite schists or gneisses are, however, rare, the only ones noted being at the old graphite mine 1 mile southwest of Johnsburg where the rocks are light to dark gray and thin to thick bedded. One specimen is almost a quartzite, but with numerous small biotite and graphite flakes. Another specimen is a feldspar-quartz schistose rock without biotite and fairly filled with graphite flakes generally from 1 to 2 millimeters across. Still another specimen is a feldspar-quartz-biotite gneiss with few graphite flakes.

Grenville stratigraphy. Any attempt to work out the stratigraphy of the Grenville series must of necessity be much more unsatisfactory than if we were dealing with a great thickness of unaltered fossiliferous strata. However, because of the excellence and frequency of the exposures in most of the Grenville areas, some unusually good results have been obtained though it should not be understood that the statements or conclusions here given are always regarded as thoroughly established. Much detailed work on the adjoining areas will have to be carried on before such statements can possibly be made.

So far as can be made out from a study of all the Grenville sections, the order of succession of the strata appears to be:

5 Dark gray biotite-garnet gneiss. Thickness unknown.
4 Dark hornblende gneiss. Thickness at least 2000 feet.
3 Crystalline limestone. Thickness of some 10,000 or 12,000 feet, but frequently interbedded with more or less hornblende or pyroxene gneisses or quartzite.
2 Quartzite. Thickness of about 3000 feet and generally pure except for very thin layers of biotite gneiss.
1 Gray, banded biotite-garnet gneiss. Thickness unknown.

Some Grenville rocks which are more locally well developed are not included in the above list because their stratigraphic positions are wholly unknown. Among such rocks are the graphite schist, the white gneiss, and the sillimanite gneiss.

The best extensive section within the quadrangle is shown by figure 1 which represents the succession of strata along a northeast-southwest line through the Grenville area between Oven mountain and Wevertown. The position of the section is indicated by the line EE on the geologic map. This is by no means a perfectly continuous section, but the outcrops are numerous enough so that the condition of things shown in the figure can not be far wrong. A total of from 18,000 to 20,000 feet of Grenville strata appears to be shown in this section. The dip and strike of the strata are pretty constant the whole length of the section, and though the Oven mountain fault probably passes across the section it is not thought materially to affect the position and thickness of the strata. The hornblende gneiss toward the top of the section forms the prominent ridge which extends northward to the Hudson river.

Figure 2 represents an east-west section across the valley one-third of a mile south of Daggett pond where there is an almost unbroken succession of nearly pure limestone whose total thickness is something like 3000 feet. On the west side, and dipping under the limestone, are some beds of hornblende-garnet gneiss.

This limestone appears to correspond with the lower part of the limestone mass in figure 1.

There is no positive proof that the quartizite shown in figure 3 is the same as that of the lower part of figure 1, but the two rock masses are of much the same character and both are of great thickness. This quartzite of figure 3, which represents a section across the valley between Chase and Bull Rock mountains, is nearly pure and shows a thickness of about 3000 feet with banded biotite-garnet gneiss dipping under it on the west side.

Figure 4 is another fine section of the quartzite which also shows the underlying rock to be a banded biotite-garnet gneiss of unknown thickness.

The limestone of the Valentine pond valley appears to dip southward under a thick belt of distinctly light and dark banded garnet gneisses, but just where these rocks belong in the columnar section can not be said.

The quartzite in the area southwest of Thurman is often very tremolitic, which suggests that it does not belong with the other quartzites of the quadrangle.

QUARTZ SYENITE

As shown on the geologic map, the syenite covers about two-ninths of the area of the quadrangle and is distributed in very irregular shaped areas. Boundary lines between the syenite and granite can not be sharply drawn because of the gradation of the one rock into the other. Against the Grenville the boundary is generally not very sharp except where the Grenville has been faulted against the syenite.

As regards granularity, structure and mineral composition the syenite is a very variable rock. The granularity ranges from fine to fairly coarse grain, with medium grain decidedly prevalent and with only rarely suggestions of a porphyritic texture. Evidence of crushing or granulation of the rock is common, especially in the cases of the more acid (granitic) syenites where the feldspars more than the other minerals are granulated. In structure the rock ranges from only faintly gneissoid to very clearly gneissoid, which is due to the arrangement of the dark colored minerals with axes parallel to the direction of foliation. All facies of the syenite are quartzose and the range in mineral composition is from pyroxene-quartz-syenite to granitic hornblende syenite as shown in table 1.[1]

[1] In this and the succeeding tables only close approximation to the volumetric proportions of minerals present is intended.

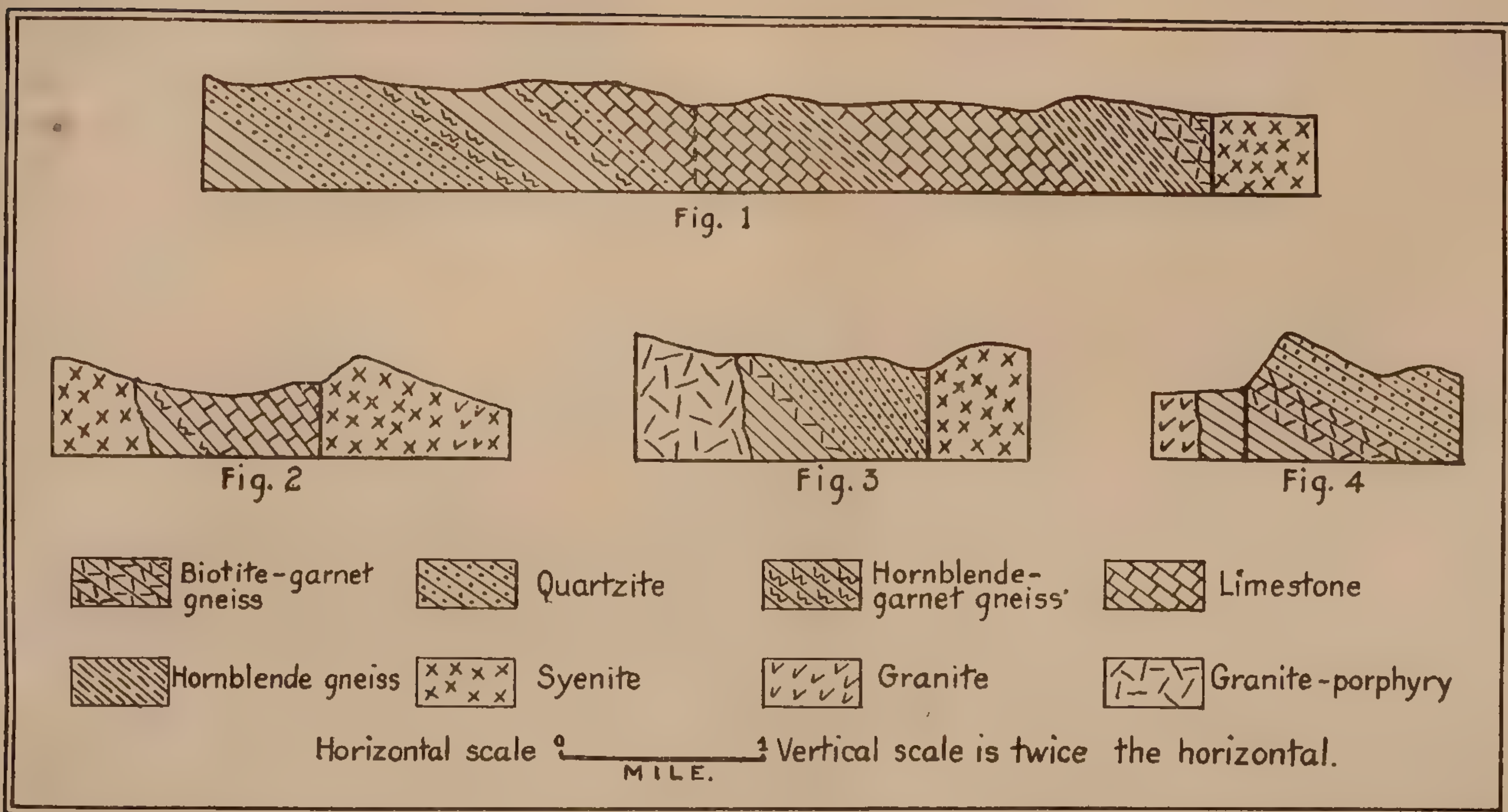


Fig. 1. Northeast-southwest section through the Grenville area which lies between Oven and Mill mountains. The exact position of the section is indicated on the geological map

Fig. 2. Section along an east-west line through the Grenville one-third of a mile south of Daggett pond

Fig. 3. Northeast-southwest section from the summit of the southern spur of Bull Rock mountain to the summit of Chase mountain and through the belt of Grenville quartzite

Fig. 4. Northeast-southwest section through the summit of Loon Lake mountain

TABLE I

Pyroxene syenite

	No. of slide	Orthoclase	Microperthite	Microcline	Plagioclase	Quartz	Hornblende	Biotite	Monoclinic pyroxene	Magnetite	Zoisite	Apatite	Zircon	Pyrite	Titanite
1	17	25	....	....	Ol-Lab 55	12	....	5	25	2	½	¼	¼	.....	..
2	13	15	25	15	Ol 14	18	1	....	10	1	½	¼	¼	.....	..
3	14	25	25	....	Ol 5	20	8	....	15	1	½	¼	¼	little	..
Granitic hornblende syenite															
4	15	25	25	....	Ol 6	22	18	2	....	1	½	¼	¼	.....	..
5	34	5	50	....	Ol 5	24	12	....	....	2	1	¼	¼	.....	½
6	12	10	35	2	Ol 12	25	14	....	....	1	½	little	½	.....	..
7	16	5	65	....	Ol 3	25	½	½	....	½	½	.....	little	.....	..

The color of the fresh rock is the usual greenish gray of the Adirondack syenites, while the weathered surfaces are of yellowish brown to brown color. Because of vigorous glaciation even the weathered surfaces are hard, decomposed rock seldom being seen except in a few protected places on the south sides of mountains. Below this weathered surface it is usually not more than a few inches to the fresh greenish gray rock.

That the syenite has been intruded into the Grenville is abundantly proved by the many inclusions of all sorts of Grenville rocks, but most of these are too small to be represented on the geologic map. Some of the best examples of Grenville inclusions are to be found in the mixed gneiss areas which will be described below.

Pyroxene syenite. This syenite represents the most basic facies of the great syenite-granite intrusive mass. The generally faint development of gneissoid structure, low quartz and hornblende contents, and the presence of pyroxene are the chief differences between this and the granitic hornblende syenite. The range in composition is well brought out in table 1 which represents thin sections of carefully selected samples. The pyroxene is seen to be the most characteristic mineral of the rock. This pyroxene is of a beautiful green color, clearly monoclinic, and shows good cleavages.

Crystal outlines are sometimes distinct. Professor Kemp has noted a similar pyroxene in the syenite of the Elizabethtown-Port Henry quadrangles and he suggests the presence of the jadeite molecule in its composition. Garnets seldom occur in this syenite.

The most basic rock of all is shown by no. 1 of the table. This rock makes up the Bull Rock mountain mass. It is unusually high in plagioclase, pyroxene, and biotite and low in quartz, and is nearer the gabbro in appearance and composition than any other rock of the whole region. It is fine to medium grained and of rather a bluish gray than greenish gray color when fresh.

Numbers 2 and 3 of the table are from the mountain 2 miles south-southeast of Riverside, and from along the road 1 mile west-southwest of Daggett pond respectively. In the field it is generally impossible to distinguish this pyroxene syenite from much of the granitic hornblende syenite and this, together with the fact that the two rocks grade perfectly into each other, renders separate mapping practically impossible. The pyroxene syenite, however, is certainly less common than the hornblende syenite.

Granitic hornblende syenite. The range in mineral composition of this rock is shown by the selected examples given in table 1. Microperthite and orthoclase are always present though in very variable amounts, while the quartz and hornblende contents are high and biotite is scarcely represented. In addition to the minerals shown in the table a few scattering garnets sometimes occur. No. 7, with its almost total lack of hornblende, is an unusual type. The gneissic structure is usually well developed though at times it becomes very faint. This granitic syenite on the one hand grades perfectly into the pyroxene syenite and on the other into the granites below described. Arbitrarily, when the quartz content passes beyond 25 per cent, the rock is classed as granite and, as nearly as possible, the rocks have been separately mapped on this basis. The very common presence of biotite in the granite has also been a help in mapping.

Numbers 4, 5, 6, and 7 are respectively from Potter mountain, 1½ miles east of Pottersville, one-third of a mile north of the north end of Loon lake, and the summit of Little mountain.

GRANITE

As already stated, the granitic syenite passes through perfect gradations into the granite and these rocks are very clearly only different phases of the same great intrusive body. The rock is rather arbitrarily called granite when it contains more than 25 per cent of quartz. By becoming coarse-grained and porphyritic it also passes gradually into the granite porphyry. As in the case of the syenite, the contact against the Grenville is seldom sharp except along the lines of faulting. The area covered by the granite is almost the same as that of the syenite or about two-ninths of the quadrangle.

This rock, too, is decidedly variable as regards color, granularity, structure and mineral composition. The colors range through greenish gray, light gray, and pinkish to almost red. These color varieties are especially well shown in the vicinity of The Glen. Pinkish granites are the most abundant.

The granularity of the rocks varies from fine to coarse grain, with a medium grain predominating. Coarse-grained types often show a tendency toward porphyritic texture and thus approach the granite porphyry. The granites are almost always highly granulated, especially the more gneissoid varieties in which the feldspars are most badly crushed. There is a wide range from poorly gneissoid rocks to those which are highly foliated and almost banded, the latter being particularly true of the commonly occurring pink granites.

The range in mineral composition is well illustrated by the selected examples given in table 2. As compared with the granitic syenite, the chief differences are the high quartz content, the common occurrence of microcline, the generally lower content of hornblende, and the almost constant presence of biotite.

TABLE 2

Granite

	No. of slide	Orthoclase	Microperthite	Microcline	Plagioclase	Quartz	Hornblende	Biotite	Zoisite	Garnet	Zircon	Magnetite	Apatite
1	21	22	22	....	Ol 7	26	20	2	....	....	little	1	......
2	35	7	30	18	Ol 3	28	8	1	½	3	¼	1	¼
3	18	17	50	....	....	30	....	2	....	....	little	1	......
4	53	10	45	4	Ol-And 5	30	5	....	....	½	¼	¼	......
5	32	5	40	....	Ol-And 10	35	7	1	½	....	½	1	little
6	31	10	18	14	Ol 10	35	6	2	1	1	½	2	½

Number 1 is a fine example of a transition rock from a granitic syenite to granite as seen along the river in big ledges one-half of a mile south of The Glen. The color of the rock is pinkish gray. Especially noteworthy are the comparatively low quartz and high hornblende contents, and the absence of microcline.

Number 3 is typical looking pink, biotite granite from the granite ridge just west of Crane mountain.

Number 6 is a very quartzose, hornblende, biotite, pink granite with considerable microcline as seen in excellent outcrops along the road 1½ miles south of Riverside.

Only a few of the observed masses of Grenville or mixed gneisses which occur within the granite are large enough to be shown on the geologic map. Small inclusions or stringers, sometimes sharply outlined and sometimes seeming to grade into the granite, are very numerous. Only a few examples will be cited. Thus, a large, homogeneous mass of very typical granite, one-quarter of a mile above the mouth of Glen brook, contains a number of clear-cut Grenville hornblende gneiss inclusions. These inclusions are mostly long (10 to 20 feet), narrow stringers which are drawn out parallel to the foliation of the granite. Similar inclusions are common 1 mile south of The Glen along the east bank of the river, and in the Mill mountain mass. On the west bank of the Hudson river and just opposite the Ferry (east of Heath mountain) a ledge of coarse-grained hornblende granite contains ten or fifteen fine examples of small (none over 3 feet long) very angular inclusions of Grenville hornblende gneiss.

Features of special interest in connection with the granites are the frequent and comparatively sudden transitions from the gray to pink varieties, and from the more syenitic or basic facies to the more truly granitic facies. The effect is to give wide bands or layers of varying color and composition and yet all clearly belonging to the same rock mass because of the true gradation of one layer or band into another. Among many places where such phenomena have been observed are in the vicinity of The Glen, and along the road one-half of a mile north of the north end of Loon lake. The writer has already described similar occurrences in the region of the Port Leyden quadrangle.[1] Professor Kemp, in the bulletin on the Elizabethtown-Port Henry region, has recently described and suggested an explanation for similar but even more extreme phenomena as follows: "The most acidic variety will quite sharply replace it [the syenite]; and in the same way a

[1] N. Y. State Mus. Bul. 135, p. 16–17.

very basic variety may come in and constitute the section for 50 or 100 feet or more. Yet, while the transition is sharp, there is no evidence of separate intrusive masses nor is one justified in inferring more than a differentiation of an eruptive mass into layers or portions of contrasted composition. . . . That this differentiation takes place in magmas is one of the growing convictions of students of igneous rocks."[1] Now, so far as the writer's observations in the North Creek region are concerned, they fully accord with Professor Kemp's interpretation of this puzzling phenomenon. Of course, the rocks have been severely compressed and possibly folded and the banded effect may thus have been accentuated, but nevertheless there appears to be no getting away from the apparent fact of some sort of differentiation of the granitic magma into layers of varying composition.

GRANITE PORPHYRY

This rock represents another phase of the great syenite-granite intrusive mass and always shows a perfect gradation into either the granite or syenite, so that sharp lines of separation between these rock types can not be drawn. On the accompanying geologic map this rock is seen to be rather widely distributed in small to large irregular shaped areas making up altogether perhaps a little less than one-ninth of the area of the quadrangle. A very similar rock occurring in the vicinity of Northville has recently been described by the writer[2] and that description applies almost perfectly to the North Creek granite porphyry. Exactly the same evidences which were presented to prove that the Northville granite porphyry is really only a facies or differentiation product of the great syenite magma, may also be applied to this granite porphyry. Still more recently such rock has been found by the writer in the northern portion of the Lake Pleasant quadrangle. Thus it is quite certain that granite porphyry is a rather widespread rock in the southeastern Adirondacks.

The typical rock is gray to pinkish gray, thoroughly gneissoid, and with beautifully developed porphyritic texture. The phenocrysts of feldspar are usually from one-half to one inch long and more or less flattened parallel to the foliation. Carlsbad twins are often easily recognizable. Feldspar, quartz, and biotite or hornblende are always plainly visible to the naked eye. Often large

[1] N. Y. State Mus. Bul. 138, p. 48 and 128.
[2] N. Y. State Mus. Bul. 153, p. 17-20.

quartz crystals are also decidedly flattened parallel to the foliation. The phenocrysts are embedded in a fine to medium-grained matrix of feldspar, quartz, and biotite or hornblende. The rock nearly always shows the effects of dynamic metamorphism, the more or less crushed and granulated feldspars generally being clearly visible to the naked eye. The degree of foliation often varies considerably from place to place, and the porphyritic texture, especially along the borders, becomes notably less prominent.

The general range in mineral composition is shown by the examples given in table 3.

TABLE 3

Granite porphyry

	No. of slide	Orthoclase	Microperthite	Microcline	Plagioclase	Quartz	Hornblende	Biotite	Magnetite	Zircon	Zoisite	Apatite	Garnet
1	25	10	10	25	Ol-And 1	44	4	4	....	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	1
2	26	10	10	25	Ol-And 5	30	10	....	1	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	8
3	27	15	20	20	....	30	8	....	1	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	5
4	28	8	35	8	Ol-And 7	30	....	10	1	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	......

Number 1 is a very typical looking granite porphyry from the quarry at Horicon. This is the rock which Professor Kemp described as the "Horicon gneiss" some years ago.[1]

Number 2 is from Kelm mountain; no. 3 from one mile south of Kelm mountain; and no. 4 from the south base of Prospect mountain.

A good example of a rather coarse, somewhat porphyritic, pink granite which might almost pass for a granite porphyry occurs in the quarry along the road 2 miles northeast of Pottersville.

It so happened that no Grenville masses within the granite porphyry were of sufficient size to be indicated on the geologic map but in the field one may see a good many small patches or streaks of Grenville gneiss sometimes as clear-cut inclusions and at other times seemingly more or less fused into the granite, thus giving very locally a sort of mixed gneiss effect.

[1] 17th Annual Rep't N. Y. State Geol. 1897, p. 510, 541.

MIXED GNEISSES

In the areas mapped as mixed gneisses, the rocks are more or less intimate associations of the various Grenville, syenite, granite, and granite porphyry gneisses. They are really areas of Grenville which have been all cut to pieces, and in some cases apparently partially fused, by the great igneous intrusives. In some areas true Grenville rocks predominate; in others true igneous rocks prevail; while in still others the most common rock appears to be of intermediate character due to an actual melting and incorporation of Grenville sediments by the molten intrusions. Except along fault lines, these mixed rocks everywhere grade into either true Grenville or syenite or granite and the drawing of boundary lines is largely a matter of personal judgment. Any attempt to separate the various members of these mixed gneiss areas would be unsatisfactory because of the general insufficiency of outcrops and the small scale of the map.

There are many places within the quadrangle where, as a result of more or less perfect assimilation, rocks of intermediate composition occur on both small and large scales. One and one-third miles northeast of Kelm mountain and near the map edge there are fine illustrations of dark Grenville garnet gneiss inclusions in the granite porphyry, the inclusions usually grading perfectly through zones of a few feet into the granite. The intermediate rock is coarse-grained, very garnetiferous, and not so porphyritic as the true granite porphyry. Similar cases of local assimilation by granite porphyry, granite and syenite have been observed at other places within the quadrangle.

On a large scale, perhaps the best examples of rocks of intermediate character make up most of the mixed gneiss area just east of Chestertown. Thus the whole top of Prospect mountain consists of gray, fine-grained, very massive rock which has the composition of a biotite granite. This rock is quite homogeneous except for occasional patches or stringers of gray Grenville gneisses which are fused into the mass. Passing southward and southwestward down the mountain side, this rock grades perfectly into a medium-grained, gray, biotite granite which contains very few Grenville inclusions, and this rock, in turn, grades perfectly into the typical biotite granite porphyry at the base of the mountain. Passing westward down the mountain side, however, the fine-grained granitic rock at the top gradually becomes coarser grained and contains more numerous and more clearly defined inclusions of Grenville gneisses, with these rocks, in turn, grading into pure biotite-garnet and quartzitic Grenville gneisses at the base of the mountain. Thus we have a perfect transition from the gray, granitic rock into the granite porphyry, on the one hand, and into the Grenville on the other so that there appears to be no escape from the idea that these gray, granitic rocks were formed by actual fusion and incorporation of more or less of the Grenville into the granite porphyry magma. The presence of the inclusions does not necessarily oppose this view because they may well enough simply represent fragments of Grenville which were caught in the granite magma just before consolidation or when the temperature was not high enough actually to melt the fragments. Gray granitic rocks of apparently the same origin are common throughout this mixed gneiss area.

Another interesting mixed gneiss area is the one just north of the village of Horicon. In the vicinity of the quarry, at the base of the mountain, the rock is very typical granite porphyry which contains a few long, narrow, sharply defined, Grenville gneiss inclusions. Going up the mountain side from the quarry, the granite porphyry, which at times (in patches or wide bands) appears typical, is intimately associated with Grenville. This Grenville occurs as large and small inclusions, often sharply defined and nearly always drawn out parallel to the foliation. The included rocks are chiefly banded biotitic, hornblendic, and quartzitic gneisses often in bands from 20 to 30 feet wide. Toward the top of the mountain the rock is mostly like the gray granitic rock already described as occurring at the top of Prospect mountain, and the inclusions are fewer and not so sharply defined. Here again this granitic gneiss appears to be an assimilation product, while farther down the mountain side the temperature seems not to have been high enough to cause any considerable melting or assimilation of the included gneisses.

In the large, mixed gneiss area south of Henderson mountain there are many fine illustrations of very intimately associated Grenville and gray granitic rocks, the Grenville often having been more or less melted into the granites. The granites predominate and some of them at least are thought to be assimilation products. Such phenomena are well exhibited from Igerna southwestward to the river.

In the mixed gneiss area which borders the Chase-Kelm mountain granite porphyry mass on the west, the prevailing rock is a

Plate 3

W. J. Miller, photo

View showing contact between Grenville limestone and granitic syenite as seen from across the Hudson river one-fourth of a mile north of the ferry (southwest of Moon mountain). The smooth ledge at the river's edge on the left and another toward the upper right hand corner are parts of a single mass of syenite mostly concealed by the trees. The other rock is Grenville limestone (white) with numerous closely involved streaks and bands of hornblende (dark) gneiss. The sharp contact between the syenite and Grenville is not well brought out in the picture.

gray, medium-grained, biotitic, granitic gneiss which is intimately associated with some Grenville gneiss. Here again it is quite certain that the granitic gneiss forms a border zone between the granite porphyry and the Grenville, where the former has more or less assimilated some of the latter.

Along the southeastern base of Moon mountain there are excellent exposures of Grenville much cut up by, and often fused into, syenite.

The mixed gneiss area at the southwestern corner of the map affords many fine examples of syenite or granite and Grenville closely involved and fused together. There are also many well-defined inclusions or stringers of Grenville scattered through the igenous rock. These phenomena are especially well shown on Wolf Pond mountain.

The mixed gneiss area which surrounds Heath mountain consists very largely of Grenville gneisses and limestones through which numerous small masses of syenite or granite have been intruded. The most interesting exposures occur along the river for nearly a mile northward from the Ferry. About 1 mile north of the Ferry and on the east side of the river, are great ledges of Grenville limestone and hornblende gneiss, these rocks being badly contorted and broken and containing some patches of good syenite, 10 to 30 feet across, and completely surrounded by either hornblende gneiss or marble. At the same locality a large mass of syenite overlies crystalline limestone and shows the actual sharp contact for fully 100 feet, there being no particular contact phenomena (see plate 3).

About one-half of a mile north of the Ferry, and along the road, there are several very interesting inclusions of Grenville limestone in the syenite. Two of these inclusions (one being 3 or 4 feet across and the other 20 feet long and 2 to 4 feet wide) are completely surrounded by, and in very sharp contact with, the syenite. The limestone is coarse, crystalline, calcitic, and contains graphite. At the contacts small green pyroxene crystals are often common.

The small area near Daggett pond is of interest because the Grenville is there interbanded with granitic syenite, the bands of each rock often being 20 to 40 feet wide and the contacts pretty sharp. One Grenville band is a garnet, pyroxene gneiss, while others are biotite or hornblende gneisses.

The area of mixed gneisses lying to the east of Stockton and Gage mountains shows numerous exposures of closely associated syenite or granite and Grenville gneisses in about equal amounts. There are few suggestions of assimilation, the igneous and sedimentary rocks generally retaining their characteristic features.

The other mixed gneiss areas require no special mention.

THE GABBRO AND ITS DERIVATIVES

Because of the large number of exposures, mode of occurrence, excellent outcrops, frequent contacts against the country rocks, and the remarkable variations in composition and appearance the gabbros are of unusual interest and will be described in considerable detail.

Mode of occurrence

The gabbro and its derivatives nearly always occur in the form of small stocks or bosses rather than as true dikes, their length ranging from 30 to 40 feet to about a mile, and with widths up to three-fourths of a mile. Sixty-one separate gabbro bodies were found and are shown on the geologic map. In spite of the detailed field work a few others have probably escaped the writer's notice.

The ground plan, as represented on the geologic map, is almost invariably elliptical, though sometimes approaching the circular. When the contact with the country rock is carefully traced out it is commonly found to be sharp and shows smooth or flowing outlines against the country rock. In only two or three cases do the gabbro masses approach the true dikelike form, and in each of these cases fine-grained tongues were found to extend into the surrounding rock. One stock, one and one-third miles southeast of Chestertown, shows several such tongues, one of them (1 to 6 inches wide) clearly cutting the granite porphyry for 30 feet. Other and smaller gabbro dikes at the summit of Hackensack mountain, and 1 mile south of South Horicon show a number of such fine-grained tongues.

At one place in the dike or boss which crosses the road 1¼ miles a little west of south of South Horicon, fairly coarse-grained gabbro is in sharp contact (for 6 or 8 feet) with fine-grained gabbro, the latter becoming coarser grained again away from the contact. This suggests a second intrusion of the gabbro after the first but after the first had cooled.

It is a striking fact that in spite of many excellent contacts which were observed, such dikelike tongues are so rare. As Harker says[1]: "Although most of the bodies of granite and other plutonic rocks

[1] Natural History of Igneous Rocks, 1909. p 86.

which have been loosely described as bosses, and so rendered in ideal sections, are doubtless of laccolitic or other stratiform shape; some, not of the largest dimensions, appear to have a pluglike form, with more or less vertical boundaries." The small stocks or bosses of the North Creek region are certainly of this pluglike or pipelike form as shown by the very character of their eroded cross-sections and also by the vertical contacts with the country rock. Among the many fine contacts which came under the writer's observation, not a single exception to the rule of vertical or practically vertical contacts was noted.

In most cases the long axes of the stocks lie parallel to the foliation of the inclosing rock, though there are some notable exceptions. It would therefore seem that the molten intrusives generally followed the lines of least resistance but, even in these cases, the broad ends of the stocks cut sharply across the foliation bands, sometimes for a distance of several hundred yards. Such a phenomenon is well exhibited at the south end of the large stock just south of Mountain Spring lake where a big quarry has been opened up along the contact.

The gabbro stocks are not at all uniformly distributed over the area of the quadrangle, the largest number being confined to a nearly north-south belt with a width of from 3 to 5 miles and extending through the middle of the quadrangle. This belt roughly corresponds to the general strike of the foliation. A secondary belt, about 1 mile wide and 5 miles long near the middle eastern boundary of the sheet, contains a dozen small stocks. With a single small exception the whole western side of the quadrangle is devoid of gabbro masses. In the northeastern portion a few stocks occur, but they may really belong to some other belt not yet mapped. Thus we see that the gabbro intrusions were limited to rather well-defined areas or belts.

Among these gabbro stocks four types of occurrence are especially noteworthy as follows: (1) The normal, dark, basic gabbro with diabasic texture and usually homogeneous throughout; (2) gabbro chiefly of the normal type but with irregular patches or masses of lighter colored rocks of syenitic or dioritic make-up, these patches blending with the normal gabbro; (3) the whole stock made up of lighter colored, more acidic rock; and (4) any one of the above types with blocks or inclusions of the country rock. These four types are all primary variations. Examples of the last three types will be given later.

Megascopic features

The gabbro and its derivatives present a truly remarkable number of facies or varieties clearly visible to the naked eye. The coarseness of grain varies from the merest fraction of a millimeter to fully an inch (for example, the stock on the south side of Loon lake). The fine-grained portions are confined to the borders of the stocks or the few branching tongues and were caused by the more rapid chilling of the rock in those positions. Even the finest grained rocks, however, are holocrystalline. As a rule the coarseness of grain increases toward the interior of the masses, though often medium to coarse grained rocks extend to the very contact. The typical or prevailing gabbro shows a medium grain; that is, the grains are from 1 to 5 millimeters across.

The texture varies from coarse to medium to fine-grained granitoid, to medium to coarse-grained diabasic (ophitic). The gabbro from the stock on the south side of Loon lake is an excellent example of diabase texture in which the feldspar laths attain a length of an inch or more. The typical gabbro always exhibits the diabasic texture.

In color, the gabbro and its derivatives range from nearly black through dark to light gray, the darker varieties often showing a slight reddish tinge due to the presence of garnets. The gray rocks all belong to the more acidic (dioritic and syenitic) facies described below. In one case a greenish gray color was noted. The very dark color of the typical gabbro is due to the fact that the feldspars are so charged with tiny black inclusions.

In the typical gabbros the minerals commonly recognizable with the naked eye or hand lens are plagioclase, pyroxene, hornblende, garnet, biotite, and ilmenite, while in addition to these orthoclase and quartz may often be seen in the more acidic phases.

Except for the rather common presence of highly gneissoid to even schistose amphibolite borders, the stocks of typical gabbro are practically devoid of gneissoid structure. Some of the lighter colored, more acidic phases, however, show fairly well-developed foliation.

It is important to note that many of the above described variations may be found within a single stock as, for example, south of Mountain Spring lake. The following statements from Smyth's description of a similar western Adirondack gabbro[1] fittingly apply here: "These [primary] changes in character take place very suddenly, and the different phases are most irregularly distributed,

[1] Amer. Jour. Sci., April 1896, p. 273-74.

Plate 4

W. J. Miller, photo

A typical exposure of gabbro as seen three-fourths of a mile south-southwest of Loon Lake mountain. Note the very irregularly jointed character of the rock and the whitish mass of pegmatite cutting the gabbro in the lower left-hand corner.

seeming to conform to no law. . . . These primary variations in the rock suffice to give considerable diversity to different portions within a limited area, but this diversity is greatly intensified by certain secondary modifications of structure and composition. As a result of the combined effect of primary and secondary variations, it would be easy to collect, within an area of a few square rods, a half dozen or more specimens whose appearance even in thin section would scarcely suggest that they had any connection with one another." Cushing says [1] of the Adirondack gabbros in general that they show much variation, both primary and secondary, from place to place. Both of these investigators proceed to discuss the secondary variations and their causes but, so far as the writer is aware, little or no attention has been given to the causes of the primary variations which will be considered below.

Microscopic features

Mineralogical composition. The following table will serve to show the great range in mineralogical composition of the gabbro and its derivatives. The figures refer to percentages by volume and are meant to be close approximations only.

TABLE 4

Mineralogical composition of the gabbro and its derivatives

	Slide No.	Orthoclase	Plagioclase	Hornblende	Hypersthene	Augite	Diallage	Ilmenite	Pyrite	Biotite	Garnet	Quartz	Zoisite	Zircon	Apatite	Olivine	Titanite
1	45	...	Lab. 50	...	15	...	...	3	.....	9	8	....	....	.....	.....	15	.....
2	6	...	Lab. 50	8	17	...	7	1	little	8	8	....	....	.....	.....	....	.....
3	2	4.5	Ol-Lab. 38	27	12.5	3	...	2.5	1	7	3.5	....	....	.....	little	....	.....
4	46	15	Lab. 30	10	15	...	...	5	.....	5	20	....	....	.....	.....	....	.....
5	42	10	Ol-Lab. 40	25	....	...	23	little	little	1	little	....	....	.....	.....	....	.....
6	47	10	Ol-Lab. 30	25	20	...	10	1	.....	2	2	....	....	.....	.....	....	.....
7	1	5	Ol-Lab. 40	16	25	...	...	1	.....	5	8	....	....	.....	.....	....	.....
8	60	20	Ol-Lab. 40	10	14	...	...	1	1	2	10	1	1	.....	.....	....	.....
9	5	5	Ol-Lab. 45	14	20	...	...	2	1	6	2	....	....	.....	.....	....	.....
10	49	32	Ol-Lab. 10	45	....	...	...	2	little	6	5	....	....	little	.....	....	.....
11	3	32	Ol-And 20	25	....	...	...	5	.....	5	.....	10	1	.....	little	....	little
12	4	15	Ol-Lab. 57	15	....	...	...	2	1	10	.....	....	....	little	.....	....	.....
13	44	50	Ol-Lab. 15	20	....	8	2	little	little	...	1	2	....	little	little	....	.....
14	43	45	Ol-And 15	28	....	2	...	1	little	...	.....	8	....	.....	little	....	.....

Perhaps the most striking feature brought out by this table is the range of rock types, through many intermediate phases, from a very basic olivine norite to quartz-hornblende syenite. Thus, no. 1 is an olivine norite; nos. 2, 3, 4, 6, 7, and 9 are hornblende norites;

[1] N. Y. State Mus. Bul. 95, p. 328.

no. 5 is a hornblende gabbro; no. 8 is a gabbro-diorite; nos. 10, 13, and 14 are hornblende syenites; no. 11 is a monzonite; and no. 12 is a diorite. The large number of minerals — sixteen in all — is also notable. It is also important to note that in the above table, nos. 3 and 4, 7 and 8, 9 and 10, and 11 and 12, respectively, come from single stocks.

The predominating mineral is feldspar which ranges from labradorite alone in some rocks through all stages, to those rocks which are rich in the more acid plagioclases or orthoclase.

Hornblende, generally in considerable amount, occurs in all but one (no. 1) of the rocks. Sometimes it makes up a fourth or more of the whole rock. Much of the hornblende in the more basic rocks, at least, is of secondary origin and forms corrosion rims (below described) around other minerals. Its color varies from green to brown. In one slide many examples of the transition from pyroxene to hornblende are perfectly shown.

Hypersthene, with a single exception (no. 5), is an important constituent of all the more basic types. It is almost always highly granulated and with pleochroism from greenish gray to pale reddish brown.

Augite and diallage of greenish gray color and with good cleavage, are only occasionally present and rarely as important constituents.

Ilmenite is invariably present in amounts up to 5 per cent and often with transition to leucoxene.

Pyrite in small amount seldom fails.

Biotite and garnet of the usual sort, though mostly in tiny flakes or grains, are present in moderate quantity in all but certain of the more acidic facies. The unusually high percentage of garnet in no. 4 is a fine-grained border phase of a stock.

Quartz, in small irregular shaped grains, is wholly confined to the acidic types.

Zoisite, in small stout prisms, sometimes makes up about 1 per cent of the rock.

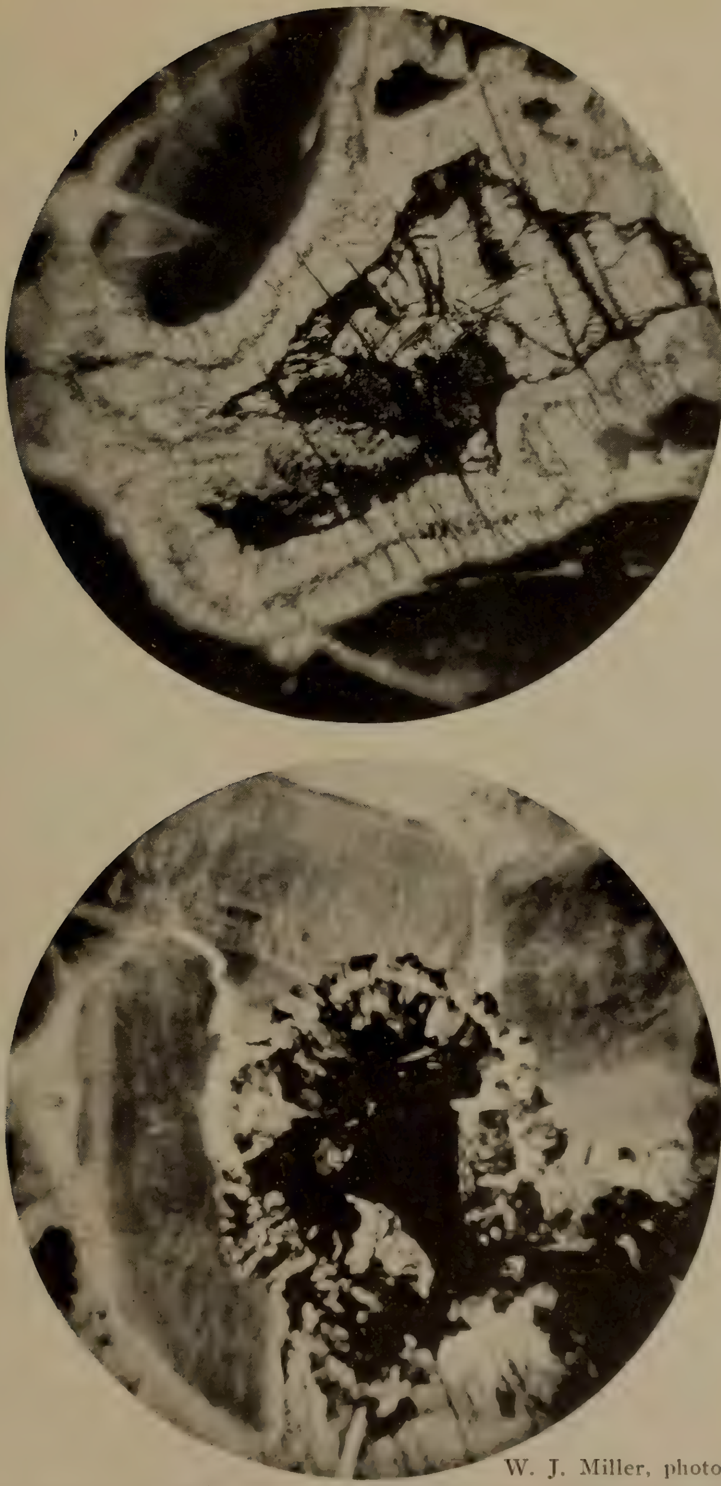
Zircon and apatite, in very small quantities, are almost wholly confined to the acidic facies. The usual absence of the apatite from the typical gabbros is especially noteworthy.

Olivine was noted in but one case (no. 1) and this in the only rock from which hornblende is missing.

Titanite in a few small grains was noted in no. 11.

Reaction or corrosion rims. Reaction or corrosion rims, which are well known in many basic rocks, are exhibited in a truly re-

Plate 5



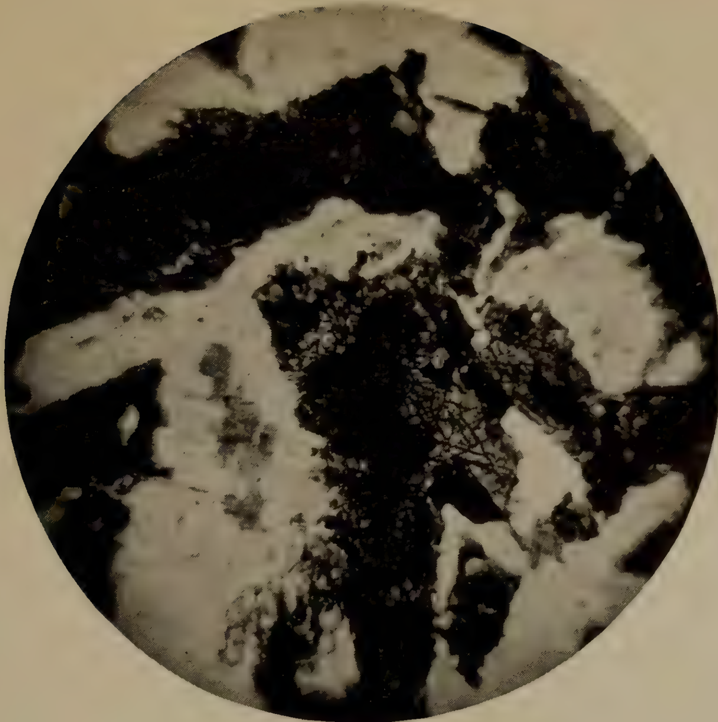
W. J. Miller, photo

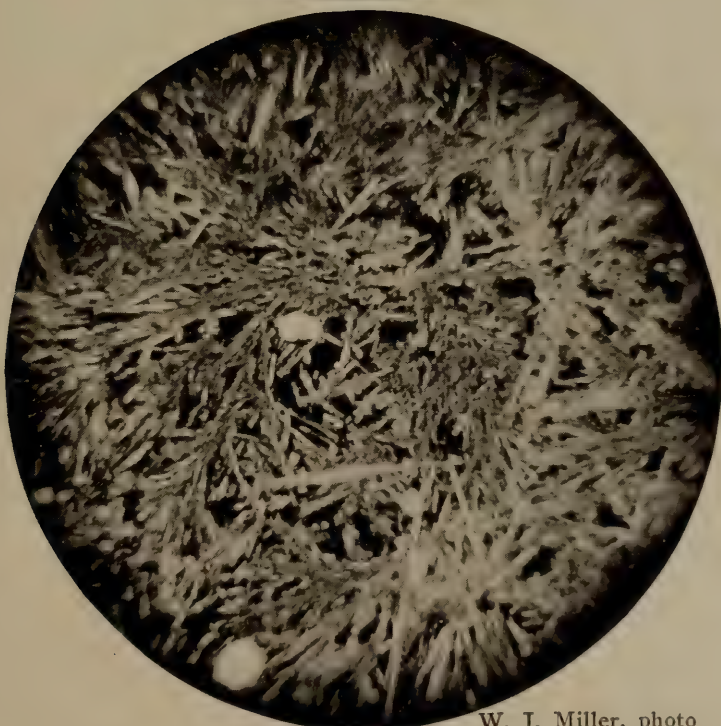
Photomicrographs of thin sections of gabbro from the stock on the south side of Loon lake. Each magnified 15 diameters.

In the upper figure the large central mineral is olivine completely surrounded by successive rims of hypersthene, biotite (narrow and dark), and garnet. Surrounding all are broad laths of labradorite.

In the lower figure the large, black, central mineral is ilmenite, followed by successive rims of biotite, hornblende, garnet and biotite. The second and third — biotite and hornblende — rims are not separable in the photograph. Surrounding all are labradorite crystals.

Plate 6





W. J. Miller, photo

Upper figure. Photomicrograph of thin section of gabbro from the top of Hackensack mountain. Magnified 15 diameters. The central mineral, with good cleavages nearly at right angles, is diallage which is almost completely surrounded by a zone of hornblende (darker colored). As seen under the microscope the rim is very clearly defined. The light gray minerals are basic plagioclase. The diabasic texture of the rock is well shown.

Lower figure. Photomicrograph of a thin section of diabase from the dike one and one-half miles southeast of Johnsburg. Magnified 15 diameters. The long, slender prisms with transverse cracks are augite; the smaller, more numerous, prisms arranged in more or less sheaf like bundles are basic plagioclase; the black areas are glassy groundmass; and the four small, white rounded areas represent quartz, probably of secondary origin.

markable manner in the North Creek region gabbros. In the examples most often described the core is olivine, but in the gabbros here considered the writer has observed cores of olivine, hypersthene, ilmenite, augite, and diallage with from one to five distinct, successive rims surrounding the cores. Professor Kemp has described [1] and figured a number of interesting examples of reaction rims observed in certain gabbros of the eastern Adirondacks.

The following nine types of reaction rims comprise most of those noted by the writer in the North Creek gabbros:

1 Ilmenite surrounded by hornblende.

2 Diallage surrounded by hornblende.

3 Augite surrounded by hornblende.

4 Hypersthene surrounded by garnet.

5 Hypersthene surrounded by successive zones of biotite and hornblende.

6 Olivine with successive zones of hypersthene, hornblende, and garnet.

7 Olivine with successive zones of hypersthene, biotite, and garnet.

8 Hypersthene with successive zones of biotite, feldspar, and garnet.

9 Ilmenite with successive zones of biotite, hornblende, garnet, and biotite.

In nearly all cases the material immediately inclosing the rims is feldspar which, in a sense, adds another zone to each of the above. No. 6 is like one of those described by Kemp. No. 9 is a remarkable example and, because of its additional outer rim of biotite, is even more interesting than a case described by Lacroix.[2] Some of the others may be new examples. The material of each rim appears to be highly granulated or at least made up of numerous small grains. It seems certain that where hypersthene envelops olivine, the former has secondarily developed from the latter. The olivine cores are of very irregular shapes and in all sizes. Where hypersthene forms the core it is probable that all the original olivine has been altered to hypersthene. The common occurrence of hornblende rims around pyroxene strongly suggests the derivation of the former from the latter. Garnet is almost invariably in contact with feldspar which suggests the partial formation, at least, of the garnet from the feldspar.

[1] Geol. Soc. Amer. Bul., 1894, 5:218-21.

[2] Bul. Soc. Min. Fr., 1889, 12:232.

Chemical composition, norm, and mode

Excellent exposures of what is regarded as very typical gabbro occur in the railroad cut 1¼ miles south of The Glen. This rock has been analyzed for the writer by Prof. E. W. Morley.

Table 5

Chemical composition and norm

	Per cent	Mol	Ilm	Ap	Na Cl	Pyr	Orth	Alb	An	Mag	Diop	Hyp	Ol
SiO_2	46.40	.773					72	258	168		152	69	54
Al_2O_3	14.17	.139					12	43	84				
Fe_2O_3	2.03	.013								13			
FeO	13.12	.182	38			2				13	76	69	108
MgO	4.94	.124											
CaO	9.65	.172		20					84		68		
Na_2O	3.14	.050			7			43					
K_2O	1.12	.012					12						
H_2O+	.02												
H_2O-	.25												
TiO_2	3.03	.038	38										
P_2O_5	.80	.006		6									
Cl	.15	.004			15								
MnO	.44	.006									6		
S	.14	.005				5							
BaO	.18	.001									1		
SrO	.10	.001									1		
F	.04	.002											
ZrO_2	.05	.000											
	99.77												

Orth	6.67
Alb	22.53
Anor	23.35
NaCl	.82
Ilm	5.78
Mag	3.02
Pyr	.24
Apat	2.02
Diop	17.53
Hyper	8.02
Oliv	9.32
H_2O+ZrO_2	.32
	99.62

Sal. = 53.37 Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{53.37}{45.93} < \frac{5}{3} > \frac{3}{5}$ = III, Salfemane

Order, $\frac{QL}{F} = \frac{.82}{52.55} < \frac{1}{7}$ = 5, Gallare

Fem. = 45.93 Rang, $\frac{K_2O^1 + Na_2O^1}{CaO^1} = \frac{62}{84} < \frac{5}{3} > \frac{3}{5}$ = 3, Camptonase

Subrang, $\frac{K_2O^1}{Na_2O^1} = \frac{12}{50} < \frac{3}{5} > \frac{1}{7}$ = 4, Camptonose

TABLE 6

Mode of gabbro

	Units measured	Rel. vols.	S. G.	Units by weight	Percentage weights
Plagioclase	2 805	38.09	2.66	7 461	32.72
Orthoclase	335	4.55	2.56	858	3.77
Hornblende	1 990	27.02	3.20	6 368	27.92
Hypersthene	932	12.65	3.50	3 262	14.30
Biotite	505	6.86	3.20	1 616	7.09
Augite	227	3.08	3.30	749	3.29
Garnet	265	3.59	3.70	980	4.30
Ilmenite	184	2.50	5.17	951	4.17
Pyrite	95	1.29	5.00	475	2.08
Apatite	26	.35	3.20	83	.36
	7 364	99.98	....	22 803	100.00

Under the old qualitative system the rock is a hornblende norite, while according to the quantitative system it is a hornblende-camptonose. In thin-section the plagioclase is seen to range from oligoclase to labradorite, and the analysis and mode show that the average composition is that of a basic andesine. The high TiO_2 of the analysis shows either ilmenite or very titaniferous magnetite, the ilmenite being far more probable because of the difficulty of otherwise accounting for such a low content of Fe_2O_3.

TABLE 7

Adirondack gabbro analyses compared

	1	2	3	4	5	6	7
SiO_2	46.40	47.88	47.42	47.16	46.74	44.97	44.77
Al_2O_3	14.17	18.90	17.34	14.45	16.63	15.40	12.46
Fe_2O_3	2.03	1.39	4.91	1.61	2.17	2.29	4.63
FeO	13.12	10.45	10.22	13.81	10.60	12.39	12.99
MgO	4.94	7.10	5.21	5.24	6.11	10.89	5.34
CaO	9.65	8.36	8.09	8.13	8.66	7.50	10.20
Na_2O	3.14	2.75	3.48	3.09	3.81	3.02	2.47
K_2O	1.12	.81	1.89	1.20	.86	.56	.95
H_2O	.27	.61	1.13	.60	.85	.75	.60
CO_2	.....	.12	.....	.35	.07	.23	.37
TiO_2	3.03	1.20	3.60	3.37	2.54	1.18	5.26
P_2O_5	.80	.20	.06	.57	.33	.14	.28
S	.14	.07	.....	.14	.11	.06	.26
MnO	.44	.16	.06	.24	.26	.22	.17
NiOCoO	.....	.02	.....	.02	.03	.02	.....
V_2O_5	.....	.....	.....	.....	.....	.02	.....
Cl	.15	.....	.21	.....	.....	.....	.....
F	.04	.....	.....	.....	.....	.....	.....
BaO	.18	.....	.04	.....	.....	.....	.....
SrO	.10	.....	.....	.....	.....	.....	.....
ZrO_2	.05	.....	.....	.....	.....	.....	.....
	99.77	100.02	100.01	99.98	99.77	99.72	100.75

1 One and one-quarter miles south of The Glen, Warren County. E. W. Morley, analyst. Described by W. J. Miller.

2 Split Rock Mine, Westport, Essex county. W. F. Hillebrand, analyst. Described by J. F. Kemp.

3 Dike near Nicholville, St Lawrence county. E. W. Morley, analyst. Described by H. P. Cushing.

4 Woolen Mill, one mile west of Elizabethtown, Essex county. W. F. Hillebrand, analyst. Described by J. F. Kemp.

5 Two miles south of Elizabethtown, Essex county. W. F. Hillebrand, analyst. Described by J. F. Kemp.

6 Same exposure as no. 5. W. F. Hillebrand, analyst. Described by J. F. Kemp.

7 Lincoln Pond, Essex county. George Steiger, analyst. Described by J. F. Kemp.

These analyses show the Adirondack gabbros to be very similar in composition, the only notable variations being in the contents of Al_2O_3, MgO, and TiO_2. The North Creek sheet gabbro (no. 1) agrees most closely with no. 4.

Cause of the primary variations

In attempting to account for the primary variations of these gabbros, the writer believes there is strong evidence favoring the application, to a greater or lesser extent, of Daly's magmatic stoping and assimilation hypothesis to the solution of the problem. For full discussions of this hypothesis the reader is referred to Daly's original papers.[1] Some of the more fundamental principles are as follows: Batholithic (or stock) magmas have reached their present positions chiefly by the successive engulfment of blocks of country rock (xenoliths) stoped or broken out of the roof and walls of the magma chamber; the xenoliths become immersed and dissolved in the depths of the original magma with the formation of a secondary magma; when the magma becomes very viscous (due to cooling) the xenoliths neither sink nor become dissolved.

Only a summary of the application of these principles to the North Creek gabbros will here be given, the writer having more fully discussed this matter in a recent paper.[2]

We have shown that the gabbro stocks are of the pluglike or pipelike form with practically vertical boundaries. Such igneous masses were not intruded by simply displacing or pushing aside the country rock, but rather there was a process of replacement. Thus the mode of occurrence of these stocks furnishes strong evidence in favor of magmatic stoping as an important factor in the intrusion.

The very presence of the inclusions as xenoliths proves that the process of stoping or rifting off blocks from the chamber vault actually did take place to some extent at least, and this when the magma had cooled to a highly viscous condition and hence had comparatively little power to stope and too low a temperature to assimilate the blocks. Thus the occurrence of such xenoliths is quite in harmony with Daly's hypothesis.

The writer believes that the more acidic patches or masses (already described) within the gabbro stocks are evidence of chemical change within the intrusive magma due to solution or partial solution and diffusion of blocks of country rock. In such cases the magma was just hot enough to melt or partially melt and only partially diffuse the blocks of country rock.

Five or six of the stocks are composed wholly of rocks more acidic than the typical gabbro. In the earlier stage of very active intrusion the invading magma was more thoroughly molten and as the blocks of country rock were stoped off they sank in the magma and became thoroughly dissolved and diffused. Since the country rock was nearly always syenite, granite, or gneiss the magma became more and more acidic.

1 Amer. Jour. Sci. 1903, 15:269–98; Amer. Jour. Sci. 1903, 16:107–26; Amer. Jour. Sci. 1908, 26:17–50.

2 Jour. of Geol. 1913, 21:160-80.

Contact phenomena

A very interesting case of contact metamorphism produced by the action of the gabbro on granite may be seen at the southern end of the large stock just south of Mountain Spring lake. In a recently opened stone quarry, and about 75 feet higher than the road on its east side, the rocks are laid bare in such a manner that an excellent opportunity is afforded for the study of the contact zones. The following nine zones, passing from the typical gabbro to the typical granite (country rock), have been studied in detail in the field and by means of thin sections and hand specimens.

Zone 1 Typical gabbro well within the gabbro stock. Nearly black, medium grained, and with diabasic texture. (Gradation from 1 to 2)

Zone 2 Syenitic phase of gabbro stock and within a few feet of the granite. Dark gray, medium grained, and with granitoid texture. (Gradation from 2 to 3)

Zone 3 One to three feet wide. Biotite-schist, border phase of the gabbro stock. Secondary origin. (Sharp contact between 3 and 4, gabbro and granite)

Zone 4 Four inches wide. Hornblendite phase of the country rock. Nearly black, medium grained, banded parallel to gabbro-granite contact. (Fairly sharp contact between 4 and 5)

Zone 5 Six inches wide. Monzonitic phase of the country rock. Yellowish gray, medium to coarse grained, and banded parallel to the main contact. (Not very sharp contact between 5 and 6)

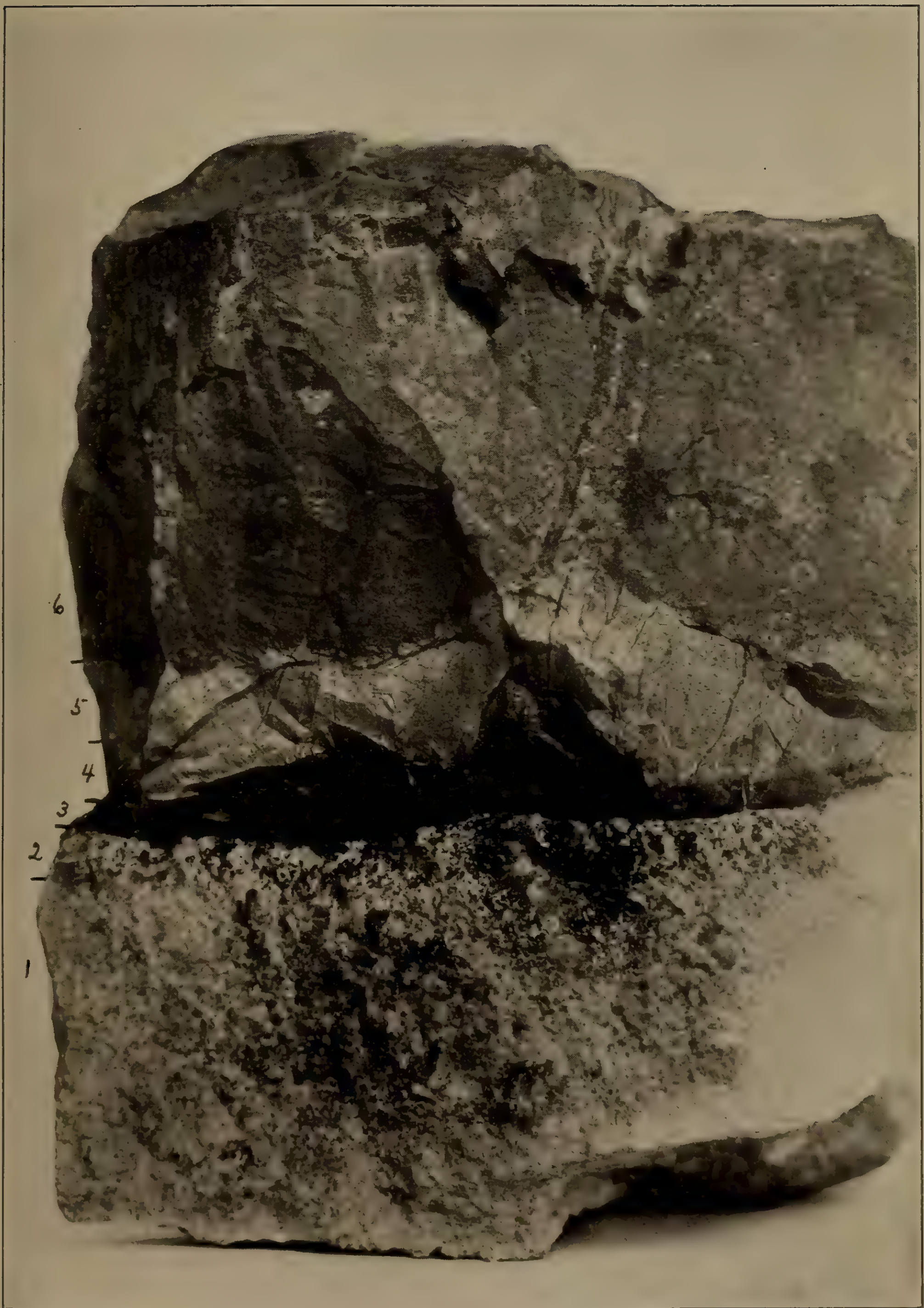
Zone 6 Fifteen to eighteen inches wide. Chiefly hornblendite phase of the country rock but with numerous very narrow streaks of no. 5. Nearly black, medium grained, and banded parallel to the main contact. (Sharp contact between 6 and 7)

Zone 7 Three and one-third feet wide. Monzonitic phase of the country rock like no. 5. Yellowish gray, fairly coarse grained, and banded parallel to the main contact. (Not very sharp contact between 7 and 8)

Zone 8 Seven feet wide. Monzonitic phase of the country rock. Light gray, fairly coarse grained, and not banded. (Gradation from 8 to 9)

Zone 9 Typical (country rock) granite. Pink, medium grained, and very gneissoid but with gneissic bands striking at almost right angles to the main contact.

Plate 7



W. J. Miller, photo

Photograph of a hand specimen showing the contact between diabase and Grenville limestone from the Asbestos mine three-fourths of a mile southeast of Thurman village. Nearly natural size. The zones numbered on the left side correspond to those described on page 43. Zone 4 is scarcely brought out in the picture and zone 3 is best shown on the right side.

TABLE 8

Mineralogical composition of each contact zone

Zone no.	Orthoclase	Microperthite	Microcline	Plagioclase	Hornblende	Hypersthene	Quartz	Biotite	Magnetite	Zircon	Zoisite	Pyrite	Garnet
1	5	....	....	Ol-lab 45	14	20	....	6	2	......	......	1	2
2	32	....	....	Ol-lab 10	45	....	....	6	2	little	......	little	5
3	Biotite-schist with some feldspar												
4	Like No. 6												
5	28	....	....	Ol-and 50	20	....	1	....	½	little	little	......	....
6	15	....	....	Ol-and 5	72	....	....	....	7	½	½	little	
7	Like No. 5												
8	33	....	....	Ol-and 55	10	....	1	....	....	½	½	little	
9	40	15	4	Ol-and 5	5	....	30	....	½	little	......	......	½

A noteworthy feature is the fact that the strike of the foliation of the very gneissoid country rock is nearly at right angles to the gabbro-granite contact, while the clearly defined contact zones are parallel to the contact.

Other features of special interest are the syenitic border (except for the secondary biotite-schist) of the gabbro near the contact, and the almost complete absence of quartz from the granite within a dozen feet of the main contact. Thus the country rock (granite) is distinctly more basic near the contact, while the gabbro is distinctly more acidic near the contact.

Whether these interesting endomorphic and exomorphic changes are to be accounted for on the basis of assimilation of some of the country rock during the intrusion of the gabbro, or on the basis of the action of vapors from the intrusive, it at least appears quite certain that the gabbro must have been considerably superheated in order to have so notably affected the granite. As judged by the mode of occurrence of the gabbro stock, the stoping hypothesis recently advocated by Daly or the hypothesis of marginal assimilation might be applied to account for the more acidic border phase of the gabbro, but the sharp contact of the gabbro against the granite would seem to preclude the possibility of accounting for the more basic contact zones of the country rock on the basis of actual assimilation of some of the granite by the gabbro.

PEGMATITE

The most interesting thing about the pegmatite is its distribution, because it is very commonly directly associated with the gabbro masses. Many times the pegmatite, in the form of dikes or veins, may be seen cutting the gabbro (see plate 4) and hence the younger age of the pegmatite. This direct association of the very acid pegmatite with basic gabbro and its age intermediate between the basic intrusives — gabbro and diabase — are rather anomalous features for which the writer can offer no explanation.

Among other places where pegmatite may be seen cutting the gabbro are: (1) at the top of Hackensack mountain; (2) 1¼ miles south-southeast of Potter mountain; (3) 1¼ miles a little east of north of The Glen; (4) 1 mile south-southeast of The Glen; (5) 1⅓ miles northeast of Pottersville; (6) 1⅔ miles southeast of Chestertown; (7) 2½ miles southeast of Chestertown; and (8) 2¾ miles south-southeast of Chestertown. At most of these places the gabbro is shot through with small pegmatite veins. At the fourth named locality one dike is 50 feet long and 25 feet wide and very rich in big orthoclase and albite feldspar crystals. At the seventh named locality a small pegmatite dike contains fine crystals of biotite, muscovite and black tourmaline. At the sixth and eighth named localities there are pegmatite dikes 50 to 100 feet long with books of muscovite up to 5 or 6 inches across at the eighth locality.

Large pegmatite dikes are not common away from the gabbro, there being but two examples worthy of mention namely: just east of the old garnet mine south of Daggett pond where there are many poorly formed black tourmaline crystals up to 6 inches long, and one-quarter of a mile above the mouth of Mill creek where there is a dike 200 feet long and 40 feet wide in granitic syenite.

DIABASE

Mode of occurrence and distribution

In striking contrast with the neighboring gabbro, the diabase invariably occurs in typical dikes which have clearly broken through narrow fissures in the country rock. They vary in length from 20 or 30 feet to 200 yards, and in width from 5½ inches to 40 feet.

The chief features of occurrence are brought out in the following description of the largest dike of the region which lies at the western base of Heath mountain or 3 miles west-northwest of Warrensburg. This dike has a maximum width of 40 feet and a length of 200 yards. It is fine to medium grained toward the interior and very fine grained along the borders. It breaks through both Grenville and granite gneisses and the contacts are everywhere perfectly sharp, there being no evidence whatever of contact metamorphism. A number of small tongues, from 1 inch to 3 or 4 feet wide, branch off the large dike and extend as much as 25 or 30 feet into the country rock. One of these branches cuts a pegmatite dike and another cuts Grenville limestone. This large dike strikes across the foliation almost at right angles.

One and one-half miles southeast of Johnsburg a diabase dike, 2½ feet wide and 60 feet long, cuts Grenville quartzite parallel to the foliation. All of this rock is fine grained but exceptionally so at the contacts, and on one side an inch wide zone of basaltic glass or obsidian is perfectly developed with some very small tongues of glass extending into the country rock.

A typical diabase dike 4 feet wide cuts the gabbro stock three-quarters of a mile south of Warner pond. The dike has fine grained borders, sharp contacts against the gabbro, and is clearly traceable for 150 feet or more.

In all eleven diabase dikes were found, being well scattered over the quadrangle. Most of them cut across the foliation of the country rock at high angles, thus differing from the gabbros, and they probably have been forced up along joint planes. In nine of the eleven occurrences the dikes strike northeast and southwest which is quite the rule for such dikes in the eastern Adirondacks. So far as can be determined, these dikes all come up vertically through the country rock.

Megascopic and microscopic features

The diabase is a very dark bluish gray to almost black rock which, in all exposures, is hard and fresh except for the immediate surface which is often weathered to reddish brown.

The granularity and texture vary from glassy to very fine grained to medium grained diabasic, the finer grained rock being wholly confined to the borders and the diabasic texture nearly always being just visible to the naked eye in the typical medium grained rock. Except for the above named differences the diabase shows no facies whatever visible to the naked eye, and this again is in marked contrast with the gabbros. The diabase is wholly devoid of any metamorphism and inclusions of country rock are never found. The only minerals recognizable by the naked eye are the tiny feldspar laths and an occasional pyrite speck.

The whole range in mineralogical composition is brought out in the following table:

TABLE 9

Mineralogical composition of the diabase

	Slide no.	Andesine to labradorite	Augite	Biotite	Ilmenite	Pyrite	Glassy ground mass	Quartz	Apatite
1	8	47	25	22.5	4	½	......	little	little
2	48	55	37 Mostly chlorite		6	little	......	2	little
3	7	55	40 Mostly chlorite.		5	....	......	little	little
4	10	5	5	......	many specks	....	85	....	....
5	9	55	14	......	5	little	25	1	....

The remarkable similarity in composition is a striking feature. Nos. 1, 2, and 3 are typical holocrystalline diabases from widely separated dikes. Nos. 4 and 5 represent finer grained or border phases and have more or less glassy ground mass. No. 5 presents a striking appearance under the microscope because the feldspar crystals which are incipient and almost indeterminate tend toward sheaflike bundles (see plate 6, lower figure).

Number 1 of table 9, which may be regarded as typical of all the diabases, is from the large dike (above described) at the base of Heath mountain. The fine to medium grained rock shows an excellent diabasic texture visible even to the naked eye. Judging by the extinction angles, the broad laths of somewhat decomposed plagioclase range from andesine to labradorite in composition. Pale reddish brown augite, in stout prisms, shows a very faint pleochroism. It exhibits good cleavage and sometimes good crystal boundaries. The biotite is much changed to chlorite and stained with black iron oxid. The ilmenite often shows transition to leucoxene. Apatite occurs in tiny needles, and pyrite and quartz in small irregular grains, the latter being probably of secondary origin.

Chemical composition, norm, and mode

The diabase from the dike at the western base of Heath mountain has been analyzed for the writer by Prof. E. W. Morley.

TABLE 10

Chemical composition and norm of diabase

	Per cent	Mol	Ilm	Apat	Fluor	Na Cl	Orth	Alb	An	Mag	Diop	Hyper	Quartz
SiO_2	50.57	.843	....	....	....	....	120	276	134	....	126	153	34
Al_2O_3	13.58	.133	....	....	....	....	20	46	67	....	....	....	....
Fe_2O_3	3.26	.020	....	....	....	....	....	....	....	20	....	....	....
FeO	10.09	.140	33	....	....	....	....	....	....	20	26	61	....
MgO	4.98	.124	....	....	....	....	....	....	....	....	37	87	....
CaO	7.67	.137	....	7	2	....	....	....	67	....	61	....	....
Na_2O	2.92	.047	....	....	....	1	....	46	....	....	....	....	....
K_2O	1.89	.020	....	....	....	....	20	....	....	....	....	....	....
H_2O+	.16	....	....	....	....	....	....	....	....	....	....	....	....
H_2O-	.94	....	....	....	....	....	....	....	....	....	....	....	....
TiO_2	2.68	.033	33	....	....	....	....	....	....	....	....	....	....
P_2O_5	.28	.002	....	2	....	....	....	....	....	....	....	....	....
Cl	.09	.002	....	....	....	2	....	....	....	....	....	....	....
F	.09	.005	....	1	4	....	....	....	....	....	....	....	....
MnO	.36	.005	....	....	....	....	....	....	....	....	....	5	....
BaO	.09	.001	....	....	....	....	....	....	....	....	1	....	....
SrO	.10	.001	....	....	....	....	....	....	....	....	1	....	....
S	.03	....	....	....	....	....	....	....	....	....	....	....	....
Total	99.78												

Qtz	2.04	Sal. = 56.01
Orth	11.12	
Alb	24.10	
Anor	18.63	
NaCl	.12	
Mag	4.64	Fem. = 42.34
Ilm	5.02	
Apat	.67	
Fluor	.16	
Diop	14.44	
Hyper	17.41	
H_2O+S	1.13	
Total	99.48	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{56.01}{42.34} < \frac{5}{3} > \frac{3}{5}$ = III, Salfemane

Order, $\frac{\text{QL}}{\text{F}} = \frac{2.26}{53.85} < \frac{1}{7}$ = 5, Gallare

Rang, $\frac{K_2O^1 + Na_2O^1}{CaO^1} = \frac{67}{67} < \frac{5}{3} > \frac{3}{5}$ = 3, Camptonase

Subrang, $\frac{K_2O^1}{Na_2O^1} = \frac{20}{47} < \frac{3}{5} > \frac{1}{7}$ = 4, Camptonose

TABLE 11

Mode of diabase

	Units measured	Rel. vols.	S. G.	Units by weight	Percentage weights
Plagioclase	2 027	46.88	2.66	5 392	40.78
Biotite	975	22.55	3.20	3 120	23.59
Ilmenite	168	3.88	5.17	868	6.56
Augite	1 090	25.21	3.30	3 597	27.20
Pyrite	30	.69	5.00	150	1.13
Quartz	26	.60	2.65	69	.52
Apatite	8	.18	3.20	26	.19
	4 324	99.99	....	13 222	99.97

Thus, according to the old qualitative classification, the rock is a biotite-diabase, while under the new quantitative chemical classification it is a biotite-camptonose. The amounts of SiO_2, Al_2O_3, and CaO in the analysis strongly bear out the determination of the plagioclase as ranging from andesine to labradorite. Such a high content of FeO in the analysis makes it certain that the biotite is rich in ferrous iron, since there is not enough magnetite and augite to account for so much FeO. The sulphur appears too low as judged by the amount of pyrite visible even to the naked eye. The high TiO_2 shows either ilmenite or that the magnetite is decidedly titaniferous, though a little of the TiO_2 may be in the biotite. The low Fe_2O_3 content in the analysis favors the presence of ilmenite.

It is important to note that the analyses of the diabase and typical gabbro are very similar except for somewhat higher silica and lower lime in the diabase, this difference probably being due to the slightly more acid character of the plagioclase in the diabase. Thus the two rocks have quite certainly been derived from the same source of basic supply though at different times.

TABLE 12

Adirondack diabase analyses compared

	1	2	3	4	5	6
SiO_2	50.57	43.41	44.51	45.46	46.73	50.89
Al_2O_3	13.58	19.42	19.99	19.94	16.66	15.39
Fe_2O_3	3.26	5.72			3.56	
FeO	10.09	6.69	7.22	15.36	8.45	5.77
MgO	4.98	5.98	8.11	2.95	8.12	7.60
CaO	7.67	9.11	8.15	8.32	8.03	8.75
Na_2O	2.92	4.39	5.24	2.12	3.73	5.67
K_2O	1.89	.47	2.60	3.21	1.64	2.72
H_2O	1.10	3.00	2.93	2.30	2.39	2.46
TiO_2	2.68	.35	......	......	.03	......
P_2O_5	.28	......	......	......	.39	......
Cl	.09	......	......	......	.18	......
F	.09	......	......	......	.26	......
Cr_2O_3	......	......	......	......	.06	......
MnO	.36	......	......	......	trace	......
BaO	.09	......	......	......	.04	......
SrO	.10	......	......	......	......	......
S	.03	......	......	......	......	......
CO_2	......	2.00	......	......	......	......
	99.78	100.54	98.75	99.66	100.27	99.25

1 From western base of Heath mountain, North Creek sheet, Warren county. Analyst Morley.

2 From summit of Mt Marcy, Essex county. Analyst Leeds. N. Y. State Mus. 30th Annual Rep't, p. 102.

3 From shore of Upper Chateaugay lake, Clinton county. Analyst Eakle. Amer. Geol. July 1893, p. 35.

4 From Palmer Hill, Black Brook township, Clinton county. Analyst Kemp. U. S. Geol. Surv. Bul. 107, p. 26.

5 From Bellmont township, Franklin county, dike 13. Analyst Morley. N. Y. State Geol. 18th Annual Rep't, p. 120.

6 From shore of Upper Chateaugay lake, Clinton county. Analyst Eakle. *Op. cit.*, p. 35.

The North Creek sheet diabase (no. 1) is lower in Al_2O_3 and CaO, and higher in TiO_2 than any of the others. It is also somewhat more acid than usual for the diabases, due to the more acid character of the plagioclase feldspar.

Lack of variation of the diabase

Because of its remarkable homogeneity in composition, the diabase presents a marked contrast to the neighboring gabbro. The diabase never contains inclusions and, with a single very local exception below described, never shows any evidence of magmatic assimilation even in the largest masses. This difference is quite certainly due to the difference in the mode and condition of intrusion, the diabase having clearly been forced through comparatively narrow fissures in the country rock and near the earth's surface as the texture shows. In such intrusions magmatic stoping would be reduced to a minimum or absent.

Contact phenomena

A small dike, 5½ inches wide, which cuts the Grenville limestone at the asbestos mine three-quarters of a mile southeast of Thurman, shows contact phenomena which deserve special mention. Following is a description based upon thin sections and hand specimens (see plate 7).

Zone 1 This is typical, unaltered, medium grained, greenish gray, serpentine marble.

Zone 2 This zone, about one-third of an inch wide, lies along the contact with the diabase. It consists of a fine grained, dark green, well-baked serpentine marble.

Zone 3 One-sixth of an inch wide. Nearly black (greenish gray in thin section), glassy looking dike rock which shows an irregular but sharp boundary against the marble. It appears to consist largely of rather homogeneous, serpentinous material (bluish gray interference tints) which is apparently igneous glass into which serpentine marble has been fused. Occasional well-formed laths of plagioclase and many specks of magnetite occur. The outer 1 or 2 millimeters of this zone are very rich in magnetite specks. This zone shows a rapid transition into the next one.

Zone 4 One-third of an inch wide. Reddish brown, glassy looking. Apparently good igneous glass filled with many tiny specks of what seem to be magnetite and perhaps 10 per cent of plagioclase mostly in laths but some in stout prisms with distinct zonal structure. This grades perfectly into the next zone.

Zone 5 One-half of an inch wide. Pale green color and much like no. 4 except for absence of the tiny specks. The green color is due to serpentinous material which appears to have been absorbed by the molten mass. The contact between this and the next zone is rugged though pretty sharp.

Zone 6 Ordinary bluish black diabase from within the dike and with no serpentinous admixture. This rock is mostly a dark glass which contains 5 per cent plagioclase laths and 5 per cent pale reddish brown, euhedral augite crystals and numerous specks of presumably magnetite.

PALEOZOIC OUTLIERS

No actual outcrop of Paleozoic strata has been found within the borders of the quadrangle, but certain nearby Paleozoic outliers have an important bearing upon the geologic history of the region. Two of these outliers have been described by Professor Kemp, one of them being Little Falls dolomite which occurs at Schroon Lake village (Schroon Lake sheet), and the other being Potsdam sandstone which occurs near the village of North River (Thirteenth Lake sheet).

During the summer of 1910 the writer discovered a small Paleozoic outlier 1 mile south of the map edge and 1 mile due west of High Street village (Luzerne sheet). The exposures are rather poor and small but the rock is quite certainly in place with the strata lying in nearly horizontal position. Both sandstone and dolomite beds occur and it is not certain whether the rocks represent the passage beds of the Theresa formation or the contact between the Potsdam and the Little Falls dolomite, though the former is more probable. This outlier lies at 1400 feet elevation and not far to the west of the No. 9 mountain fault and on its downthrow side.

The important outlier at Wells (Lake Pleasant sheet), which shows rocks from Potsdam to Canajoharie, has been known since the early days of the State Survey. The nearby occurrences of Little Falls dolomite along the southern portion of Lake George should also be mentioned.

Within the map limits, certain drift boulders are significant as showing proximity to concealed outcrops or ledges which were scraped off by ice erosion. Thus a fragment of Potsdam sandstone 2 feet across and very angular was seen just east of the old garnet mine near Daggett pond, and many Potsdam fragments up to 1 foot across occur in the river valley bottom between Moon and Heath mountains.

The occurrences of early Paleozoic marine strata on all sides of the North Creek quadrangle furnish practically conclusive evidence that much, if not all, of the area of the quadrangle was covered by that early Paleozoic sea. Thus the Potsdam (upper Cambric) sea, which encroached over northern New York from the northeast, must have swept over the North Creek region and this was quite certainly succeeded by the Theresa and Little Falls seas. Regarding the presence or absence of the Ordovician sea, we have no positive knowledge, though the Wells outlier suggests that it, too, was present.

It is well known that when the Potsdam sea encroached upon the eastern Adirondacks, the region was greatly worn down to the condition of nearly a peneplain. Since some portions stood out above the general level of the peneplain, it is quite possible that the Potsdam sea, and even the later Cambric, did not cover the higher portions as Professor Kemp has suggested. At any rate the evidence is strong that very much if not all of the North Creek area was covered by the late Cambric sea and probably also by the Ordovician sea. The deposits made in those seas have all been removed by erosion except for the small outlying masses above described. It is important to note that each one of these outliers has been very considerably faulted downward from the original position of the strata and thus they have been protected against complete removal by erosion during so many million years.

STRUCTURAL FEATURES

FAULTS

General considerations. That the eastern Adirondacks are extensively faulted has been recognized for some years, but thus far comparatively little attention has been paid to the detailed study and mapping of these faults well within the Precambric area. The North Creek quadrangle, which lies in the midst of this eastern Adirondack faulted region, is literally cut to pieces by faults. On the accompanying geologic map the writer has indicated the positions of over forty faults, most of which show unmistakable evidences of their presence, while the others, shown on the map by the heavy broken lines, are more or less certainly present.

The faults are all of the normal type with fault planes vertical or very steep. Because of the character and structure of the rock masses and the lack of any well-defined stratigraphic relations, it is practically impossible to determine the actual amounts of displacement, though in many cases minimum approximations can be made. Such minimum figures commonly range from a few hundred to a thousand feet or more. One feature worthy of special mention is the frequent rapid diminution of throw within very short distances. Thus in many respects the North Creek faults are much like those of the Mohawk and Champlain valleys, which is to be expected as the faults of this whole eastern Adirondack region were all produced at the same time or times. With regard to the strike, however, the North Creek faults are rather exceptional because the general trend of the Adirondack faults is north-northeast by south-southwest, while within the North Creek quadrangle this trend is the rule only in its northern portion.

As a rule, faults within the Precambric area are difficult to locate and trace with any great degree of accuracy and certainty because of the general similarity of the rocks and the lack of ordinary fossiliferous strata. In the North Creek region, however, the conditions are particularly favorable for locating faults both because of the unusual excellence of exposures and the large amount of widely distributed weak Grenville strata.

Frequently the line of contact between the syenite or granite and the Grenville is very regular and sharp, the Grenville often seeming to dip under the igneous rock with the latter rising abruptly and to a great height above the Grenville. Among the best examples of such phenomenon are the southern sides of Huckleberry, Crane, and Little mountains, and the western sides of Oven, Prospect, Birch, and Potter mountains. There are only two possible explanations of this phenomenon, namely, either that the igneous rocks were intruded into the positions which they now occupy or that faulting has occurred. If this is to be explained simply on the basis of intrusion, then we are forced to assume a remarkably irregular surface

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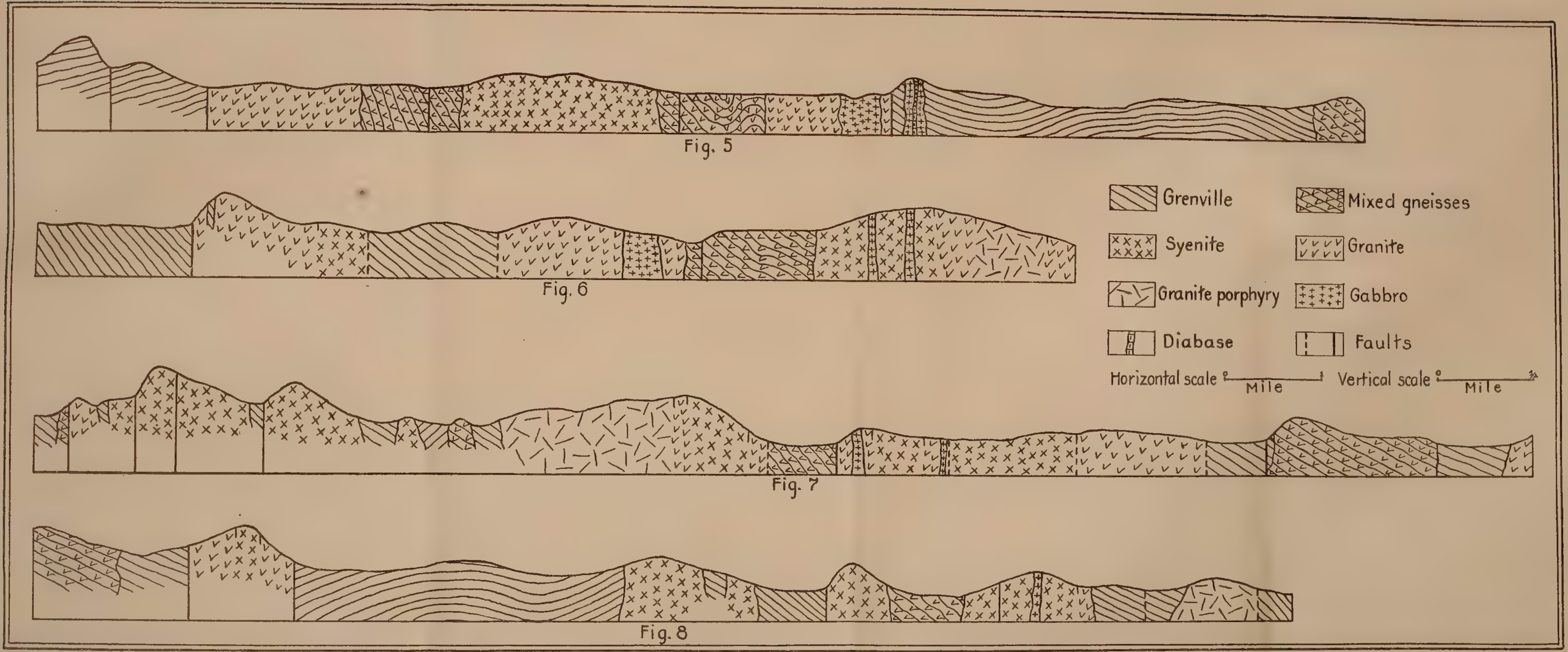

Fig. 5–8. Structure sections across the North Creek quadrangle. The position of the section lines is shown on the geologic map.

of the newly cooled magma and also that the molten masses, in all these cases, broke through the Grenville along very straight or regular lines often for miles. Both of these assumptions are out of harmony with well-known observations in other regions.

The very common dip of the Grenville downward against the faults is due to the fact that most of the prominent fault scarps face the west while the prevailing dip of the Grenville is toward the east.

Among the more positive criteria for the recognition of the faults are the following: (1) actual steep to vertical scarps, often in hard, perfectly homogeneous rock, and frequently in such positions as to preclude the possibility of their having been formed by ice or stream erosion; (2) the distinct tilting of the earth blocks gradually downward away from the scarps; (3) the frequent presence of actual crushed, sheared, or brecciated fault zones; and (4) the long, straight contact lines between the Grenville and the igneous rocks, with the latter rising abruptly high above the former.

What is the age of the faulting? That some, at least, occurred during Precambric time has been pretty well established but, so far as known, such faults are of minor importance and certainly have no appreciable influence upon existing topography. But a single case of such very ancient faulting has come under the writer's notice within the area of the quadrangle and this occurs along the road three-fifths of a mile southwest of Sullivan pond. A fault, plainly visible for 12 feet, there passes across a glaciated ledge of quartz syenite. On the east side, for a width of 7 or 8 feet, the whole mass is a fault breccia. This breccia is fine at the fault and coarser, with fragments up to 1½ feet across, away from the fault. The fault strikes north 30° east and is in no way related to existing topography.

There is good reason to think that considerable faulting occurred during the Paleozoic era after the deposition of the Ordovicic sediments because rocks of that age are involved in the faulting along the eastern and southern borders of the Adirondacks. Cushing has suggested that the faulting may have been initiated at the time of the Taconic revolution when the rocks immediately eastward were so greatly disturbed, but he says:[1] "The great earth disturbance (Appalachian revolution) which prevailed in the Appalachian zone toward the close of the Paleozoic would seem more likely to have brought about the major faulting of the region." We know that

[1] N. Y. State Mus. Bul. 95, p. 405.

the whole State was then upraised practically without folding, and the conditions were certainly favorable for extensive fracturing of the strata.

Any fault scarps or ridges produced during or at the close of the Paleozoic must have been quite or nearly obliterated during the long Mesozoic period of erosion. If so, how do we account for the present Adirondack ridges which follow fault lines? As a result of the uplift of the Cretacic peneplain one or both of the following things happened, namely, either that there was renewed faulting or that, as a result of unequal erosion (due to differences in rock character) on opposite sides of the faults, the old fault scarps were renewed. It is quite certain that both things occurred and thus we account for the present Adirondack fault ridges. That some of the faulting actually dates from the uplift of the Cretacic peneplain, or possibly even later, is proved by the existence of certain fault cliffs in perfectly homogeneous rock masses, and by the fact that many of the tilted fault blocks have been little modified by erosion since their formation. Among many good examples of fault scarps in homogeneous rocks are those on the west sides of Moon, Kelm, and Chase mountains, while tilted fault blocks little affected by erosion are those of Moon, Birch, Crane and Huckleberry mountains.

Little-Crane-Huckleberry mountain faults. The structural relations shown by these three mountain masses are truly remarkable and the faults are the most interesting within the quadrangle. The deep, narrow rift between Huckleberry and Crane mountains was carefully examined and, judging by the frequency of outcrops, it is quite certain that a narrow belt of Grenville separates the mountain masses as shown on the map. A narrow valley of Grenville, chiefly limestone, with almost continuous outcrops separates Crane mountain from the granite ridge just south. Likewise there is a valley of Grenville, chiefly limestone, immediately to the south of the granite ridge (Little mountain and its westward extension).

In each case the mountain mass of igneous rock presents a high and very steep to almost precipitous wall on the south side, and in each case the belt of Grenville comes abruptly against the igneous rock wall. A slight exception to the latter statement is along the southwestern base of Crane mountain where a small belt of syenite intervenes between the Grenville and the high mountain mass. Almost invariably the rocks of the Grenville belts dip at high angles downward and against the faults. The great

Plate 8

W. J. Miller, photo

Crane mountain as viewed from Thurman village. This great dome of quartz-syenite rises 2000 feet above the valley at its base. The valley is underlain with Grenville, chiefly limestone. The steep slope on the left (south) side is due to a fault scarp, and the down tilt of the great mountain block toward the right (north) is plainly shown. The escarpment at the summit is due to the passage of a minor fault.

bare wall of syenite rising to a height of a thousand feet or more on the south side of Crane mountain is a truly impressive sight as viewed from the valley or ridge just to the south. As viewed from the summit of Crane mountain, the sharp-crested granite ridge forming the westward extension of Little mountain bears a close resemblance to a typical hogback ridge. All these mountain masses show decided, though much more gradual, downward slopes toward the north, this being perfectly shown by Crane and Huckleberry mountains and not so well by the Little mountain ridge. Thus the general areal distribution and structural relations of the rocks, more especially the long, regular or straight contact lines between the Grenville and igneous rocks; the high, steep walls of igneous rocks rising above the Grenville; and the distinct downward tilt of the mountain blocks northward and away from the scarps make the presence of three faults here practically certain. The picture of Crane mountain (plate 8) clearly shows the character of this earth block with its steep scarp on the south and long northward slope.

For reasons already stated, nothing like exact figures can be given as to the amounts of displacement but, judging by the present height of the scarps, the throw of Crane mountain fault appears to be more than a thousand feet, while the throw of the Huckleberry and Little mountain ridge faults are no less than 500 to 800 feet. The very rapid dying out of these faults is rather remarkable, but perhaps not more so than in the case of the Batchellerville fault of the Broadalbin quadrangle recently described by the writer.

As shown on the geologic map, a minor fault extends across the top of Crane mountain and parallel to the great fault just south. Three high points, 2682, 2829, and 3254 feet respectively, are arranged along the crest of the fault scarp with very steep south fronts or cliffs. The scarp on the south side of the highest peak (3254 feet) is a sheer precipice more than 200 feet high, which forms what is locally called the "Nose" of Crane mountain. It is well shown in plate 8. At several places the line of fracture is marked by distinct crushed or sheared zones where the rock is biotitic and almost like a schist in appearance.

The eastern face of Crane mountain rises abruptly along a straight line to a height of more than a thousand feet, and certainly bears every resemblance to a fault scarp. This topographic evidence,

[1] N. Y. State Mus. Bul. 153, p. 45.

together with the fact that this abrupt change in slope occurs in homogeneous syenite and away from any possible stream action, makes the presence of a fault here quite certain.

The eastern face of Little mountain is also very steep, much more so in fact than the contour lines indicate, and the general topographic and structural relations here also strongly suggest faulting. Some signs of shearing were noted. The northward extension of this fracture (dotted on the map) is more doubtful though the topography, not well shown on the map, points to minor faulting there. The strike of these two last named faults is almost exactly at right angles to the other larger faults of the group.

Moose-No. 9 mountain faults. The Moose mountain fault, as shown on the map south of Thurman village, is really only the northern end of a very prominent fault which has formed the steep escarpment along the eastern side of Moose mountain (Luzerne sheet).

No. 9 mountain fault strikes due north and south and has caused the steep western front of the mountain. Some evidence of shearing was noted. The displacement appears to have been no less than 500 feet, and the eastward downtilt of the earth block is evident.

Potter-Birch-Heath mountain faults. The Potter-Birch mountain mass is a fine illustration of a fault block with steep western front and gradual slope away from the scarp toward the east. On the western side of Birch mountain there is a very distinct shear zone along which the syenite has been badly crushed and made to appear much like a biotite schist. The Grenville, mostly limestone, dips at high angles eastward sharply against the syenite along the fault. The very distinct curving in of the fault against the syenite mass is here better shown than for any other fault of the quadrangle. The steepest portion of the scarp is at Daggett pond where an almost precipitous wall of syenite rises 555 feet above the pond. Judging by the present topography, the displacement of this fault ranges from 300 to 600 feet, being greatest at Potter mountain.

The Heath mountain mass is a good illustration of a small fault block eastwardly downtilted. The displacement is no less than 300 or 400 feet. It is possible that this fault is really a continuation of the Potter mountain fault, though it is more than likely a separate fracture as shown on the map.

The small mountain of syenite lying just across the river from Heath mountain is a still smaller fault block much like that of Heath mountain.

Moon-Hackensack mountain fault. This is a well-defined fault whose presence is proved by most of the criteria generally applicable in this region. The strike is northwest-southeast and in perfect harmony with that of Moon and Hackensack mountains. The trend of the fault scarp is clearly marked by the topography, the western face of Moon mountain being especially high and steep (see plate 9). Between the two mountains the scarp is lowest because the weaker Grenville there has been worn down most rapidly. This whole earth block shows the eastward downtilt, particularly in the case of Moon mountain. In a large prospect hole at the western base of Hackensack mountain and close to the road there is much evidence of shearing along the fault. Near the source of the small stream along the fault and half way between the mountains there is a fine exhibition of crushed and brecciated Grenville gneiss. Sheared rock was also noted along the western side of Moon mountain. The maximum throw of this fault appears to have been no less than 600 feet.

County House mountain fault. This fault is shown dotted on the map because its presence is not altogether certain. The steep eastern front of the County House-Kelm mountain masses and the fact that the Grenville (much limestone) comes in rather sharply against the bases of these mountains are the principal evidences for the faulting. The Grenville here, contrary to the usual thing, either dips away from the fault or its strike is at high angles against the fault.

Kelm mountain fault. This is a good example of a fault wholly within a mass of very homogeneous, igneous rock. The fault scarp is much more in evidence than the contour lines suggest, and there is a rather distinct eastward downtilt of the block. Shear zones were noted in two or three places. The displacement is as much as 300 feet.

Millington brook fault. This fault lies along the eastern side of the valley of Millington brook and strikes north-northwest by south-southeast. Where it crosses the road, 1¼ miles southwest of Kelm pond, the rocks are considerably sheared and brecciated. On the western side of the small mountain (1302 feet), near the north end of the fault, sheared rock was also noted. The extension of this fault southward to the western base of County House mountain is somewhat doubtful though the relations of the rock masses and the topography strongly suggest it. The throw of this fault is probably not over a few hundred feet.

Chase mountain fault. This fault strikes nearly north and south and the chief evidences for its existence are the very prominent scarp in the homogeneous granite porphyry and some suggestions of shearing. The usual tilted character of the blocks is not here shown. This fault probably continues southward to join the Millington brook fault as indicated on the map.

Tripp mountain faults. A fault whose trend is almost exactly north and south lies along the western base of Tripp mountain as shown on the map. The evidence for this fault is largely topographic, such as the presence of a very distinct scarp along a straight line for several miles in homogeneous igneous rock, and also the rather distinct downslope toward the east from the scarp. Near the south end of the fault and on the west side of the hill (1221 feet) some sheared rock was noted, but for most part the line of the fault is covered with rock debris. A maximum displacement of no less than 300 to 400 feet seems to be shown.

The southeastern face of Tripp mountain is a steep scarp which has almost certainly been produced by faulting because of its presence in homogeneous granite porphyry and away from any considerable stream. A throw of several hundred feet is represented.

Tripp pond fault. This fault strikes northwest-southeast and passes along the north side of Tripp pond and along the bases of the mountains whose elevations are respectively 1662 and 1389 feet. The very steep scarp rising to a height of 700 feet and forming the southwestern face of the mountain (1662 feet) just north of Tripp pond is almost certainly a fault scarp. At the opposite end of the fault the scarp is distinctly traceable along the southwestern face of the low mountain (1389 feet) and the little hill just southwest of Sullivan pond. The scarp here strikes at a high angle across the foliation and in homogeneous rock.

Bull Rock mountain faults. These two faults form the western boundary of the mass of syenite which lies along the east-central margin of the map. The shorter one strikes northwest-southeast and lies along the western border of the Bull Rock mountain mass, and the smaller mountain (1560 feet) just to the northwest. Grenville, chiefly quartzite, dips downward sharply against the fault.

The longer fault follows a perfectly straight line of hills or low mountains whose elevations are respectively 1560, 1512, 1200, and 1140 feet, the throw of the fault apparently gradually diminishing toward the north. The Grenville in the valley immediately west of the fault consists of various gneisses with varying dips and

Plate 9

W. J. Miller, photo

The Moon mountain fault-scarp as seen from directly across the Hudson river, which is just visible in the foreground. Many exfoliation slabs can be seen near the mountain top. A heavy (wooded) talus slope covers the base of the mountain. The rock is quartz syenite.

strikes. The usual evidences prove the faulting, the eastward downtilt of the fault block being especially well shown. Neither of the two faults just described has a maximum displacement of more than a few hundred feet.

Brant lake faults. A very prominent fault, which may be called the Brant lake fault, passes along the northern side of the lake of the same name within the adjoining Bolton sheet. The lake clearly occupies a depression at the base of this fault scarp. Only the western end of this fault comes into the North Creek quadrangle where it passes along the southern base of the mountain at the village of Horicon. It can not be traced across the Schroon river. Near the village of Horicon distinctly sheared and slickensided rock may be seen in the granite quarry. At the village the displacement appears to be no less than 400 or 500 feet.

On the south side of the narrow valley at Horicon a smaller fault, parallel to the larger one, is clearly indicated by a crushed zone in the granitic syenite. The eastward extent of this fault is not known.

Chestertown faults. A prominent fault with northwest-southeast strike lies along the southwestern base of Prospect mountain and is thought to be continuous with the fault shown on the map just east of Loon lake. These two are certainly exactly in line and, though they have not been positively connected, they will be regarded as parts of the same line of fracture. At the Loon lake end the fault shows an almost vertical scarp 300 feet high where it passes along the western border of the gabbro stock. The scarp there consists of badly sheared gabbro, and Grenville limestone dips directly against the base of the scarp. The southwestern side of Prospect mountain is a fine example of a high, steep fault scarp with banded Grenville gneisses dipping eastward against the base of the mountain which consists of a granitelike mass of gneiss. A displacement of no less than 700 feet is shown here. The southern end of the fault is marked by a rather steep scarp several hundred feet high and in the homogeneous granite porphyry.

There is fairly good reason to think that another fault with north-south strike passes through the western edge of the village of Chestertown, but since its presence is not certain it is represented on the map by a broken line. The fairly prominent scarp which forms a long straight boundary between the Grenville and the igneous rocks is the chief evidence for considering a fault here. The fault plane is mostly concealed by heavy drift.

The Glen-Riparius fault. This fault, whose length is some 8 or 9 miles, is clearly the longest one lying wholly within the quadrangle. It is topographically very plainly marked, a whole line of low mountain peaks forming the crest of the scarp. This great fault block shows a very distinct downtilt toward the east which accounts for the peculiar drainage condition because no considerable streams enter the Hudson river from the east along the line of the fault but, instead, the streams all drain from the crest of the scarp down the eastward slope and into the Friends and Loon lake basins. The Hudson river itself has had its course determined along the base of the scarp. A displacement of from 300 to 600 feet is commonly shown.

Gage-Stockton mountain fault. As shown on the map by the heavy broken line, a prominent fault is thought to extend along the eastern bases of Mill, Stockton, and Gage mountains and southward to The Glen. The principal evidences for faulting here are the arrangement of the high, steep mountains along a regular line and the long, smooth contact between the areas of Grenville and mixed gneisses and the igneous rocks. The usual tilted character of the fault blocks is here not shown. Shear zones were not noted though this is of little significance because exposures on the line of the fault are very scarce. The displacement of this fault appears to be as much as 800 or 1000 feet.

If this fault is actually present, then the large wedge of Grenville and mixed gneisses in the valley bottom is of the nature of a through fault block.

Oven-Mill mountain faults. These faults are most likely parts of the same line of fracture, though the connection has not been positively traced. In each case Grenville (chiefly limestone) dips eastward and directly against the base of the mountain. The Oven mountain fault scarp, which rises nearly 900 feet and is very steep to almost precipitous, is an impressive sight as viewed from the west. An eastward downtilt of the block is fairly well shown. The Mill mountain scarp is not so steep but rises to a height of over 700 feet. Because of the much weaker Grenville between the two mountains, no distinct fault scarp is there present.

North Creek fault and branch. This prominent fault strikes north-northeast by south-southwest and passes through the village of North Creek. Northward from the village it is very clearly traceable as a topographic feature for at least 10 or 12 miles and well into the Schroon lake quadrangle along the west side of the

Plate 10

W. J. Miller, photo

View across the Hudson river from a point just south of the railroad station at Riverside, and typical of the region through which the river flows. The mountain consists of quartz-syenite. The Glen-Riparius fault, which the river follows for some miles, lies along the base of this mountain.

valley of Minerva stream. From North Creek to the map edge the line of the fault is marked by a distinct depression which has been formed along the belt of weakness. Except near the Hudson river where the weak Grenville is crossed by the fault, a well-defined fault scarp forms the upthrow side on the west and it is important to note that this scarp strikes at a high angle across the foliation of the rocks, thus proving the independence of the fault and foliation planes. One and one-fourth miles north of North Creek decomposed and somewhat crushed granite marks the passage of the fault. Just at the map edge the eastern face of the Moxham mountain mass is a fine illustration of a steep fault scarp rising to height of 900 feet. Since the fault here passes through a great mass of rather homogeneous, igneous rock, it is certain that the amount of displacement is not less than 1000 feet. An interesting feature is the large inclusion of Grenville gneiss just south of Moxham mountain; it occupies such an unusual position because it lies on the upthrow side of the fault in a place fairly well protected from erosion.

In the stone quarry just east of the main fault and near the map edge, a fault plane with breccia is clearly exposed in both walls of the quarry. Its strike is north 30° east and it appears to be a minor fracture parallel to the larger one.

At the map edge a fault branches off the main line of fracture and follows the steep mountain side to Fuller pond. Just east of the pond the scarp of Grenville gneiss rises almost vertically for several hundred feet.

South of the village the North Creek fault is clearly traceable by the steep mountain sides of igneous rock against which the Grenville comes in contact along a straight or at least very regular line as far south as Baker's Mills (Thirteenth Lake sheet).

Holcombville fault. There is considerable evidence for a fault with a northwest-southeast strike along a nearly straight line passing through the village of Holcombville. It is represented by a broken line on the map because its presence is not regarded as conclusive. It is thought to extend for some miles into the Thirteenth Lake quadrangle or nearly to the village of North River. The chief evidences for faulting are the long, straight contacts of the Grenville against the bases of the high Oven mountain mass of igneous rock and the great mass of syenite within the Thirteenth Lake sheet. No shear zones were noted and the usual steep scarp and the tilted character of the fault block are absent.

Collins brook fault. The Collins brook fault lies nearly parallel to the Holcombville fault and it is named from the small brook which follows the base of the scarp near its north end. It is clearly marked by the topography for a distance of 5 miles between the Hudson river and Mill creek near Wevertown. The evidence for its existence is threefold, namely: (1) the long, regular scarp of granite whose crest is lined with peaks rising from 300 to 600 feet above the base of the scarp; (2) the long, smooth contact of the Grenville against the base of the scarp; and (3) the distinctly eastward downslope of the earth block away from the crest of the scarp.

Henderson mountain faults. The principal fault of this group strikes northeast-southwest along the western base of the Henderson mountain mass. Its position is plainly marked by the topography, and though the scarp is not as steep as usual, it is nevertheless very prominent and straight and cuts across the foliation of the rocks at a high angle. The sharp swing of the Hudson river northeastward for 1½ miles along the line of the fault has been determined by the crushed belt of weakness. North of the river the position of the stream which flows through Bird pond has also been determined by the fault. As judged by the height of the scarp at the south end and also at the base of Henderson mountain, the displacement is fully 700 feet. Where the fault crosses the belt of mixed gneisses the scarp is much less prominent because of the relative weakness of the rocks there. No tilting of this fault block is noticeable. This fault certainly continues for some 3 miles northward into the Schroon Lake quadrangle along the western bases of Green and Pine hills.

The second fault of this group strikes almost parallel to the Henderson mountain fault and lies at the eastern foot of the mountain whose elevation is 1915 feet. The very steep side of this mountain rises 700 feet and is another good example of a fault scarp wholly within homogeneous rock. Where the fault passes into the area of weaker mixed gneisses the scarp is much less prominent.

The third fault of this group is a small one which lies south of Igerna and along the north side of the Hudson river. It is wholly within the area of mixed gneisses but at some places almost vertical scarps rise fully 200 feet.

Schroon lake faults. The larger of the two faults here described strikes northeast-southwest and extends along the eastern side of the south end of Schroon lake and thence southward to the north end of Loon lake. At two places along Schroon lake the fairly steep scarp rises fully 400 feet. The southern end of the fault block is a mass of Grenville (chiefly quartzite) whose bold scarp at one place rises 400 feet. The whole fault block, especially the southern part, shows the usual downslope toward the east. This scarp strikes at a high angle across the foliation bands and hence it is difficult to account for except on the basis of faulting.

A smaller fault along the western side of the southern end of Schroon lake has a prominent scarp rising some 300 to 400 feet. Where it cuts across the gabbro stock near the map edge the fault scarp rises as a high vertical wall along which the rock is unusually soft and weathered and evidently sheared.

Loon Lake mountain fault. The short fault shown on the map just east of the north end of Loon lake and at the base of Loon Lake mountain is one of special interest. Here again the contours are not close enough together since the fault scarp which rises to a height of 700 feet is very steep, the upper 300 or 400 feet being a sheer precipice. We have here at once the highest steep ledge of Grenville and the finest example of a practically unaltered fault cliff within the quadrangle (see plate 10). The upper portion of the cliff consists of quartzite in thin to thick beds with low northeasterly dip so that the truncated edges of the quartzite layers are distinctly visible in the face of the cliff. The less steep scarp forming the western face of this fault block as well as its downtilt toward the east are due to the Schroon lake fault already described. Plate 11 gives a good idea of the appearance of this fault block mountain.

Other faults. The small fault north of Valentine pond strikes due north and south and shows a prominent scarp near its north end. The contours are not close enough together on the mountain side since the wall of rock, which rises fully 600 feet, is very steep to actually vertical in places. Hard, distinctly banded Grenville gneiss makes up the upper three-fourths of the wall and rests upon granite. The fault has broken sharply across the strike of the foliation of both the Grenville and granite.

As judged wholly by the topography, there appears to be a considerable fault block just west of Loon lake. The fault and its scarp lie from 1 to 1½ miles west of the lake and the downtilt toward the lake is very noticeable.

The shape of the lake basin and character of the topography suggest the presence of a fault along the west side of Friends lake.

As shown on the map, short faults are suggested at the eastern base of Mill mountain, the western base of Stockton mountain, and the northern base of Wolf pond mountain. Except for some evidence of shearing on the side of Stockton mountain, the only evidence for these faults is topographic, it being difficult to account for these steep scarps except on the basis of faulting.

The writer believes it quite likely that other, chiefly minor, faults occur within the quadrangle, but the ones above described are the only ones he feels justified in representing on the geologic map as actually or very probably present.

FOLIATION

All the rocks except the diabase and pegmatite show more or less of the foliated structure. It is best seen in the Grenville gneisses which are commonly distinctly banded due to differences in the composition of the beds, the foliation so far as observed always being parallel to the bedding. The syenite, granite, and granite porphyry are always gneissoid but never distinctly banded, the structure being accentuated by a drawing or flattening out of the dark colored minerals parallel to the foliation. The more basic pyroxene and hornblende syenites are, as a rule, not very gneissoid, as, for example, the Bull Rock mountain syenite. In fact it may be stated as a very general rule that the more basic, even and medium grained rocks of the syenite-granite series are least gneissoid; while the more acid rocks carrying hornblende and some biotite are clearly gneissoid; and the most acid rocks rich in quartz and biotite are very gneissoid. In these last named rocks the very presence of biotite flakes and the tendency of the quartz to become flattened favor the development of the foliated structure. Again, it often happens that when members of the great intrusive series, especially the granites, are close to the Grenville the rocks are more gneissoid. Thus, at the top of Heath mountain the pink granite is rather poorly gneissoid while at the base of the mountain it is very gneissoid.

The typical basic gabbro stocks seldom show a gneissoid structure except rather often in the narrow amphibolite borders. Some of the more acid stocks are clearly gneissoid.

An interesting feature is the common occurrence of rapid changes in degree of foliation even within the same rock ledge. Thus, just west of The Glen (on the mountain side) there are big ledges of

Plate 11

W. J. Miller, photo

The Loon Lake mountain fault-block, as viewed from a point three-fourths of a mile to the south-southwest. On the left (west) side the steep slope is that scarp of the larger of the two Schroon lake faults. The down-tilt of the block toward the east is perfectly shown. The cliff, several hundred feet high, which faces the south, is the scarp of the fault along the south side of the mountain. The upper portion of this mountain, which rises 600 feet above the valley, consists of Grenville quartzite and its lower portion of biotite-garnet gneiss.

hornblende granite. At times the rock is pinkish gray, medium to coarse grained, and not very gneissoid; while again, and by rapid changes, the rock is gray, fine grained, and very gneissoid to almost schistose. Both rock types have the same composition and both show signs of granulation, but the latter rock especially so. One of these clearly does not cut the other, but rather there is a rapid gradation from one to the other parallel to the foliation, and it seems clear that the fine grained, very gneissoid rocks were produced along belts of shearing perhaps at the time of the development of the foliation. Such a rapid transition from fine to medium grained granite is also well shown even in a hand specimen from the summit of Oven mountain.

Many dip and strike observations on the foliation were made, the more representative ones being plotted on the accompanying map. Strike observations can generally be made with a fair degree of accuracy, but dips can seldom be determined to nearer than 5 or 10 degrees. The amount of dip is usually rather moderate, most often ranging from 30 to 60 degrees. Considered as a whole, the prevailing strike of the foliation ranges from north and south to northwest and southeast with dips almost uniformly toward the east. The northern central portion is exceptional with its east and west strike and northward dip. Also there are important departures from the prevailing direction of dip and strike in certain Grenville areas as south of Johnsburg, south of Thurman, and between Pottersville and Starbuckville, in which areas the directions are very variable. On the Long lake sheet, according to Professor Cushing, the foliation is more erratic in the eruptives than in the Grenville, but here precisely the reverse is true.

FOLDING

Before any important general statements can be made regarding the character of the folding, a wider area will have to be studied. A striking feature is the almost uniform eastward to northeastward dip of the foliation, which suggests the possibility of isoclinal folding but aside from this uniform direction of dip, there is much evidence against such isoclinal folding. The generally moderate angles of dip; the perfect agreement of foliation and bedding planes even where the strikes and dips are erratic; and the utter lack of any evidence for repetition of the strata even in long sections like that of figure 1 are strong points against isoclinal folding. Professors Cushing and Kemp recently stated with reference to the Long Lake and Port Henry-Elizabethtown quadrangles that the Precambric rocks show no good evidence of having been more than moderately folded or tilted, and this appears to be true of the North Creek quadrangle as well.

Locally, the limestone and accompanying pyroxene gneiss may be intensely contorted or twisted, probably being due to the more plastic character of the limestone when subjected to great pressure. The pyroxenic bands are often pulled apart into small lens-like masses as shown in plate 11 and figure 9. Other fine cases of contorted limestone may be seen at the river bridge near Thurman station (off the map); just north of the Ferry at the river's edge (see plate 3); along the road 1¼ miles southwest of Kelm pond; and along the road a little east of north of County House mountain.

Figure 9 represents a sketch, drawn to scale, of a mass of limestone on the south side of Crane mountain which has been contorted and forced for 20 feet across the foliation bands of the associated hornblende-garnet gneiss.

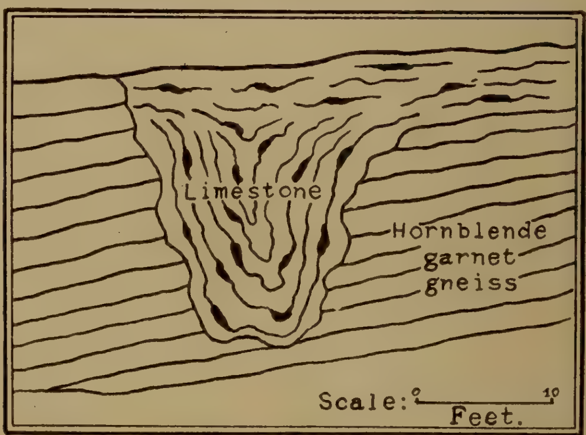

Fig. 9 Sketch showing a peculiar arrangement of Grenville rocks as seen by the roadside on the south side of Crane mountain and three-fifths of a mile from the summit of the mountain. The limestone has been contorted and forced across the foliation bands of the associated gneiss. The black patches represent drawnout fragments of pyroxenic gneiss.

SURFACE OF THE GREAT SYENITE-GRANITE INTRUSIVE MASS

The very ancient Grenville strata were invaded by a vast mass of molten syenite and granite which, in part, pushed aside or upward or engulfed some of the Grenville and, in part, left patches of greater or lesser extent practically intact. This has largely given rise to the very decided "patchwork" appearance of the geologic map.

Plate 12

W. J. Miller, photo

Contorted Grenville limestone as seen near the road one and one-half miles southeast of Johnsburg. The darker streaks are pyroxenic bands which have been badly twisted and drawn out.

The sharpness of the contact between the igneous rocks and the Grenville and the altitude of the igneous masses above the Grenville have often been accentuated by the faulting, but in spite of this some idea of the irregular surface of the great intrusive mass may be gained. Thus, the Grenville between Kelm and County House mountains occupies a depression fully 300 or 400 feet deep in the granite porphyry; while between Mill and Oven mountains the Grenville occupies a depression some 700 or 800 feet deep in the granite. Even if we grant the possibility of some faulting of the Pine-Gage mountain mass, it seems clear that this igneous rock rose by intrusion some hundreds of feet through the Grenville. In spite of the accentuated heights of the igneous masses of Hackensack, Moon, Heath, Potter, Huckleberry, and Crane mountains, it seems necessary to regard a considerable amount of the elevation of the igneous rocks above the Grenville as due to the intrusion itself. The only other alternative is the untenable view that faults completely surround these igneous bodies.

In general, then, we see that the great intrusive body often shows irregularities on its surface which vary in altitude by hundreds of feet within from 1 to 3 or 4 miles.

TOPOGRAPHY

RELATION OF TOPOGRAPHY TO ROCK CHARACTER

The surface configuration of the North Creek sheet is almost perfectly adjusted to rock character. A glance at the geologic map will show that the Grenville rocks, with few exceptions, occupy the lowlands; this is because of the relative weakness of those rocks as compared with the intrusives. The limestone areas or belts, being weakest of all, are invariably found in the valleys, and stream courses have commonly developed along such belts. Occasionally the more resistant Grenville gneisses, even where unaffected by faulting, have stood out fairly well against erosion as, for example, south of Valentine pond and south-southwest of Thurman. The Grenville quartzite being quite pure and very resistant usually stands out fairly conspicuously in the Grenville areas. This is well shown in the area south of Warner pond, though the height is there accentuated by faulting. The steep slope of the quartzite ridge east of Tripp pond appears to be due to more rapid wearing away of the much weaker underlying Grenville. In the mixed gneiss areas, particularly where the Grenville is abundant, the topographic development has been very similar to that of the Grenville areas.

The igneous rocks, where homogeneous and free from Grenville inclusions, without exception form the highest mountain masses. Occasionally the gabbro bosses appear to be slightly more resistant than the country rock and they then form the tops of low mountains or hills.

Another topographic feature often locally conspicuous is the sand flat or flat-topped sand terrace. Among the best examples are: in the vicinity of Warrensburg and Pottersville, west of Starbuckville, southwest of North Creek, and at a number of places southwest of Johnsburg. These represent delta deposits which were formed in glacial lakes which will be described in the succeeding pages.

RELATION OF TOPOGRAPHY TO ROCK STRUCTURES

Some of the most prominent topographic features of the quadrangle are the bold escarpments, more or less well-defined ridges, and isolated mountain masses or domes of igneous rock. These rock domes will be especially treated under the next heading. Most of the escarpments or ridges are due to faulting and have already been described. Some ridges, however, especially those in the Grenville areas, are due to other structural features combined with rock character. Thus the prominent ridge of gneiss which runs several miles southeastward from North Creek is due to the fact that a belt of weak limestone everywhere dips sharply under the harder rock of the ridge. The ridge south of Valentine pond is to be explained in a similar manner. Many small streams in the Grenville have developed along structural belts of weakness.

In the igneous rocks, too, there is a notable tendency for local short ridges and valleys to develop along lines parallel to the direction of foliation.

The most remarkable topographic feature in the whole region is the deep, narrow rift between Crane and Huckleberry mountains, which is certainly due to a combination of faulting, a belt of weak Grenville, and some erosion since the faulting.

EXFOLIATION DOMES [1]

One of the most striking features of the landscape, especially in the southern two-thirds of the quadrangle, is the prevalence of distinct, isolated, domelike, topographic forms which rise hundreds

[1] For a fuller discussion of this subject, see paper by the writer in N. Y. State Mus. Bul. 149, p. 187–94.

Plate 13

W. J. Miller, photo

Mill mountain, as seen from a point three-fourths of a mile to the southwest. This is a perfectly isolated dome of gray to pinkish-gray granite which rises fully 700 feet above the surrounding country.

W. J. Miller, photo

Potter mountain, four miles west-northwest of Warrensburgh, as viewed from a point one mile south-southwest. Quartz-syenite makes up the mountain mass, while Grenville limestone underlies the valley in the foreground. This mountain is a fine example of the exfoliation domes which are so common within the quadrangle. The dome rises 700 feet above the valley.

of feet above the comparatively lowland of the region. A comparison of the North Creek sheet with all other published Adirondack maps shows that, from the physiographic standpoint, this region is noticeably different from the Adirondacks in general.

Some of the best examples of such domes are: Kelm, Chase, Tripp, Hackensack, Moon, Heath, Potter, Birch, No. 9, Little, Crane, Huckleberry, Mill, Stockton, and Prospect mountains. The greatest of these domes is Crane mountain which rises 2000 feet above the immediately surrounding country. The upper 1000 to 1500 feet of this mountain are very steep to almost precipitous on all sides except the north making this great rock dome a grand sight as viewed from Thurman (see plate 8). Mill and Stockton mountains deserve special mention because they rise as two great isolated masses above the comparatively low and featureless surrounding country and form conspicuous features of the landscape as viewed from any of the higher points for a number of miles around (see plate 13). As viewed from the south, Potter mountain is a fine example of a rock dome which rises 700 feet above the general level of the country (see plate 14).

The domes may be classified under three headings according to shape: (1) those with nearly circular bases and which are very symmetrical and almost uniformly steep on all sides, as Potash, Mill, and Stockton mountains and the top of Kelm mountain; (2) those with elliptical bases and represented by nearly concentric elliptical contours to the summit, as Moon, Birch, No. 9, and Huckleberry mountains; and (3) those of irregular shape as shown on a large scale by Crane mountain and many smaller masses.

After climbing all the domes the writer has been impressed by the almost universal occurrence of exfoliation on a large scale over their surfaces. These mountains are literally peeling or shelling off by the removal of exfoliation sheets of great size, some having been noted as much as 50 to 75 feet across and from 1 to 3 feet thick. Among many other good places to observe this phenomenon are on the west or south sides of Moon, Crane, or Huckleberry mountains. Not infrequently, especially during the fall and spring months, slabs loosen up and go thundering down the mountain sides. Though the rocks are all clearly gneissoid, the exfoliation appears entirely to disregard this structure and often great sheets come off at right angles to the foliation.

This very common occurrence of exfoliation domes in the region the writer believes to be due to a combination of factors especially prominent in this part of the Adirondacks. Among these factors are: (1) character and distribution of the rocks whereby small to large masses of hard, homogeneous, igneous rocks have broken through the comparatively weak Grenville strata to produce a sort of "patchwork" effect so that, as a result of long erosion, the hard, igneous masses have stood out prominently above the Grenville; (2) faulting, whereby the "patchwork" effect and steep scarps have been either produced or sharply accentuated; (3) glaciation, whereby the isolated mountains of igneous rock were swept clean of decomposed surface rock and more or less smoothed or rounded off, thus favoring postglacial exfoliation; and (4) temperature changes, humidity etc., whereby the bare slopes of the isolated elevations of crystalline rock, under the conditions of comparatively rapid temperature changes in this the driest part of the State, are favorable for exfoliation.

PENEPLAINS

It is well known, especially as a result of the work of Professor Kemp and, more recently, that of Professor Cushing on the Saratoga sheet and of the writer on the Broadalbin sheet, that the southeastern Adirondack region had been worn down to the condition of a fairly good peneplain immediately prior to the advance of the upper Cambric (Potsdam) sea. Altitudes above the general peneplain level were not over a few hundred feet at the most. This conclusion has been reached through a study of those places along the borders of the Adirondacks where the Paleozoic rocks directly overlie the Precambrics. The position of the North Creek quadrangle renders it practically certain that this very ancient (Cambric) peneplain extended over its area, but because of the extensive faulting and erosion of the region, that old peneplain surface is nowhere certainly recognizable.

Again, it is well known that, by the close of the Mesozoic era, a fairly well-developed peneplain condition had once more been produced over this region in common with southern New England, New York, and the northern Appalachians. Professor Davis has shown [1] that the Berkshire hills area, during the late Mesozoic, had been worn down to a fairly good peneplain with occasional low mountains (monadnocks) rising above the general level. There is strong reason to believe that a similar condition prevailed over the southeastern Adirondack region, but with the monadnock

[1] Physical Geography of Southern New England in Physiography of the United States.

feature probably even more prominent. The comparatively even sky line of the western Adirondacks together with the high plateau called Tug Hill just west of the Black River valley, practically prove the former peneplain condition of that portion of the Adirondacks. This peneplain is known to have been elevated late in the Cretacic period or the early Tertiary period and, as already stated, much of the faulting of the eastern Adirondacks occurred at the time of that great uplift or even later. Thus the fact that this peneplain had considerable irregularities on its surface, combined with the facts of excessive tilting of the earth blocks by faulting and subsequent erosion, have quite effectually masked even this later peneplain surface. Doctor Ogilvie says with reference to the Paradox lake quadrangle,[1] that the even sky line of some of the mountains suggests an uplifted peneplain, and also that the long, smooth, eastward slopes of the fault blocks probably represent portions of the peneplain surface which were produced before the faulting. Similar evidences occur within the North Creek quadrangle as, for example, the rather even sky lines of the Henderson, Pine-Gage, Huckleberry, and Chase mountain masses, and the numerous eastward-sloping fault blocks already described. Anything like accurate knowledge of the character of this Mesozoic peneplain within the map limits is, however, lacking.

GLACIAL AND POSTGLACIAL GEOLOGY

CHANGES OF LEVEL

It is important to recall the well-known fact that the eastern portion of North America, including the Adirondack region, immediately preceding and doubtless during a good part of the Glacial epoch was notably higher than it is today. The submerged channels of the lower Hudson and St Lawrence rivers prove that the land there must have been something more than 1000 feet higher than now in order to have allowed the channel cutting. Toward the closing stages of the Ice age, and directly after it, there was a submergence of the whole region to below the present level as shown by the so-called raised beaches or delta deposits in the Hudson and Champlain valleys. In the Champlain valley the deposits are chiefly clays which were formed in an arm of the sea as proved by the presence of marine fossils. These deposits are now several hundred feet above sea level in the Champlain valley, which proves

[1] N. Y. State Mus. Bul. 96, p. 468.

at once that during the time of maximum subsidence the region stood several hundred feet lower than now, and that the most recent land movement has been one of elevation which has brought the marine deposits to their present position several hundred feet above sea level. This last (upward) movement has a direct bearing upon the glacial lake deposits of the North Creek quadrangle, and it is important to note that this upward movement was differential with greatest uplift toward the north. Using the figures of Professor Woodworth, the greater uplift of the land toward the north, passing along the southern part of the Champlain valley, has amounted to about 3½ feet a mile.[1] Practically this same figure may be applied to the North Creek area since it is so close to the southern end of the Champlain valley.

DIRECTION OF ICE FLOW

The evidence is conclusive that the North Creek quadrangle was vigorously glaciated. Many widely distributed glacial striae — sixty in all — have been observed within the map limits and are all recorded on the geologic map. Such a large number of striae is very unusual, certainly being far greater than for any other quadrangle so far mapped in the eastern, central, or southern Adirondacks. As usual the striae are most frequently seen along the highways in the valleys and on ledges from which the glacial drift covering has recently been removed. A number of striae have been found away from the roads and even on mountain sides, but never on mountain tops because where exposed on the bare ledges they have been obliterated by postglacial weathering.

Of the sixty recorded striae, the extreme range in direction is only from south 20° east to south 20° west, with the north-south direction nearly an average. In fact many of the striae do run north-south and very few vary more than 10° either side of this. The direction of ice movement indicated by these striae is exceptional for the central and eastern Adirondacks as judged by observations made on the Long lake, Paradox lake, and Elizabethtown-Port Henry sheets over which areas the general movement was southwestward at the time of maximum glaciation. The reason for the southward movement over the North Creek sheet is not an easy thing to account for, though it may possibly have been due to a crowding of the ice into the Hudson valley and a local deflection of the general southwesterly current where the ice flowed

[1] N. Y. State Mus. Bul. 84, p. 206, 228 and plate 28.

against the much higher mountains which are arranged along the eastern side of the adjoining Thirteenth Lake sheet.

Some of the striae are so situated in valleys as to suggest that, locally at least, the ice currents followed the valleys, but many others are situated wholly without reference to the topography. Among the best examples of striae which are significant as proving that the general ice movement was irrespective of even the major topographic features are the following: just north of Mud pond and immediately south of the Huckleberry-Crane-Little mountain masses, thus showing the retention of the southward course in spite of those mountains; immediately under the steep fault scarp on the east side of Loon lake; at the north bases of Pine and Gage mountains, showing that the ice current headed straight for those high mountains; and on the hilltop just northwest of Johnsburg where the ice left its record after having plowed diagonally up the hill for an altitude of several hundred feet instead of following the valley.

The great depth of ice over the region is proved by the frequent occurrence of drift boulders even on the high mountains, the high altitudes of some of the striae, and the glacial lake on Crane mountain. Some of the striae at considerable altitudes are as follows: north of Mud pond (southwest corner) at nearly 2000 feet; 2 miles east of Cherry ridge at from 1500 to 1600 feet; west base of No. 9 mountain at 1600 feet; 2½ miles southwest of Johnsburg; at 1550 feet; on the side of Stockton mountain at over 1500 feet; and one-half of a mile northwest of Johnsburg on a hilltop at 1480 feet. On this basis, granting a fairly level ice surface, the depth of ice must have been at least 1000 feet or the difference between these highest striae and the Hudson river to the east. However, the presence of the glacial lake with drift dam well up on Crane mountain, and at an altitude of 2620 feet, shows that the ice was deep enough to cover the mountain that high up at least. According to this the ice must have been at least 1500 feet deep in the valley just north of Thurman and fully 2000 feet deep in the valley of the Hudson river.

ICE EROSION

To say the least, ice erosion was very effective in the removal of nearly all preglacial soils, decomposed rock, and loose joint blocks. The mountains were swept clean of such materials and left standing as more or less rounded off bare rock ledges, while during the retreat of the great ice sheet the valleys were partially filled with drift deposits. Decomposed rock material of preglacial age can now be seen at very few localities and those in specially sheltered places on steep south slopes where ice erosion was very ineffective. One such place is along the road 1 mile east-northeast of Wevertown at the south base of the mountain where the granite is decomposed, and another is just west of Crane mountain where the south side of a ridge of hornblende gneiss is badly decomposed to a reddish brown color.

Where favorably situated with reference to the direction of ice flow, the fault scarps were freshened up chiefly by the removal of the heavy talus slopes. An especially noteworthy example is the steep scarp 1⅓ miles north of Valentine pond where, on the nearly vertical wall of rock, good glacial striae may be seen. Heavy talus deposits which were not favorably situated for removal by ice erosion occur at the base of the Loon lake mountain scarp on the south side, and also at the base of the scarp next to the south.

There is good evidence for vigorous ice erosion in the valleys in the southeastern portion of the quadrangle, some of the facts favoring this view being: (1) the abundance of scratched, polished, and rounded rock surfaces; (2) the comparative freshness of the rocks, even in the case of the weak Grenville; (3) the unusual weakness of much of the rock, especially limestone, which occupies the valleys; (4) the fact that these belts of weak rock must have been deeply decomposed during the long preglacial time, thus favoring extensive removal of material; and (5) the north-south movement of the ice being parallel to the Grenville valleys and hence being favorable for ice erosion because of easy flowage of the deep ice through the valleys. Other Grenville valleys were doubtlessly also similarly lowered by ice erosion.

GLACIAL DEPOSITS

Glacial boulders or erratics are very common over the entire area and, as usual, most of them are of local origin. This fact of local origin was successfully employed to locate certain important outcrops, especially of gabbro or diabase, by tracing the line of boulders to the parent ledge. All sorts of Precambric rocks of the region are represented among the boulders, the granite and syenite naturally being the most common. A type of boulder wholly derived from without the quadrangle, and especially abundant in its northern portion, is the coarse grained anorthosite whose nearest parent ledges are in the northern portion of the Schroon lake sheet. Such boulders several feet across are frequently encountered. The only Paleozoic rock boulders noted were of Potsdam sandstone and, as already stated, these are nearly all confined to the Hudson valley between Heath and Moon mountains.

Glacial till or ground moraine material is quite widespread, especially over the lowlands, but no great thickness was noted at any place. It would seem that more material was scraped off by ice erosion than was deposited as till. As would be expected from the nature of the rocks, the till is always sandy or gravelly and generally filled with boulders. Not a single good example of real boulder clay was observed.

Kames are of uncommon occurrence. Three or four good ones, large enough to be shown by the contour lines, lie in the little valley a mile west of No. 9 mountain. Some other stratified sand and gravel deposits of rather doubtful kame origin occur in the valley between Chestertown and Tripp pond.

But one fairly well-defined boulder moraine came to the writer's notice and this is quite clearly traceable as a belt 1 to 3 miles wide from the vicinty of South Horicon westward around Prospect mountain, thence across the southern part of Loon lake and a mile or so southward, thence over the southern end of the ridge just west of the lake, and nearly to the river. The ice front must have been nearly stationary for some time along this line to allow the accumulation of so many boulders.

GLACIAL LAKES

Glacial Lake Warrensburg. This extinct glacial lake, recently described by the writer, is so named because of the location of the village of Warrensburg upon the old lake deposit which is especially well shown as a sand plain area between the village and the Hudson river. The concordant altitudes of this sand flat, where unaffected by subsequent erosion; the remarkable freedom of the surface from boulders; and the crudely stratified character of the material as shown in cuts all afford conclusive evidence for static water conditions here, the sand plain material having been formed as a delta deposit in the lake. This is a good example of a small pitted sand plain, there being two notable depressions (one containing a pond) below the level of the plain. Such depressions are thought to be due either to unequal deposition of the delta material or the presence of large buried blocks of ice which on melting would leave the depressions. The contact of the lake surface, at its height, with the surrounding land is quite accurately indicated by the 760 foot contour line but, because of postglacial changes of level, the actual altitude of the lake above the sea is not known. On a line passing east and west through Warrensburg the main body of water showed its greatest width of about 3 miles. Clearly defined sand terraces, the highest of which always rise to the 760 or 780 foot contour lines, prove that important arms of the lake extended fully 9 miles up the Schroon river valley above Warrensburg; nearly 4 miles up the Hudson valley above the mouth of the Schroon; and at least 2 miles down the Hudson from the mouth of the Schroon. The altitudes of these sand terraces gradually increase slightly toward the north because of the postglacial warping of the region as explained on page 66.

In the vicinity of Warrensburg, and especially along the Schroon river, the lake deposits, though deeply trenched, have seldom been cut through to the underlying rock. As a result of the meandering of the Hudson and Schroon rivers, during the process of trenching the old lake deposits, fine terraces have been developed. Such terraces are particularly well shown between Potter, Heath, and Moon mountains where they are at two or three different levels and from a quarter to a half mile back from the river as the contour lines partly indicate.

The cause of the standing water was a blockade, probably of glacial drift, in the Stony Creek gorge (Luzerne sheet).

Glacial Lake Pottersville. This lake, here described for the first time, must take rank as one of the largest and most interesting extinct glacial lakes yet recognized in the Adirondacks. It is so named because the best example of sand flat delta deposit formed in the lake lies in the vicinity of Pottersville. This sand plain covers fully a square mile at an altitude of about 800 feet, though the highest waterlaid sands and gravels occur from one-third to two-thirds of a mile northwest of the village and at an altitude of nearly 900 feet. This material was all formed as a delta deposit by Trout brook in a body of water which stood at a level corresponding approximately to the present 900 foot contour line at Pottersville. This body of water was Lake Pottersville of which Schroon lake is only a shrunken remnant. The

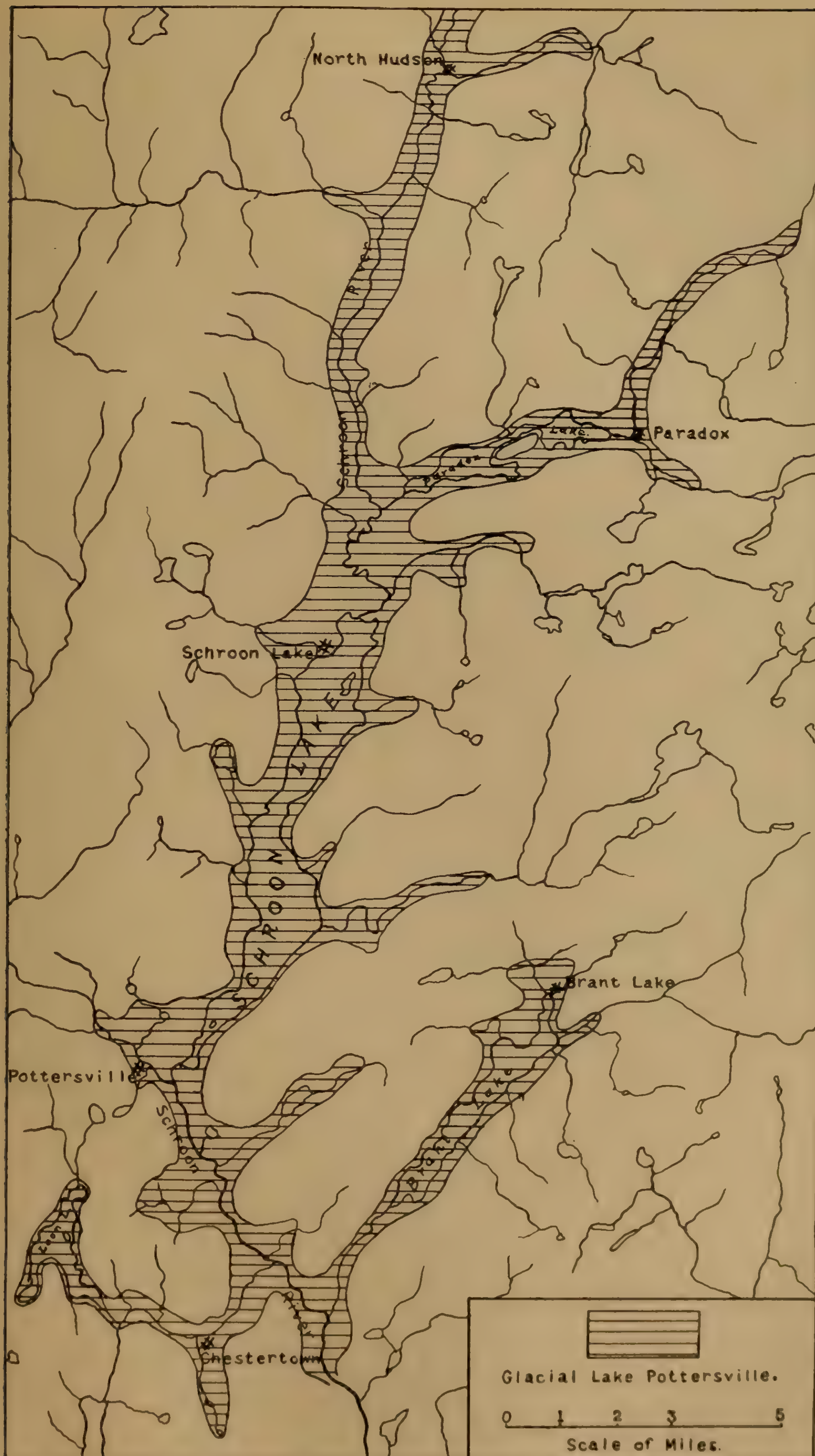

Fig. 10 Sketch map to show the extent of Glacial Lake Pottersville

existence of many sand flat delta or lake deposits makes it practically certain that this was a very extensive lake. It extended northward up the Schroon river as a long, narrow body of water at least as far as North Hudson, with a branch extending eastward to form an enlarged Paradox lake. Southward from Pottersville, all the lowland (below the 880 foot contour) southward to South Horicon and Meade pond (south of Chestertown) was occupied by the lake, with a prominent branch extending northeastward over the Brant lake area, and a smaller branch over Valentine pond. Another branch appears to have reached northwestward from Chestertown over the Loon lake area, though this is not quite so certain. The dam which held this water at so high a level was quite certainly one of glacial drift across what is now the deep, narrow channel of Schroon river 1 mile south of South Horicon. It is important to note in this connection that the boulder moraine, above described, crosses the river here. The Schroon lake reservoir, which may some day be built by the State by means of an artificial dam across the river at this same point, would largely restore the former lake.

Sand terraces around Brant lake, especially toward the east end along Mill brook, prove the former higher water level of that lake. Around Loon lake there are suggestions of lake deposits about 10 or 15 feet above the present water level but they are not very decisive. In the immediate vicinity of Chestertown and one-half of a mile west of Starbuckville, there are waterlaid sands or sand flats reaching altitudes of about 880 feet as nearly as can be judged from the contour lines. At Pottersville the delta material lies at from 880 to 900 feet; north of Schroon lake village up to 920 feet; and at North Hudson (Paradox lake sheet) up to 960 feet. Between Schroon lake village and North Hudson there is an almost continuous succession of such terraces along Schroon river, with gradually increasing altitudes toward the north. The rate of increasing northward elevation of these old lake delta deposits is in almost perfect harmony with the figures given by Professor Woodworth for the warping of the Lake Champlain terraces. As stated on page 66, the rate of northward increase at the latitude of Schroon lake should be about 3½ feet a mile. The altitude of the terraces at Chestertown is 880 feet; at Schroon Lake village 920 feet; and at North Hudson 960 feet. This is a total difference in altitude of 80 feet in the distance of 22 miles from Chestertown to North Hudson, or at the rate of 3.6+ feet a mile, which is very close to the figure given by Woodworth for the lower Champlain valley.

Glacial Lake Johnsburg. This was a small irregular shaped lake extending for about 2½ miles southwestward from Johnsburg as proved by a number of well-distributed sand flats or terraces at, or a little above, the 1300 foot contour line which approximately marks the old shore line. The best terraces, practically unrepresented on the contour map, are : two-thirds of a mile west, three-quarters of a mile southwest, three-quarters of a mile south-southwest, and at several places about 2 miles south-southwest of Johnsburg.

The cause of this static water condition appears to have been either an ice or glacial drift dam across the Mill creek channel at or not far east of Johnsburg.

Glacial Lake North Creek. The former presence of a lake in the vicinity of North Creek is proved by the existence of thick stratified sands, comprising terraces and flats. South of the village the sands show a depth of over 100 feet where they have been trenched by the small creek. Holcombville lies on a sand flat at 1160 feet, and the tongue of sand just southwest of North Creek rises to nearly the same altitude. Just north of the river the sands were, no doubt, largely removed by postglacial stream work. From 1½ to 2 miles north-northeast of North Creek (along the new State road) there are stratified sands and gravels running up as high as 1140 or possibly 1160 feet, and these seem to correlate with the deposits south of the village. The precise location of the retaining dam of this lake can not be given but it was either ice or drift, probably the latter, across the Hudson channel not over 2 miles east of North Creek.

One-half of a mile due east of Holcombville there is a small but finely developed flat-topped sand terrace at an altitude of 1240 feet. It extends out as a distinct apron from the mountain side of syenite. The depth of sand in this terrace is fully 200 feet, and it was probably formed in a small, marginal, high level lake when the ice was still present.

The Glen glacial lake. This body of water extended from near the headwater of Millington brook northwestward to the Hudson river, thence along the river channel past The Glen, and to near the mouth of Mill creek. Sand flats at an altitude of 800 feet or a little over, are well shown from 1 to 1½ miles east of the mouth of Millington brook, and a perfect sand terrace, fully 200 yards wide, three-quarters of a mile long, and at an altitude of about 800 feet, lies against a granite ridge two-thirds of a mile northeast of the mouth of the brook. One-half of a mile above the mouth of Potter brook, and also nearly 2 miles above its mouth, are perfect, small sand terraces at from 800 to 820 feet. At The Glen the railroad passes along the base of a fine flat-topped terrace which rises over 60 feet above the track. It is not shown on the map but by lock level its altitude was found to be a little over 800 feet. From 1 to 2 miles north of The Glen and on the east side of the river there is an extensive sand and gravel flat whose altitude is about 820 feet.

It is interesting to note that the coarsest deposits are toward the north because there the Hudson river with its load of debris entered the lake. The deposits of this extinct lake also rise gradually toward the north because of the postglacial land tilting. Near The Glen the lake was very narrow. The water of this lake appears to have been ponded by a drift dam across the Hudson river just below the mouth of Millington brook.

Other extinct lakes. Many other smaller glacial lakes, now either wholly or partly extinct, occur within the map limits. Thus Tripp pond was formerly much larger as shown by a number of fine flat-topped sand terraces lying at from 1020 to 1040 feet. The former lake was over 2 miles long with a drift dam a little over a mile north of the present lake.

The little valley shown on the map 2 miles southeast of Chestertown is certainly an old lake bottom. Most of the swamp areas are also old lake or pond bottoms.

Existing lakes. None of the lakes of the quadrangle are of preglacial origin. Some of them, such as Schroon lake, Valentine pond, Tripp pond, Smith pond, and probably Loon lake, are merely shrunken remnants of former larger bodies of water as already described. The waters of all the lakes and ponds are held in either by glacial drift or old lake deposit dams and most of them show evidence of having been at more or less higher levels. Some of the ponds seem to occupy depressions in the irregularly deposited drift. Ice erosion may have been effective in deepening some of the basins as, for example, that of Friends lake, though positive proof is wholly lacking.

POSTGLACIAL DRAINAGE CHANGES

Aside from the destruction or partial destruction of glacial lakes by cutting down the outlets or filling them up or both, and the moderate amount of downcutting by the larger streams with resulting development of terraces, there appear to have been no important drainage changes. Due to the irregular distribution of the glacial drift many of the small streams have postglacial courses, but the larger streams, like the Hudson and Schroon rivers, are believed to follow practically their preglacial channels which are well adjusted to the character and structures of the rock masses over which they flow.

In a recent paper [1] the writer discussed certain important postglacial drainage changes in the southeastern Adirondacks, and since one of the changes concerns the Hudson river immediately after it leaves the North Creek sheet, a very brief statement will here be made.

Instead of the present long, circuitous course of the Hudson river past Stony Creek, Luzerne, Corinth, and thence across the Luzerne mountain to Glens Falls, the preglacial Hudson certainly took a shorter course, most likely through the channel from Warrensburg to Caldwell and thence to Glens Falls.

The great gorge of the Hudson above Stony Creek station is surely of either interglacial or postglacial origin and in its stead a preglacial divide was located there. Evidences favoring this view are given in the paper above cited.

Since the preglacial Hudson river did not flow southward across the Luzerne sheet, it must have flowed eastward across the low mountain ridge between Warrensburg and the Lake George depression. There are but two possible channels there, namely: the Warrensburg-Hillview channel and the Warrensburg-Caldwell channel. In the paper above cited, arguments are presented to show that the latter channel was the more likely one. The preglacial Hudson was joined by the Schroon just east of Warrensburg, while a short tributary, having its source on the Stony Creek divide, flowed northward into the Hudson. An important preglacial stream, called the Luzerne river by the writer, had its source on the Stony Creek divide and flowed southward past Luzerne and Corinth and through the broad valley west of Saratoga Springs.

[1] Preglacial Course of the Upper Hudson River. Geol. Soc. Amer. Bul. 1911, 22: 177-86.

SUMMARY OF GEOLOGICAL HISTORY

A brief outline of the geological history of the portion of the Adirondacks covered by the North Creek sheet is here given in order to bring together the principal events of that history in the regular order of their occurrence so far as known.

The oldest known records of the region are written in the Grenville rocks which, by their very character and composition, are undoubted metamorphosed sediments. Because of the great thickness and widespread distribution of these strata in New York and Canada, we know they were deposited in an extensive ocean and that the length of time required for this sedimentation must have been at least some millions of years. While it is as yet impossible definitely to classify the Grenville with either the Archean or Algonkian (Proterozoic), the evidence is decidedly against its late Precambric age.

After the deposition of the Grenville sediments, the whole Adirondack region, including the area of the North Creek sheet, was elevated well above sea level. At this time the Grenville strata were probably folded. Great masses of molten rock, now represented by the syenite, granite, and granite porphyry, were intruded just before, during, or after the uplift, the most reasonable view being that the intrusion occurred during the uplift because the same great pressure could well have pushed up the molten masses during the process of elevation. In some cases the Grenville appears to have been pushed upward and to have been largely removed by erosion since; in other cases the Grenville was more or less engulfed by, or involved with, the molten flood as shown by the numerous Grenville inclusions and the areas of mixed gneisses; while in still other cases the Grenville rocks were left practically intact as shown by the large Grenville areas. These intrusives now exposed at the surface were, at the time of their intrusion, deeply buried under a great thickness of overlying rock material. This we know because they are true plutonic rocks which could have cooled only under such conditions. The vast amount of erosion since their intrusion has exposed them.

Following this great period of igneous intrusion there was a time of minor igneous activity when the gabbros, in molten condition, were forced upward into the crust of the earth. Since the gabbros now exposed at the surface are true plutonic rocks they too must have been deeply buried under material which has been removed by erosion.

After the intrusions the whole region was subjected to intense compression and metamorphism when the gneissic or foliated structure of all the rocks so far mentioned was developed. This structure is now shown in the rocks at the earth's surface; but, since such a structure can develop only in rock masses which are deeply buried, we know that at the time of the compression the present surface rocks were deeply covered.

The rocks represented by the coarse grained pegmatite dikes of the quadrangle were intruded after this period of intense compression because they lack the gneissic structure, and before the diabase because the latter rock cuts the pegmatite.

The great elevation of the region, above referred to, inaugurated a long period of erosion to be measured by at least some millions of years, and extending into the early Paleozoic era.

After the removal, by erosion, of some thousands of feet of rock materials, the last igneous activity of the region occurred when the molten diabase was forced through narrow fissures in the earth to cool in the form of dikes. The utter lack of metamorphism and the fact that they cut all the other rocks show that this diabase is the youngest of the intrusives. That it must have cooled rather close to the earth's surface is evidenced by the fine grained to even glassy texture.

As a result of the vast erosion, the whole area was worn down to near sea level and presented only a moderate relief. Then a gradual sinking took place when the sea steadily encroached upon the old land from the east, and the early Paleozoic sediments were deposited upon the old land surface. As the nearby outliers show, the first sediment to cover the area of the quadrangle was the upper Cambric (Potsdam) sandstone, followed in turn by the Theresa passage beds and the Little Falls dolomite which are also of Cambric age.

Recent studies have shown that, toward the close of the Cambric, there was a gentle upward movement of the Adirondack region to above sea level after which some erosion took place. Then, early in the Ordovicic period, the Champlain and Mohawk valley regions sank below the ocean surface when the thick limestones and shales of that period were laid down. It is highly probable that the North Creek area was also submerged under the Ordovicic sea, though positive evidence is lacking. At any rate we have no reason to think that this area, or in fact any of the Adirondack region outside of the immediate Champlain and St Lawrence valleys, was ever again below sea level after the Ordovicic period.

Thus it is more than probable that northern New York underwent erosion during all of the late Paleozoic era and certainly during the Mesozoic era, when an immense amount of Paleozoic sediment and some Precambric rock were stripped off by erosion. By the close of the Mesozoic northern New York was reduced to the condition of a fairly good peneplain with some hard rock masses rising to moderate heights above the general level.

At the close of the Mesozoic, or the beginning of the Cenozoic era, the great peneplain was upraised and a new period of active erosion was inaugurated to continue to the present time.

Much of the faulting of the area dates from the time of this peneplain uplift or even later, though it is likely that some dates from toward the close of the Paleozoic era at the time of the great Appalachian revolution.

Immediately preceding and probably during much of the great Ice age this region, like all the northeastern United States, was considerably higher than now as proved by such drowned river channels as those of the lower Hudson and St Lawrence.

During the Ice age of the Quaternary period, the area of the quadrangle, in common with all New York State, was buried under a great ice sheet which has left many records such as striae, glacial boulders, moraines, and drift deposits in general. The preglacial topography was not profoundly altered by ice erosion and deposition. The many extinct and existing lakes of the quadrangle were formed either by the actual presence of the ice dam itself or, more commonly, by irregular deposits of drift across old stream channels.

A subsidence of the land several hundred feet below the present level took place toward the closing stages of the Ice age or immediately after it for this latitude, when arms of the sea extended through the Champlain and St Lawrence valleys.

The most recent movement of the land has been a differential uplift with greater elevation toward the north. At the latitude of the North Creek sheet, this postglacial uplift has amounted to a few hundred feet, the differential character of the uplift being shown by the tilting of certain of the extinct glacial lake deposits.

ECONOMIC GEOLOGY

GARNET

At the time of the field work but one garnet mine was in actual operation within the map limits, but in all there are at least five localities where more or less garnet mining has been carried on as follows: (1) near the top of Oven mountain; (2) one-half of a mile southeast of Holcombville (Rexford's mine); (3) in the mixed gneiss area just south of Daggett pond (Elisha Parker farm); (4) near the mouth of Mill creek (Sanders Brothers mine now in operation); and (5) three-fourths of a mile east of Fuller pond. Besides these the principal garnet mines of the Adirondack region lie in the northern portion of the adjoining Thirteenth lake sheet. One of these is the Rogers (Barton) mine near the top of Gore mountain and the other is the Hooper mine on the west side of Thirteenth lake. In all cases open pit methods of mining are employed.

The Oven mountain mine has not been worked for nearly twenty years, and at no time was a crushing plant operated. After blasting out the garnet-bearing rock and reducing it in size by means of sledge hammers, the large garnets were picked out by hand. The mode of occurrence is of unusual interest. The matrix, or rock carrying the garnets, is a gray, medium grained, feldspar, hornblende, biotite, gneiss, a thin section showing 20 per cent orthoclase; 25 per cent oligoclase to labradorite; 50 per cent hornblende; 2 per cent biotite; 2 per cent magnetite; together with a little pyrite, zoisite, and apatite. Imbedded in this gray matrix are numerous, well-scattered, translucent, pale reddish brown garnets ranging in size up to several inches. These garnets are always quite well granulated and never show crystal outlines. Each garnet is completely inclosed within an envelop of pure, black, medium grained hornblende crystals. Occasionally a half-inch, irregular shaped crystalline mass of acid plagioclase or biotite may lie just between the garnet and the hornblende rim. These reddish garnets completely surrounded by rims of black hornblende, which are in turn imbedded in the gray gneiss matrix, present a very striking appearance. As shown on the geologic map, this garnet-bearing rock occurs as a long, narrow inclusion of Grenville gneiss within the Oven mountain granite.

At the Rexford mine there are several large openings but none have been worked for about fifteen years. The mode of occurrence is almost exactly like that in Oven mountain, only here there appear to be several (smaller) inclusions of the garnet-bearing hornblende gneiss instead of one, and the country rock is a very gneissoid syenite. Garnets up to 5 inches across and always with hornblende rims occur here.

By way of comparison with the Oven mountain and Rexford mines, the Rogers mine on Gore mountain should be mentioned as of exactly the same type of occurrence but with garnets generally much larger, those of 5 or 6 inches in diameter being very common and the largest ones taken out are said to have been nearly the size of a bushel basket. As a rule the hornblende rims increase in width with the size of the garnets, and the large garnets imbedded in the walls of this mine present a most interesting appearance. The garnet-bearing hornblende gneiss here forms an inclusion in syenite fully three-fourths of a mile long and 200 feet wide. Several large openings have been made in this rock.

At the old mine on the Parker farm the rocks are a mixture of granitic syenite and Grenville interbanded parallel to the strike of the foliation. These bands of rock are often 20 to 40 feet wide, one of them being made up of a nearly pure, granular, medium grained mass of irregular crystals of reddish brown garnet and bright green pyroxene (coccolite?). About twenty years ago this band of garnet rock was mined, crushed, and put into barrels, there being no attempt to separate the pyroxene from the garnet.

At the Sanders Brothers mine the mode of occurrence is very similar to that of the Parker mine, the bands of Grenville being, however, somewhat less pronounced and numerous. The rock which is mined is quite badly granulated, and consists mostly of intimately associated reddish brown garnet and green pyroxene (coccolite?) in small grains, with sometimes a little feldspar. There are some streaks or patches of nearly pure garnet. Work began in 1907 on the south side of the creek but now all the mining is confined to the north side (see map). The garnet, pyroxene rock is crushed, put into bags, and shipped to various parts of the world.

Years ago an attempt was made to mine the garnets which occur in the coarse, feldspar, biotite, quartz, garnet (Grenville) gneiss about three-fourths of a mile east of Fuller pond.

At the Hooper mine, near Thirteenth lake, the garnets occur as crystals, often with good crystal boundaries, up to an inch or more in diameter. They are thickly scattered through a medium to fairly coarse-grained, dark to light gray, very gneissoid hornblendic rock which has the composition of a basic syenite or acidic diorite. These garnets never show the rims of hornblende. This type of occurrence has not been noted on a large scale within the map limits of the North Creek sheet, though a rock almost exactly like it does occur at the Rogers mine as a distinct zone (wall rock) intermediate in position and composition between the typical garnet gneiss and the country rock of syenite, where the garnet rock grades perfectly into the syenite.

All modes of occurrence of garnets observed by the writer on the North Creek and Thirteenth lake sheets may be summarized as follows: (1) as crystals or grains in various Grenville rocks, as the garnet-pyroxene gneisses, the dark hornblende-garnet gneiss, the gray feldspar-biotite-garnet gneisses or schists, and the white or very light gray feldspar gneisses; (2) as distinct crystals frequently occurring in all types of intrusive rocks — syenite, granite, granite porphyry, and gabbro — except the diabase; (3) as large more or less rounded masses, with distinct hornblende rims, in the long, lenslike inclusions of Grenville hornblende gneiss in syenite or granite; and (4) as more or less distinct crystals, without hornblende rims, in a certain special basic syenitelike or acidic dioritelike rock.

In case no. 1 (for example Sanders Brothers and Parker mines) the garnets have, in the usual way, crystallized out of masses of sediments under conditions of thermal and dynamic metamorphism.

In case no. 2 the garnets appear mostly to have crystallized out of the original magmas, their presence possibly being due to some assimilation of Grenville sediments, though this is by no means proved. Sometimes, as in the gabbros, the garnets may have been produced secondarily after the cooling of the igneous masses.

Case no. 3 (for example, Oven mountain, Rexford, and Rogers mines) is of particular interest because of the very large garnets surrounded by reaction rims. Without question the garnets occur in lenses of Grenville sediment which were caught up or included in the great igneous masses at the time of their intrusion, the tremendous heat and pressure being especially favorable for a very complete rearrangement and crystallization of the masses of sediment which were rather low in silica. The hornblende rims or envelops are quite certainly great reaction rims around the garnets, but just at what stage of the metamorphism they were produced is not at all clear to the writer. The rounded and granulated condition of the garnets suggest that the reaction rims of hornblende may have formed some time after the crystallization of the garnets and possibly at the time when the great pressure producing the foliation was brought to bear.

A clew to the origin of the garnets in case no. 4 (for example, Hooper's mine) is furnished by a study of the wall rock in the mine on Gore mountain. The typical garnet-bearing rock of the mine passes by perfect gradations through an 8 or 10 foot zone into a basic (quartzless) syenite which contains garnet crystals up to an inch or more across but never with hornblende rims, and this rock in turn grades into the typical country rock of syenite which is somewhat garnetiferous. The writer is fully convinced that this transition zone (wall rock) has been formed by the assimilation or actual melting or fusing together of the syenite and the border of the great inclusion at the time of the intrusion of the syenite. In hand specimens and in thin sections, as shown in the field, the garnet rock at the Hooper mine is almost exactly like this wall or transition rock of the Rogers mine and it also appears to grade into the country rock. In the Hooper mine this transition rock makes up practically the whole mass of rock which is mined and is hence much more extensive than at the Rogers mine. All evidence strongly points to the origin of the Hooper mine rock as due to rather thorough melting together of an admixture of syenite and Grenville hornblende gneiss where the Grenville inclusion was perhaps deeper down in the magma and hence subjected to much greater heat, or possibly a number of smaller hornblende gneiss inclusions were assimilated by the molten syenite or granite.

GRAPHITE

Within the map limits but one graphite mine has ever been in actual operation, though prospect holes have been made at various places. The mine, including an open pit and short tunnel and separating mill, is located 1 mile southwest of Johnsburg. The graphite occurs in small flakes in gray, thin to thick bedded, Grenville gneisses which are usually very rich in quartz. A detailed description of specimens from this mine has been given on page 14. Some graphitic limestone was taken out from near the mine entrance. The rocks strike north 70° east and dip 35° to the south. This mine was worked as late as June 1910 but apparently has not been very successful. An interesting feature is a quartz vein up to a foot wide, which cuts across the graphitic beds at a high angle and which contains rich seams (as much as an inch wide) of pure graphite. The mine superintendent stated that in 1899 one piece of graphite weighing 543 pounds was taken out. Excellent specimens of associated quartz and graphite may be obtained from the mine dumps.

A prospect hole 2½ miles due south of Pottersville and close to the road was opened in limestone some years ago. Some of the limestone beds are pyroxenic to serpentinous. The limestone contains occasional flakes of graphite up to one-half of an inch across, as well as some phlogopite, pyrite, brown hornblende, and a few octahedrons of brown spinel.

One-half of a mile beyond the northern map limit and near where the road crosses Trout brook there is an old graphite mine which was not visited by the writer.

Throughout the quadrangle scattering flakes of graphite are rarely absent from the crystalline limestone, and more seldom they are found in other rocks of the sedimentary series.

MICA

The only place where mica mining has been attempted is in a large pegmatite dike, which comes against the long gabbro mass on its east side, 2¾ miles south-southeast of Chestertown. At the time of the writer's visit (1910) the mine was being worked in a small way by two or three men. While occasionally mica is present in considerable quantity, it seldom occurs in books up to 5 or 6 inches across. Muscovite mica is often associated with the pegmatite dikes but thus far no place has been discovered which could really be called a good mining proposition.

ASBESTOS

The only attempt to mine asbestos is at the locality three-fourths of a mile southeast of Thurman village. During the summer of 1910 large prospect holes had been opened up and mining machinery was being installed, though the writer does not know whether the mine is now in operation. The asbestos is of the serpentine variety, known as chrysotile, and occurs in numerous irregular veins in the greenish gray serpentine marble. Of all the veins noted in the prospect holes, the widest was less than an inch, though wider veins may since have been found. The asbestos is of good quality, but numerous fairly thick veins must be found in order to make a paying proposition of the mine.

FELDSPAR

Orthoclase feldspar is of course one of the commonest minerals in the whole region, but only where it occurs in large crystals in the pegmatite dikes is it likely ever to become of commercial importance. In all the numerous pegmatite dikes examined, the orthoclase almost invariably occurs in crystals which are too small and too intimately associated with much quartz and acid plagioclase feldspar to be worth considering as mining propositions. Perhaps the most favorable locality is the pegmatite dike lying along the west side of the gabbro dike on the mountain top 1 mile south-southeast of The Glen. A single mass of pegmatite there is about 25 feet wide and 50 feet long and very rich in orthoclase and albite crystals up to 5 or 6 inches in length, together with more or less quartz and black tourmalin. The nearness to the railroad station and the fact that an old road now extends nearly to the top of the mountain, are features favorable to mining here, but the small size of the exposed mass and the abundance of albite are unfavorable.

ROAD METAL

Rock such as that of the diabase dikes of the quadrangle is popularly known as "trap rock," and it takes rank among the finest natural road building materials because of its hardness, fineness of grain, homogeneity, and good binding power. So far not a single quarry has been opened in any of these dikes though some of them are large and well situated with respect to roads and good quarry drainage. Among such dikes are those at the west base of Heath mountain (Ingraham farm); 1½ miles north-northeast of Pottersville; and two-thirds of a mile a little south of west of Igerna. Smaller, but well located, dikes are three-fourths of a mile southeast of Kelm mountain and one-half of a mile southeast of The Glen.

The gabbro masses, especially the more basic ones, would furnish a very large amount of good road material. This rock is hard, homogeneous and rich in iron-bearing minerals to give good binding power. So far but two quarries have been opened in the gabbros and these for State road purposes. One of these quarries is in the south end of the large, coarse grained, gabbro boss on the south side of Loon lake, and the other is in the gabbro boss 1 mile west of Riverside and near the new State road.

The basic varieties of syenite, especially those free from mica and low in quartz, would also make good road metal, but no quarries have yet been opened in such rock.

The granite and granite porphyry in general are rather poor road materials because of the high quartz and mica content and the usual deficiency of iron-bearing minerals to furnish a good binder. Such rock has, however, been rather extensively quarried at three places for State road work. One of these quarries is situated two-thirds of a mile north of the north end of Loon lake and above the road; the second is along the State road 1¾ miles northeast of

Pottersville; while the third is by the State road 3¼ miles north-northeast of North Creek.

The Grenville gneisses are nearly always of poor quality for road work because of the high quartz and mica content and the heterogeneity of the rocks which are in layers of varying composition. In spite of this, one quarry for State road purposes has recently been operated near the southeastern end of Loon lake.

BUILDING STONE

There is an inexhaustible supply of building stone of excellent quality within the map limits. The syenite, granite, and granite porphyry all rank as very strong and durable building stones. Of these the granite porphyry would perhaps make the most effective and beautiful stone when highly polished because of the large, scattering, pink, feldspar crystals which are set in the much finer grained gray matrix. The color of this rock would remain practically unaltered on exposure to the weather. Some of this rock from the quarry at Horicon is said to have been used in the State Capitol at Albany. The pink granites, too, would make beautiful and very durable building stones not subject to color change. The syenites, which are generally greenish gray when fresh, would weather to light brown on exposure to the atmosphere but, as regards durability and strength, they would be excellent stones. These igneous rocks are considerably used locally but because of the distance from population centers, no quarries have been opened up for shipping purposes. The pinkish gray granite used in the construction of the new Warrensburg High School building was obtained from the south side of Hackensack mountain and just off the map.

The only stone which has been quarried for shipping purposes is the green marble or so-called verde antique of the Grenville series. Though occurring at a number of localities, the only place where quarrying has been done, and this years ago, is one-half of a mile west-southwest of Thurman village. This rock is a medium grained, white to greenish gray marble through which are scattered many streaks and blotches of bright green serpentinous material, so that the polished stone presents a striking effect.

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EDUCATION DEPARTMENT
JOHN M CLARKE
STATE GEOLOGIST

UNIVERSITY OF THE STATE OF NEW YORK
STATE MUSEUM

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